

ENGINEERING AAV

CROSS-REFERENCE TO RELATED APPLICATIONS

- 5 [0001] This application claims the benefit of and priority from United States Provisional Applications 62/839,421, filed April 26, 2019; 62/915,386, filed October 15, 2019 and 62/939,094, filed November 22, 2019. Each of the foregoing applications is incorporated by reference herein in its entirety.

SEQUENCE LISTING

- 10 [0002] The instant application contains a Sequence Listing which has been submitted electronically in ASCII format and is hereby incorporated by reference in its entirety. Said ASCII copy, created on April 17, 2020, is named 000222-0002-WO1_SL.txt and is 70,821 bytes in size.

TECHNICAL FIELD

- 15 [0003] The present disclosure is in the fields of delivery of molecules associated with genome engineering and gene therapy.

BACKGROUND

- [0004] Artificial nucleases, such as engineered zinc finger nucleases (ZFN), transcription-activator like effector nucleases (TALENs), the CRISPR/Cas system with
20 an engineered crRNA/tracrRNA ('single guide RNA'), also referred to as RNA guided nucleases, and/or nucleases based on the Argonaute system are revolutionizing the fields of medicine, biotechnology and agriculture. These molecular tools are allowing the genetic manipulation (*e.g.* editing) of genomes in organisms to a level never-before possible. In addition, gene therapy (delivery of a transgene to a cell in the body that is
25 maintained extra-chromosomally and expresses a product encoded by the transgene) is being studied in the clinic to deliver such needed proteins as clotting factors and proteins to treat ocular disorders. The promise of these revolutionary technologies is dependent on efficient delivery of the nuclease systems and/or transgenes to the appropriate tissue in the body.
- 30 [0005] Adeno-associated virus (AAV) is a promising *in vitro* and *in vivo* gene delivery vector for delivering nuclease systems described above as well as the vectors associated with gene therapy. There are several naturally occurring ("wild-type")

serotypes and over 100 known variants of AAV, each of which differs in amino acid sequence, particularly within the hypervariable regions of the capsid proteins, and thus in their gene delivery properties. AAV has not been associated with any human disease, making recombinant AAV attractive for clinical applications. AAV also displays
5 several additional favorable characteristics including an absence of pathogenicity, low immunogenicity, and stable episomal transgene expression. However, the use of AAV also has some issues including promiscuous viral tropism, limited ability to circumvent biological barriers, and the high prevalence of pre-existing neutralizing antibodies against AAV capsid proteins in human subjects that potentially limit their efficacy.
10 Thus, improvements in AAV design are needed to fully exploit these new systems.

SUMMARY

[0006] The present disclosure provides methods and compositions to develop AAV capsids with a desired characteristic compared to a natural AAV serotype. These capsids are useful, for example, for the delivery of genome engineering molecules and
15 gene therapy molecules for the treatment of a subject in need thereof. In some embodiments, the capsids are used to deliver a payload to a desired tissue, cell or organelle.

[0007] In a first aspect, the present disclosure provides a method of identifying an AAV capsid variant with a desired characteristic compared to a natural AAV serotype,
20 comprising: (i) contacting a cell, cell line, or tissue with a library of AAV variants, wherein each member of the library comprises: a) a nucleic acid encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein; and one or more of: b) one or more silent mutations in the nucleic acid sequence flanking the peptide insertion site in the AAV
25 variant capsid protein of a); c) a nucleic acid encoding a localization signal; d) a nucleic acid comprising a barcode; and e) a nucleic acid encoding a reporter protein; (ii) allowing the AAV variants in said library to transduce the cell, cell line, or tissue; (iii) recovering from the cell, cell line, or tissue the AAV variant; and (iv) identifying the AAV capsid variant with the desired characteristic.

30 [0008] In some embodiments, each member of the library used in the methods disclosed herein comprises a) a nucleic acid encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein and b) one or more silent mutations in the nucleic acid sequence

flanking the peptide insertion site in the AAV variant capsid protein. In some embodiments, each member of the library used in the methods disclosed herein comprises a) a nucleic acid encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, b) one or more silent mutations in the nucleic acid sequence flanking the peptide insertion site in the AAV variant capsid protein, and c) a nucleic acid encoding a localization signal. In some embodiments, each member of the library used in the methods disclosed herein comprises a) a nucleic acid encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, b) one or more silent mutations in the nucleic acid sequence flanking the peptide insertion site in the AAV variant capsid protein, c) a nucleic acid encoding a localization signal, and d) a nucleic acid comprising a barcode. In some embodiments, each member of the library used in the methods disclosed herein comprises a) a nucleic acid encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, b) one or more silent mutations in the nucleic acid sequence flanking the peptide insertion site in the AAV variant capsid protein, c) a nucleic acid encoding a localization signal, d) a nucleic acid comprising a barcode, and e) a nucleic acid encoding a reporter protein.

[0009] In some embodiments, each member of the library used in the methods disclosed herein comprises a) a nucleic acid encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, and c) a nucleic acid encoding a localization signal. In some embodiments, each member of the library used in the methods disclosed herein comprises a) a nucleic acid encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, c) a nucleic acid encoding a localization signal, and d) a nucleic acid comprising a barcode. In some embodiments, each member of the library used in the methods disclosed herein comprises a) a nucleic acid encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, c) a nucleic acid encoding a localization signal, and e) a nucleic acid encoding a reporter protein. In some embodiments, each member of the library used in the methods disclosed herein comprises a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop

of the variant capsid protein, c) a nucleic acid encoding a localization signal, d) a nucleic acid comprising a barcode, and e) a nucleic acid encoding a reporter protein.

[0010] In some embodiments, each member of the library used in the methods disclosed herein comprises a) a nucleic acid encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, and d) a nucleic acid comprising a barcode. In some embodiments, each member of the library used in the methods disclosed herein comprises a) a nucleic acid encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, and e) a nucleic acid encoding a reporter protein. In some embodiments, each member of the library used in the methods disclosed herein comprises a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, and e) a nucleic acid encoding a reporter protein.

[0011] In a second aspect, the present disclosure provides a method of identifying an AAV capsid variant with a desired characteristic compared to a natural AAV serotype, comprising: (i) contacting a cell, cell line, or tissue with a library of AAV variants, wherein each member of the library comprises: a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein; and one or more of: b) one or more silent mutations in the nucleic acid encoding the AAV variant capsid protein of a), wherein the one or more silent mutations are in the nucleic acid sequence flanking the peptide insertion site; c) a nucleic acid encoding a localization signal; d) a nucleic acid comprising a barcode; and e) a nucleic acid encoding a reporter protein; (ii) allowing the AAV variants in said library to transduce the cell, cell line, or tissue; (iii) recovering from the cell, cell line, or tissue the AAV variant; and (iv) identifying the AAV capsid variant with the desired characteristic.

[0012] In some embodiments, each member of the library used in the methods disclosed herein comprises a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, and b) one or more silent mutations in the nucleic acid encoding the AAV variant capsid protein of a), wherein the one or more silent mutations are in the nucleic acid sequence flanking the peptide insertion site. In some embodiments, each member of the library used in the methods disclosed herein comprises a) an AAV variant capsid protein

comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, and b) one or more silent mutations in the nucleic acid encoding the AAV variant capsid protein of a), wherein the one or more silent mutations are in the nucleic acid sequence flanking the peptide insertion site, and c) a nucleic acid encoding a localization signal. In some embodiments, each member of the library used in the methods disclosed herein comprises a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, and b) one or more silent mutations in the nucleic acid encoding the AAV variant capsid protein of a), wherein the one or more silent mutations are in the nucleic acid sequence flanking the peptide insertion site, c) a nucleic acid encoding a localization signal, and d) a nucleic acid comprising a barcode. In some embodiments, each member of the library used in the methods disclosed herein comprises a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, and b) one or more silent mutations in the nucleic acid encoding the AAV variant capsid protein of a), wherein the one or more silent mutations are in the nucleic acid sequence flanking the peptide insertion site, c) a nucleic acid encoding a localization signal, d) a nucleic acid comprising a barcode, and e) a nucleic acid encoding a reporter protein.

[0013] In some embodiments, each member of the library used in the methods disclosed herein comprises a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, and c) a nucleic acid encoding a localization signal. In some embodiments, each member of the library used in the methods disclosed herein comprises a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, c) a nucleic acid encoding a localization signal, and d) a nucleic acid comprising a barcode. In some embodiments, each member of the library used in the methods disclosed herein comprises a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, c) a nucleic acid encoding a localization signal, and e) a nucleic acid encoding a reporter protein. In some embodiments, each member of the library used in the methods disclosed herein comprises a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, c) a nucleic acid encoding a localization signal, d) a nucleic acid comprising a barcode, and e) a nucleic acid encoding a reporter protein.

[0014] In some embodiments, each member of the library used in the methods disclosed herein comprises a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, and d) a nucleic acid comprising a barcode. In some embodiments, each member of the library used in the methods disclosed herein comprises a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, d) a nucleic acid comprising a barcode, and e) a nucleic acid encoding a reporter protein. In some embodiments, each member of the library used in the methods disclosed herein comprises a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, and e) a nucleic acid encoding a reporter protein.

[0015] In some embodiments, the nucleic acid encoding an AAV variant capsid protein, and the nucleic acid encoding a localization signal, the nucleic acid comprising a barcode, and/or the nucleic acid encoding a reporter protein, are located in separate nucleic acid molecules. In other embodiments, the nucleic acid encoding an AAV variant capsid protein, the nucleic acid encoding a localization signal, the nucleic acid comprising a barcode, and/or the nucleic acid encoding a reporter protein, are located in one nucleic acid molecule. In some embodiments, the nucleic acid encoding an AAV variant capsid protein, and the nucleic acid encoding a localization signal, the nucleic acid comprising a barcode, and/or the nucleic acid encoding a reporter protein, are linked to each other in any order. In some embodiments, each member of the library comprises: a 5' ITR sequence, the nucleic acid comprising a barcode, the nucleic acid encoding a reporter protein, the nucleic acid encoding an AAV variant capsid protein, and a 3' ITR sequence, in that order.

[0016] In some embodiments, the library of AAV variants used in the methods disclosed herein comprises AAV variant capsid proteins derived from two or more AAV serotypes. In some embodiments, the AAV serotype is selected from one or more of: AAV1, AAV2, AAV3B, AAV5, AAV6, AAV8, AAV9, AAV3, AAV4, AAV7, AAV11, AAVrh10, AAVrh39, and AAVrh74.

[0017] In some embodiments, the nucleic acid encoding the reporter protein and the nucleic acid encoding the AAV variant capsid are under the control of separate promoters. In some embodiments, the nucleic acid encoding the reporter protein and the nucleic acid encoding the AAV variant capsid are each independently operatively linked to a promoter.

[0018] In some embodiments, the desired characteristic of the AAV capsid variant identified by the methods disclosed herein is enhanced cell or tissue tropism.

[0019] In a third aspect, the disclosure provides a method of identifying an AAV capsid variant with a desired characteristic compared to a natural AAV serotype, comprising: (i) inserting a plurality of nucleic acids encoding peptides, into a population of nucleic acids encoding a hypervariable and/or surface-exposed loop of an AAV capsid protein to create a library of nucleic acids encoding AAV variant capsid proteins; (ii) linking each nucleic acid encoding an AAV variant capsid protein in said library to one or more of: (a) a nucleic acid comprising a barcode, (b) a nucleic acid encoding a reporter protein, and (c) a nucleic acid encoding a localization signal; (iii) manufacturing a library of AAV variants in producer cells by providing adenovirus helper and AAV rep functions *in trans*; (iv) purifying the library of AAV variants; (v) contacting a cell, cell line, or tissue with the library of AAV variants; (vi) recovering the AAV variants from the target cell, cell line, or tissue; and (vii) identifying the AAV capsid variant with the desired characteristic.

[0020] In some embodiments, each nucleic acid encoding an AAV variant capsid protein in said library used in the methods disclosed herein is linked to (a) a nucleic acid comprising a barcode. In some embodiments, each nucleic acid encoding an AAV variant capsid protein in said library used in the methods disclosed herein is linked to (a) a nucleic acid comprising a barcode, and (b) a nucleic acid encoding a reporter protein. In some embodiments, each nucleic acid encoding an AAV variant capsid protein in said library used in the methods disclosed herein is linked to (a) a nucleic acid comprising a barcode, and (c) a nucleic acid encoding a localization signal. In some embodiments, each nucleic acid encoding an AAV variant capsid protein in said library used in the methods disclosed herein is linked to (a) a nucleic acid comprising a barcode, (b) a nucleic acid encoding a reporter protein, and (c) a nucleic acid encoding a localization signal. In some embodiments, each nucleic acid encoding an AAV variant capsid protein in said library used in the methods disclosed herein is linked to (a) a nucleic acid comprising a barcode, and (d) one or more silent mutations in the nucleic acid sequence flanking the peptide insertion site. In some embodiments, each nucleic acid encoding an AAV variant capsid protein in said library used in the methods disclosed herein is linked to (a) a nucleic acid comprising a barcode, (b) a nucleic acid encoding a reporter protein, and (d) one or more silent mutations in the nucleic acid sequence flanking the peptide insertion site. In some embodiments, each nucleic acid

encoding an AAV variant capsid protein in said library used in the methods disclosed herein is linked to (a) a nucleic acid comprising a barcode, (b) a nucleic acid encoding a reporter protein, (c) a nucleic acid encoding a localization signal and (d) one or more silent mutations in the nucleic acid sequence flanking the peptide insertion site.

- 5 [0021] In some embodiments, each nucleic acid encoding an AAV variant capsid protein in said library used in the methods disclosed herein is linked to (b) a nucleic acid encoding a reporter protein. In some embodiments, each nucleic acid encoding an AAV variant capsid protein in said library used in the methods disclosed herein is linked to (b) a nucleic acid encoding a reporter protein, and (c) a nucleic acid encoding a localization signal. In some embodiments, each nucleic acid encoding an AAV variant capsid protein further comprises one or more silent mutations in the nucleic acid sequence flanking the peptide insertion site. In some
10 embodiments, each nucleic acid encoding an AAV variant capsid protein in said library used in the methods disclosed herein is linked to (b) a nucleic acid encoding a reporter protein, and (d) one or more silent mutations in the nucleic acid sequence flanking the peptide insertion site. In some embodiments, each nucleic acid encoding an AAV variant capsid protein in said library used in the methods disclosed herein is linked to (c) a nucleic acid encoding a localization signal and (d) one or more silent mutations in the nucleic acid sequence flanking the peptide insertion site. In some
15 embodiments, each nucleic acid encoding an AAV variant capsid protein in said library used in the methods disclosed herein is linked to (d) one or more silent mutations in the nucleic acid sequence flanking the peptide insertion site.
- 20 [0022] In some embodiments, step (iv) further comprises combining libraries of variant AAVs based on two or more AAV serotypes to generate a single pool. In some embodiments, the population of nucleic acid sequences encoding a hypervariable and/or surface-exposed loop of an AAV capsid protein used in the methods disclosed herein comprises sequences derived from two or more AAV serotypes. In some
25 embodiments, the AAV serotype is selected from one or more of: AAV1, AAV2, AAV3B, AAV5, AAV6, AAV8, AAV9, AAV3, AAV4, AAV7, AAV11, AAVrh10, AAVrh39, and AAVrh74.

[0023] In some embodiments, the adenovirus helper functions used in the methods disclosed herein comprise one or more of E2A, E4, VA, E1A, and E1B. In some

embodiments, the AAV rep function comprises rep78, rep 68, rep 52 and rep40 genes. In some embodiments the start codon of the rep78 and/or rep68 gene used in the methods disclosed herein is modified from ACG to ATG. In some embodiments, the producer cells used in the methods disclosed herein are HEK293 cells.

5 [0024] In some embodiments, the nucleic acid encoding an AAV variant capsid protein, the nucleic acid comprising a barcode, the nucleic acid encoding a reporter protein, and/or a nucleic acid encoding a localization signal used in the methods disclosed herein are linked to each other in any order. In some embodiments, each member of the library comprises: a 5'ITR sequence, the nucleic acid comprising a
10 barcode, the nucleic acid encoding a reporter protein, the nucleic acid encoding an AAV variant capsid protein, and a 3'ITR sequence, in that order.

[0025] In some embodiments, the nucleic acid encoding a reporter protein and the nucleic acid encoding the AAV variant capsid used in the methods disclosed herein are under the control of separate promoters. In some embodiments, the nucleic acid
15 encoding a reporter protein and the nucleic acid encoding the AAV variant capsid used in the methods disclosed herein are each independently operatively linked to a promoter.

[0026] In some embodiments, the desired characteristic of the AAV capsid variant is enhanced cell or tissue tropism.

20 [0027] In some embodiments of the methods disclosed herein, the AAV capsid variant with the desired characteristic is identified through sequencing of the associated barcode. In some embodiments of the methods disclosed herein, the AAV capsid variant with the desired characteristic is identified through sequencing of the associated one or more barcode. In some embodiments, a first barcode operatively linked to a
25 promoter identifies barcoded transcripts in a target cell population, for example neurons or hepatocytes, because the promoter is only expressed in a specific cell population. In some embodiments, a second barcode identifies expression in all cell types, because it is operatively linked to a promoter which drives ubiquitous expression.

[0028] In some embodiments of the methods disclosed herein, the AAV capsid
30 variant with the desired characteristic is identified by purification and sequencing of the AAV genome.

[0029] In some embodiments of the methods disclosed herein, the cell or tissue includes but is not limited to a cell or tissue from the CNS, heart, lung, trachea, esophagus, muscle, bone, cartilage, stomach, pancreas, intestine, liver, bladder, kidney,

ureter, urethra, uterus, fallopian tube, ovary, testes, prostate, eye, blood, lymph, or oral mucosa.

[0030] In some embodiments of the methods disclosed herein, the cell includes, but is not limited to, neurons, glial cells, astrocytes, oligodendroglia, microglia, Schwann
5 cells, ependymal cells, hepatocytes, stellate fat storing cells, Kupffer cells, liver endothelial cells, epithelial cells, cardiomyocytes, smooth muscle cells, T-cells, B cells, hematopoietic stem cells, and embryonic stem cells.

[0031] In some embodiments of the methods disclosed herein, one or more of (i) the nucleic acid encoding a localization signal; (ii) the nucleic acid comprising a barcode;
10 and (iii) the nucleic acid encoding a reporter protein are provided in *trans* with respect to the nucleic acid encoding the AAV variant capsid protein comprising the inserted peptide. In some embodiments of the methods disclosed herein, i) the nucleic acid encoding a localization signal; (ii) the nucleic acid comprising a barcode; and (iii) the nucleic acid encoding a reporter protein are all provided in *trans* with respect to the
15 nucleic acid encoding the AAV variant capsid protein comprising the inserted peptide. In some embodiments of the methods disclosed herein, one or more of (i) the nucleic acid encoding a localization signal; (ii) the nucleic acid comprising a barcode; and (iii) the nucleic acid encoding a reporter protein are provided in *cis* with respect to the nucleic acid encoding the AAV variant capsid protein comprising the inserted peptide.
20 In some embodiments of the methods disclosed herein, i) the nucleic acid encoding a localization signal; (ii) the nucleic acid comprising a barcode; and (iii) the nucleic acid encoding a reporter protein are all provided in *cis* with respect to the nucleic acid encoding the AAV variant capsid protein comprising the inserted peptide. .

[0032] In a fourth aspect, the present disclosure provides a library of AAV variants,
25 wherein each member of said library comprises: a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein; and one or more of: b) one or more silent mutations in the nucleic acid sequence flanking the peptide insertion site in the AAV variant capsid protein of a); c) a nucleic acid encoding a localization signal;
30 d) a nucleic acid comprising a barcode; and e) a nucleic acid encoding a reporter protein.

[0033] In some embodiments, each member of the library disclosed herein comprises a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein and b) one or more silent mutations in the nucleic acid sequence flanking the

peptide insertion site in the AAV variant capsid protein. In some embodiments, each member of the library disclosed herein comprises a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, b) one or more silent mutations in the nucleic acid sequence flanking the peptide insertion site in the AAV variant capsid protein, and c) a nucleic acid encoding a localization signal. In some embodiments, each member of the library disclosed herein comprises a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, b) one or more silent mutations in the nucleic acid sequence flanking the peptide insertion site in the AAV variant capsid protein, c) a nucleic acid encoding a localization signal, and d) a nucleic acid comprising a barcode. In some embodiments, each member of the library disclosed herein comprises a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, b) one or more silent mutations in the nucleic acid sequence flanking the peptide insertion site in the AAV variant capsid protein, c) a nucleic acid encoding a localization signal, d) a nucleic acid comprising a barcode, and e) a nucleic acid encoding a reporter protein.

[0034] In some embodiments, each member of the library disclosed herein comprises a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, and c) a nucleic acid encoding a localization signal. In some embodiments, each member of the library disclosed herein comprises a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, c) a nucleic acid encoding a localization signal, and d) a nucleic acid comprising a barcode. In some embodiments, each member of the library disclosed herein comprises a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, c) a nucleic acid encoding a localization signal, and e) a nucleic acid encoding a reporter protein. In some embodiments, each member of the library disclosed herein comprises a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, c) a nucleic acid encoding a localization signal, d) a nucleic acid comprising a barcode, and e) a nucleic acid encoding a reporter protein.

[0035] In some embodiments, each member of the library disclosed herein comprises a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, and d) a nucleic acid comprising a barcode. In some embodiments, each member of the library disclosed herein comprises a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, d) a nucleic acid comprising a barcode, and e) a nucleic acid encoding a reporter protein. In some embodiments, each member of the library disclosed herein comprises a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, and e) a nucleic acid encoding a reporter protein.

[0036] In a fifth aspect, the present disclosure provides a library of AAV variants, wherein each member of said library comprises: a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein; and one or more of: b) one or more silent mutations in the nucleic acid encoding the AAV variant capsid protein of a), wherein the one or more silent mutations are in the nucleic acid sequence flanking the peptide insertion site; c) a nucleic acid encoding a localization signal; d) a nucleic acid comprising a barcode; and e) a nucleic acid encoding a reporter protein.

[0037] In some embodiments, each member of the library disclosed herein comprises a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, and b) one or more silent mutations in the nucleic acid encoding the AAV variant capsid protein of a), wherein the one or more silent mutations are in the nucleic acid sequence flanking the peptide insertion site. In some embodiments, each member of the library disclosed herein comprises a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, and b) one or more silent mutations in the nucleic acid encoding the AAV variant capsid protein of a), wherein the one or more silent mutations are in the nucleic acid sequence flanking the peptide insertion site, and c) a nucleic acid encoding a localization signal. In some embodiments, each member of the library disclosed herein comprises a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, and b) one or more silent mutations in the

nucleic acid encoding the AAV variant capsid protein of a), wherein the one or more silent mutations are in the nucleic acid sequence flanking the peptide insertion site, c) a nucleic acid encoding a localization signal, and d) a nucleic acid comprising a barcode. In some embodiments, each member of the library disclosed herein comprises

5 a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, and b) one or more silent mutations in the nucleic acid encoding the AAV variant capsid protein of a), wherein the one or more silent mutations are in the nucleic acid sequence flanking the peptide insertion site, c) a nucleic acid encoding a localization signal, d) a nucleic acid comprising a barcode, and e) a nucleic acid encoding a reporter protein.

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[0038] In some embodiments, each member of the library disclosed herein comprises a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, and c) a nucleic acid encoding a localization signal. In some embodiments, each member of the library disclosed herein comprises

15 a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, c) a nucleic acid encoding a localization signal, and d) a nucleic acid comprising a barcode. In some embodiments, each member of the library disclosed herein comprises

20 a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, c) a nucleic acid encoding a localization signal, and e) a nucleic acid encoding a reporter protein. In some embodiments, each member of the library disclosed herein comprises a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, c) a nucleic acid encoding a localization signal, d) a nucleic acid comprising a barcode, and e) a nucleic acid encoding a reporter protein.

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[0039] In some embodiments, each member of the library disclosed herein comprises a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, and d) a nucleic acid comprising a barcode. In some embodiments, each member of the library disclosed herein comprises a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, d) a nucleic acid comprising a barcode, and e) a nucleic acid encoding a reporter protein. In some

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embodiments, each member of the library disclosed herein comprises a) an AAV

variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, and e) a nucleic acid encoding a reporter protein.

[0040] In some embodiments, the nucleic acid encoding an AAV variant capsid protein, and the nucleic acid encoding a localization signal, the nucleic acid comprising a barcode, and/or the nucleic acid encoding a reporter protein, are located in separate nucleic acid molecules. In other embodiments, the nucleic acid encoding an AAV variant capsid protein, the nucleic acid encoding a localization signal, the nucleic acid comprising a barcode, and/or the nucleic acid encoding a reporter protein, are located in one nucleic acid molecule. In some embodiments, the nucleic acid encoding an AAV variant capsid protein, and the nucleic acid encoding a localization signal, the nucleic acid comprising a barcode, and/or the nucleic acid encoding a reporter protein, are linked to each other in any order. In some embodiments, each member of the library disclosed herein comprises: a 5' ITR sequence, the nucleic acid comprising a barcode, the nucleic acid encoding a reporter protein, the nucleic acid encoding an AAV variant capsid protein, and a 3' ITR sequence, in that order.

[0041] In some embodiments, the library of AAV variants disclosed herein comprises AAV variant capsid proteins derived from two or more AAV serotypes. In some embodiments, the AAV serotype is selected from one or more of: AAV1, AAV2, AAV3B, AAV5, AAV6, AAV8, AAV9, AAV3, AAV4, AAV7, AAV11, AAVrh10, AAVrh39, and AAVrh74.

[0042] In some embodiments, the nucleic acid encoding the reporter protein and the nucleic acid encoding the AAV variant capsid are under the control of separate promoters. In some embodiments, the nucleic acid encoding the reporter protein and the nucleic acid encoding the AAV variant capsid are each independently operatively linked to a promoter.

[0043] In a sixth aspect, the present disclosure provides an AAV variant comprising: a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein; and one or more of: b) one or more silent mutations in the nucleic acid sequence flanking the peptide insertion site in the AAV variant capsid protein of a); c) a nucleic acid encoding a localization signal; d) a nucleic acid comprising a barcode; and e) a nucleic acid encoding a reporter protein.

[0044] In some embodiments, an AAV variant disclosed herein comprises a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein and b) one or more silent mutations in the nucleic acid sequence flanking the peptide insertion site in the AAV variant capsid protein. In some embodiments, an AAV variant disclosed herein comprises a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, b) one or more silent mutations in the nucleic acid sequence flanking the peptide insertion site in the AAV variant capsid protein, and c) a nucleic acid encoding a localization signal. In some embodiments, an AAV variant disclosed herein comprises a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, b) one or more silent mutations in the nucleic acid sequence flanking the peptide insertion site in the AAV variant capsid protein, c) a nucleic acid encoding a localization signal, and d) a nucleic acid comprising a barcode. In some embodiments, an AAV variant disclosed herein comprises a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, b) one or more silent mutations in the nucleic acid sequence flanking the peptide insertion site in the AAV variant capsid protein, c) a nucleic acid encoding a localization signal, d) a nucleic acid comprising a barcode, and e) a nucleic acid encoding a reporter protein.

[0045] In some embodiments, an AAV variant disclosed herein comprises a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, and c) a nucleic acid encoding a localization signal. In some embodiments, an AAV variant disclosed herein comprises a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, c) a nucleic acid encoding a localization signal, and d) a nucleic acid comprising a barcode. In some embodiments, an AAV variant disclosed herein comprises a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, c) a nucleic acid encoding a localization signal, and e) a nucleic acid encoding a reporter protein. In some embodiments, an AAV variant disclosed herein comprises a) a nucleic acid sequence encoding an AAV

variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, c) a nucleic acid encoding a localization signal, d) a nucleic acid comprising a barcode, and e) a nucleic acid encoding a reporter protein.

- 5 [0046] In some embodiments, an AAV variant disclosed herein comprises a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, and d) a nucleic acid comprising a barcode. In some embodiments, an AAV variant disclosed herein comprises a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, d) a nucleic acid comprising a barcode, and e) a nucleic acid encoding a reporter protein. In some embodiments, an AAV variant disclosed herein comprises a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, and e) a nucleic acid encoding a reporter protein.

- 10 [0047] In a seventh aspect, the present disclosure provides an AAV variant comprising: a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein; and one or more of: b) one or more silent mutations in the nucleic acid encoding the AAV variant capsid protein of a) in the nucleic acid sequence flanking the peptide insertion site; c) a nucleic acid encoding a localization signal; d) a nucleic acid comprising a barcode; and e) a nucleic acid encoding a reporter protein.

- 15 [0048] In some embodiments, an AAV variant disclosed herein comprises a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, and b) one or more silent mutations in the nucleic acid encoding the AAV variant capsid protein of a), wherein the one or more silent mutations are in the nucleic acid sequence flanking the peptide insertion site. In some embodiments, an AAV variant disclosed herein comprises a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, and b) one or more silent mutations in the nucleic acid encoding the AAV variant capsid protein of a), wherein the one or more silent mutations are in the nucleic acid sequence flanking the peptide insertion site, and c) a nucleic acid encoding a localization signal. In some embodiments, an AAV variant disclosed herein comprises a) an AAV variant capsid protein comprising a peptide

inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, and b) one or more silent mutations in the nucleic acid encoding the AAV variant capsid protein of a), wherein the one or more silent mutations are in the nucleic acid sequence flanking the peptide insertion site, c) a nucleic acid encoding a localization signal, and
5 d) a nucleic acid comprising a barcode. In some embodiments, an AAV variant disclosed herein comprises a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, and b) one or more silent mutations in the nucleic acid encoding the AAV variant capsid protein of a), wherein the one or more silent mutations are in the nucleic acid sequence
10 flanking the peptide insertion site, c) a nucleic acid encoding a localization signal, d) a nucleic acid comprising a barcode, and e) a nucleic acid encoding a reporter protein.

[0049] In some embodiments, an AAV variant disclosed herein comprises a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, and c) a nucleic acid encoding a localization
15 signal. In some embodiments, an AAV variant disclosed herein comprises a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, c) a nucleic acid encoding a localization signal, and d) a nucleic acid comprising a barcode. In some embodiments, an AAV variant disclosed herein comprises a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid
20 protein, c) a nucleic acid encoding a localization signal, and e) a nucleic acid encoding a reporter protein. In some embodiments, an AAV variant disclosed herein comprises a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, c) a nucleic acid encoding a localization signal, d) a nucleic acid comprising a barcode, and e) a nucleic acid
25 encoding a reporter protein.

[0050] In some embodiments, an AAV variant disclosed herein comprises a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, and d) a nucleic acid comprising a barcode.
30 In some embodiments, an AAV variant disclosed herein comprises a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, d) a nucleic acid comprising a barcode, and e) a nucleic acid encoding a reporter protein. In some embodiments, an AAV variant disclosed herein comprises a) an AAV variant capsid protein comprising a peptide

inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, and e) a nucleic acid encoding a reporter protein.

[0051] In some embodiments, the nucleic acid encoding an AAV variant capsid protein, and the nucleic acid encoding a localization signal, the nucleic acid comprising a barcode, and/or the nucleic acid encoding a reporter protein, are located in separate nucleic acid molecules. In other embodiments, the nucleic acid encoding an AAV variant capsid protein, the nucleic acid encoding a localization signal, the nucleic acid comprising a barcode, and/or the nucleic acid encoding a reporter protein, are located in one nucleic acid molecule. In some embodiments, the nucleic acid encoding an AAV variant capsid protein, and the nucleic acid encoding a localization signal, the nucleic acid comprising a barcode, and/or the nucleic acid encoding a reporter protein, are linked to each other in any order. In some embodiments, an AAV variant comprises: a 5' ITR sequence, the nucleic acid comprising a barcode, the nucleic acid encoding a reporter protein, the nucleic acid encoding an AAV variant capsid protein, and a 3' ITR sequence, in that order.

[0052] In some embodiments, an AAV variant disclosed herein is derived from the group consisting of: AAV1, AAV2, AAV3B, AAV5, AAV6, AAV8, AAV9, AAV3, AAV4, AAV7, AAV11, AAVrh10, AAVrh39, and AAVrh74.

[0053] In some embodiments, the nucleic acid encoding the reporter protein and the nucleic acid encoding the AAV variant capsid are under the control of separate promoters. In some embodiments, the nucleic acid encoding the reporter protein and the nucleic acid encoding the AAV variant capsid are each independently operatively linked to a promoter.

[0054] In an eighth aspect, the present disclosure provides a nucleic acid molecule comprising a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein; and one or more of: b) a nucleic acid sequence encoding a variant capsid protein comprising one or more silent mutations in the nucleotide sequence flanking the peptide insertion site in the hypervariable and/or surface-exposed loop of the variant capsid protein; c) a nucleic acid sequence encoding a localization signal; d) a nucleic acid sequence comprising a barcode; and e) a nucleic acid sequence encoding a reporter protein.

[0055] In some embodiments, a nucleic acid disclosed herein comprises a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted

into a hypervariable and/or surface-exposed loop of the variant capsid protein and b) one or more silent mutations in the nucleic acid sequence flanking the peptide insertion site in the AAV variant capsid protein. In some embodiments, a nucleic acid disclosed herein comprises a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, b) one or more silent mutations in the nucleic acid sequence flanking the peptide insertion site in the AAV variant capsid protein, and c) a nucleic acid encoding a localization signal. In some embodiments, a nucleic acid disclosed herein comprises a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, b) one or more silent mutations in the nucleic acid sequence flanking the peptide insertion site in the AAV variant capsid protein, c) a nucleic acid encoding a localization signal, and d) a nucleic acid comprising a barcode. In some embodiments, a nucleic acid disclosed herein comprises a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, b) one or more silent mutations in the nucleic acid sequence flanking the peptide insertion site in the AAV variant capsid protein, c) a nucleic acid encoding a localization signal, d) a nucleic acid comprising a barcode, and e) a nucleic acid encoding a reporter protein.

[0056] In some embodiments, a nucleic acid disclosed herein comprises a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, and c) a nucleic acid encoding a localization signal. In some embodiments, a nucleic acid disclosed herein comprises a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, c) a nucleic acid encoding a localization signal, and d) a nucleic acid comprising a barcode. In some embodiments, a nucleic acid disclosed herein comprises a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, c) a nucleic acid encoding a localization signal, and e) a nucleic acid encoding a reporter protein. In some embodiments, a nucleic acid disclosed herein comprises a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the

variant capsid protein, c) a nucleic acid encoding a localization signal, d) a nucleic acid comprising a barcode, and e) a nucleic acid encoding a reporter protein.

[0057] In some embodiments, a nucleic acid disclosed herein comprises a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, and d) a nucleic acid comprising a barcode. In some embodiments, a nucleic acid disclosed herein comprises a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, d) a nucleic acid comprising a barcode, and e) a nucleic acid encoding a reporter protein. In some embodiments, a nucleic acid disclosed herein comprises a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein, and e) a nucleic acid encoding a reporter protein.

[0058] In some embodiments of a method, library, AAV variant, or nucleic acid disclosed herein, the peptide inserted into a variant capsid protein has a length of 4-15 amino acids. In some embodiments, the peptide has a length of 6-15 amino acids. In some embodiments, the peptide has a length of 7, 10, or 15 amino acids. In some embodiments, the peptide has a length of 7 amino acids. In some embodiments, the inserted peptide comprises at least 4 contiguous amino acids of an amino acid sequence set forth in any one of SEQ ID NO: 1-32. In some embodiments, the inserted peptide comprises at least 4 contiguous amino acids of an amino acid sequence set forth in any one of SEQ ID NO: 68-110. In some embodiments, the peptide comprises an amino acid sequence set forth in any one of SEQ ID NO: 1-32. In some embodiments, the peptide comprises an amino acid sequence set forth in any one of SEQ ID NO: 68-110.

[0059] In some embodiments, the peptide is inserted into the VR-I, VR-II, VR-III, VR-IV, VR-V, VR-VI, VR-VII, VR-VIII or VR-IX region of the capsid protein. In some embodiments, the peptide is inserted into the VR-I of the capsid protein. In some embodiments, the peptide is inserted into the VR-IV of the capsid protein. In some embodiments, the peptide is inserted into the VR-VIII of the capsid protein. In some embodiments, the peptide is inserted into the capsid protein VP1, VP2, or VP3. It is well recognized that VP2 and VP3 proteins are truncated forms of VP1 protein.

[0060] In some embodiments, the peptide is inserted at a location between amino acid residues 450 and 600 of the capsid protein. In some embodiments, (i) the AAV serotype is AAV1 and the peptide is inserted at amino acid position 590 of the capsid protein,

- (ii) the AAV serotype is AAV6 and the peptide is inserted at amino acid position 454 or 590 of the capsid protein, (iii) the AAV serotype is AAV2 and the peptide is inserted at amino acid position 588 of the capsid protein, (iv) the AAV serotype is AAV3B and the peptide is inserted at amino acid position 589 of the capsid protein, (v) the AAV serotype is AAV5 and the peptide is inserted at amino acid position 578 of the capsid protein, (vi) the AAV serotype is AAV8 and the peptide is inserted at amino acid position 591 of the capsid protein, or (vii) the AAV serotype is AAV9 and the peptide is inserted at amino acid position 266, 455, or 589 of the capsid protein, wherein the positions correspond to the numbering of VP1 in the AAV serotype.
- 10 [0061] In some embodiments of a method, library, AAV variant, or nucleic acid disclosed herein, the nucleic acid encoding an AAV variant capsid protein is under the control of the p40 promoter. In some embodiments of a method, library, AAV variant, or nucleic acid disclosed herein, the nucleic acid encoding an AAV variant capsid protein is operatively linked to the p40 promoter.
- 15 [0062] In some embodiments of a method, library, AAV variant, or nucleic acid disclosed herein, the nucleic acid encoding the reporter protein encodes a fluorescent protein. In some embodiments, the reporter protein is selected from the group consisting of: EGFP, mCherry, mClover3, mRuby3, mApple, iRFP, tdTomato, mVenus, YFP, RFP, firefly luciferase, and nanoluciferase.
- 20 [0063] In some embodiments, the nucleic acid encoding a reporter protein is under the control of a cell type and/or tissue specific promoter. In some embodiments, the nucleic acid encoding a reporter protein is operatively linked to a cell type and/or tissue specific promoter. In some embodiments, the nucleic acid encoding a reporter protein is operatively linked to a cell-type specific RNA polymerase II promoter (e.g. transthyretin or hSynapsin1). In some embodiments, the cell type and/or tissue specific promoter is selected from the group consisting of: human synapsin promoter (hSyn1), transthyretin promoter (TTR), cytokeratin 18, cytokeratin 19, unc-45 myosin chaperon B (unc45b) promoter, cardiac troponin T (cTnT) promoter, glial fibrillary acidic protein (GFAP) promoter, myelin basic protein (MBP) promoter, and methyl CpG-binding protein 2 (MeCP2) promoter. In some embodiments, the cell type and/or tissue specific promoter is the hSyn1 promoter. In some embodiments, the cell type and/or tissue specific promoter is the TTR promoter.
- 25 [0064] In some embodiments of a method, library, AAV variant, or nucleic acid disclosed herein, the reporter protein is fused to the localization signal. In some
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embodiments, the localization signal is fused N-terminally, C-terminally or both N-terminally and C-terminally to the reporter protein. In some embodiments, the localization signal is a nuclear localization signal (NLS), a nuclear envelope binding domain or a histone binding domain. In some embodiments, the NLS is the SV40 NLS.

5 In some embodiments, the nuclear envelope binding domain is a KASH domain. In some embodiments, the histone binding domain is H2B.

[0065] In some embodiments of a method, library, AAV variant, or nucleic acid disclosed herein, the barcode is 5-18 nucleotides long.

[0066] In some embodiments of a method, library, AAV variant, or nucleic acid
10 disclosed herein, the nucleic acid comprising the barcode comprises a sequence selected from any one of sequences SEQ ID NO: 111-154 or 155-198. In some embodiments, the nucleic acid comprising the barcode comprises a sequence selected from any one of sequences SEQ ID NO: 111-154. In some embodiments, the nucleic acid comprising the barcode comprises a sequence selected from any one of sequences SEQ ID NO:
15 155-198. In some embodiments of a method, library, AAV variant, or nucleic acid disclosed herein, the nucleic acid comprising the barcode is selected from any one of sequences SEQ ID NO: 111-154 or 155-198. In some embodiments, the nucleic acid comprising the barcode is selected from any one of sequences SEQ ID NO: 111-154. In some embodiments, the nucleic acid comprising the barcode is selected from any
20 one of sequences SEQ ID NO: 155-198.

[0067] In some embodiments of a method, library of AAV variants, AAV variant, or nucleic acid disclosed herein, each member of the library comprises a first nucleic acid comprising a first barcode and a second nucleic acid comprising a second barcode. In some embodiments, the first nucleic acid comprising the first barcode and the second
25 nucleic acid comprising the second barcode are different. In some embodiments, the first nucleic acid comprising the first barcode comprises a sequence selected from any one of sequences SEQ ID NO: 111-154 or is selected from any one of sequences SEQ ID NO: 111-154. In some embodiments of the method, library of AAV variants, AAV variant, or nucleic acid disclosed herein, the second nucleic acid comprising the second
30 barcode comprises a sequence selected from any one of sequences SEQ ID NO: 155-198 or is selected from any one of sequences SEQ ID NO: 155-198. In some embodiments, the first nucleic acid comprising the first barcode comprises a sequence selected from any one of sequences SEQ ID NO: 111-154 or is selected from any one of sequences SEQ ID NO: 111-154 and the second nucleic acid comprising the second

barcode comprises a sequence selected from any one of sequences SEQ ID NO: 155-198 or is selected from any one of sequences SEQ ID NO: 155-198. In some embodiments, each of the first nucleic acid comprising the first barcode and the second nucleic acid comprising the second barcode is independently operatively linked to a promoter. In some embodiments, said promoter is different for each of the first barcode and the second barcode. In some embodiments, each of the first nucleic acid comprising the first barcode and the second nucleic acid are independently controlled under a different promoter. In some embodiments, the promoter operatively linked to the first nucleic acid comprising the first barcode and the promoter operatively linked to the second nucleic acid comprising the second barcode is each independently an RNA Pol II promoter (e.g., human synapsin promoter (hSyn1), transthyretin promoter (TTR), cytokeratin 18, cytokeratin 19, unc-45 myosin chaperon B (unc45b) promoter, cardiac troponin T (cTnT) promoter, glial fibrillary acidic protein (GFAP) promoter, myelin basic protein (MBP) promoter, or methyl CpG-binding protein 2 (Mecp2) promoter). In some embodiments, the promoter operatively linked to the first nucleic acid comprising the first barcode and the promoter operatively linked to the second nucleic acid comprising the second barcode is each independently an RNA Pol III promoter (e.g., U6 promoter, H1 promoter or 7SK promoter). In some embodiments, the promoter operatively linked to the first nucleic acid comprising the first barcode is an RNA Pol II promoter and the promoter operatively linked to the second nucleic acid comprising the second barcode is an RNA Pol III promoter. In some embodiments, the nucleic acid comprising the barcode further comprises a reporter gene, a nuclear localization signal and a polyadenylation signal.

[0068] In some embodiments, of a method, library, AAV variant, or nucleic acid disclosed herein, each inserted peptide coding sequence is synthesized with multiple different nucleic acid sequences, all encoding the same peptide. Each nucleic acid sequence is linked to a unique bar code such that performance (*e.g.* enrichment) of an inserted peptide can be verified when two or more variants are identified with the same inserted peptide sequence but wherein different nucleic acid sequences encode that inserted peptide.

[0069] In some embodiments, of a method, library, AAV variant or nucleic acid disclosed herein, one or more of (i) the nucleic acid encoding a localization signal; (ii) the nucleic acid comprising a barcode; and (iii) the nucleic acid encoding a reporter protein are provided *in trans* with respect to the nucleic acid encoding the AAV variant

capsid protein comprising the inserted peptide. In some embodiments of a method, library, AAV variant or nucleic acid disclosed herein, (i) the nucleic acid encoding a localization signal, (ii) the nucleic acid comprising a barcode; and (iii) the nucleic acid encoding a reporter protein are all provided in *trans* with respect to the nucleic acid encoding the AAV variant capsid protein comprising the inserted peptide. In some embodiments of a method, library, AAV variant or nucleic acid disclosed herein, one or more of (i) the nucleic acid encoding a localization signal; (ii) the nucleic acid comprising a barcode; and (iii) the nucleic acid encoding a reporter protein are provided in *cis* with respect to the nucleic acid encoding the AAV variant capsid protein comprising the inserted peptide.

5 encoding the AAV variant capsid protein comprising the inserted peptide. In some embodiments of a method, library, AAV variant or nucleic acid disclosed herein, (i) the nucleic acid encoding a localization signal; (ii) the nucleic acid comprising a barcode; and (iii) the nucleic acid encoding a reporter protein are all provided in *cis* with respect to the nucleic acid encoding the AAV variant capsid protein comprising the inserted peptide.

10 comprising the inserted peptide. In some embodiments of a method, library, AAV variant or nucleic acid disclosed herein, (i) the nucleic acid encoding a localization signal; (ii) the nucleic acid comprising a barcode; and (iii) the nucleic acid encoding a reporter protein are all provided in *cis* with respect to the nucleic acid encoding the AAV variant capsid protein comprising the inserted peptide.

15 [0070] In a ninth aspect, an AAV variant disclosed herein is used to deliver a transgene to a target cell or tissue. In some embodiments, the transgene is useful in gene therapy. In some embodiments, the transgene is useful in genome editing.

[0071] In a tenth aspect, the present disclosure provides an AAV vector comprising a nucleic acid encoding a peptide that comprises at least 4 contiguous amino acids of an amino acid sequence set forth in SEQ ID Nos. 1-32 or 68-110. In some embodiments, the AAV vector comprises a nucleic acid encoding a peptide that comprises at least 4 contiguous amino acids of an amino acid sequence set forth in SEQ ID Nos. 1-32. In other embodiments, the AAV vector comprises a nucleic acid encoding a peptide that comprises at least 4 contiguous amino acids of an amino acid sequence set forth in SEQ ID Nos. 68-110. In some embodiments, the nucleic acid encodes an amino acid sequence of any one of SEQ ID Nos. 1-32 or SEQ ID Nos. 68-110. In some embodiments, the nucleic acid encodes the amino acid sequence is any one of SEQ ID Nos. 1-32. In some embodiments, the nucleic acid encodes the amino acid sequence of any one of SEQ ID Nos. 68-110. In some embodiments, the inserted amino acid sequence is a part of a capsid protein. In some embodiments, the capsid protein is VP1, VP2, or VP3. In some embodiments, the amino acid sequence is inserted at a location between amino acid residues 450 and 600 of the capsid protein. In some embodiments, amino acid sequence is inserted at (i) amino acid position 590 of an AAV1 capsid protein, (ii) amino acid position 454 or 590 of an AAV6 capsid

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protein, (iii) amino acid position 588 of an AAV2 capsid protein, (iv) amino acid position 589 of an AAV3B capsid protein, (v) amino acid position 578 of an AAV5 capsid protein, (vi) amino acid position 591 of the an AAV8 capsid protein, or (vi) amino acid position 266, 455, or 589 of an AAV9 capsid protein, wherein the positions
5 correspond to the numbering of VP1 in the AAV serotype.

[0072] In an eleventh aspect, the present disclosure provides a pharmaceutical composition comprising an AAV vector disclosed herein and a pharmaceutically acceptable carrier.

[0073] In a twelfth aspect, the present disclosure provides a peptide comprising an
10 amino acid sequence set forth in any one of SEQ ID Nos. 1-32 or 68-110. In some embodiments, the peptide comprises an amino acid sequence set forth in any one of SEQ ID Nos. 1-32. In some embodiments, the peptide comprises an amino acid sequence set forth in any one of SEQ ID Nos. 68-110. In some embodiments, the peptide is any of the sequences set forth in SEQ ID Nos. 1-32. In some embodiments,
15 the peptide is any of the sequences set forth in SEQ ID Nos. 68-110. In some embodiments, the peptide is part of an AAV vector. In some embodiments, the peptide is part of a capsid protein of the AAV vector.

[0074] In a thirteenth aspect, the present disclosure provides a capsid protein comprising a peptide comprising at least 4 contiguous amino acids of an amino acid
20 sequence set forth in SEQ ID Nos. 1-32 or 68-110. In some embodiments, the capsid protein comprises an inserted peptide comprising at least 4 contiguous amino acids of an amino acid sequence set forth in SEQ ID Nos. 1-32. In some embodiments, the capsid protein comprises the amino acid sequence set forth in any one of SEQ ID Nos. 1-32. In some embodiments, the capsid protein comprises an inserted peptide
25 comprising at least 4 contiguous amino acids of an amino acid sequence set forth in SEQ ID Nos. 68-110. In some embodiments, the capsid protein comprises the amino acid sequence set forth in any one of SEQ ID Nos. 68-110.

[0075] In a fourteenth aspect, the present disclosure provides a nucleic acid sequence encoding the peptides or capsid proteins disclosed herein.

30 [0076] In a fifteenth aspect, the present disclosure provides a method of delivering a nucleic acid to a target cell or tissue of a subject, comprising: administering a composition comprising an AAV vector comprising the nucleic acid, and wherein the AAV vector further comprises a capsid protein comprising an inserted peptide comprising at least 4 contiguous amino acids of an amino acid sequence set forth in

SEQ ID Nos. 1-32 or 68-110. In some embodiments, the capsid protein comprises an inserted peptide comprising at least 4 contiguous amino acids of an amino acid sequence set forth in SEQ ID Nos. 1-32. In other embodiments, the capsid protein comprises an inserted peptide comprising at least 4 contiguous amino acids of an amino acid sequence set forth in SEQ ID Nos. 68-110. In some embodiments, the capsid protein comprises an amino acid sequence set forth in any one of SEQ ID Nos. 1-32. In other embodiments, the capsid protein comprises an amino acid sequence set forth in any one of SEQ ID Nos. 68-110.

[0077] In some embodiments, the target cell or tissue includes, but is not limited to, a cell or tissue from the CNS, heart, lung, trachea, esophagus, muscle, bone, cartilage, stomach, pancreas, intestine, liver, bladder, kidney, ureter, urethra, uterus, fallopian tube, ovary, testes, prostate, eye, blood, lymph, or oral mucosa. In some embodiments, the target cell or tissue includes, but is not limited to CNS, heart, lung, trachea, esophagus, muscle, bone, cartilage, stomach, pancreas, intestine, liver, bladder, kidney, ureter, urethra, uterus, fallopian tube, ovary, testes, prostate, eye, blood, lymph, or oral mucosa. In some embodiments, the target cell or tissue is CNS cell or tissue. In other embodiments, the target cell or tissue is liver cell or tissue.

[0078] In some embodiments, the target cell includes, but is not limited to, neurons, glial cells, astrocytes, oligodendroglia, microglia, Schwann cells, ependymal cells, hepatocytes, stellate fat storing cells, Kupffer cells, liver endothelial cells, epithelial cells, cardiomyocytes, smooth muscle cells, T-cells, B cells, hematopoietic stem cells, and embryonic stem cells.

[0079] In some embodiments, the target cell or tissue is from liver.

[0080] In some embodiments, the target cell or tissue is from CNS.

[0081] These and other aspects will be readily apparent to the skilled artisan in light of the disclosure as a whole.

BRIEF DESCRIPTION OF THE DRAWINGS

[0082] The patent or application file contains at least one drawing executed in color. Copies of this patent or patent application publication with color drawing(s) will be provided by the Office upon request and payment of the necessary fee.

[0083] **Fig. 1** depicts information relating to the assembly of the capsid libraries. Panel A is an illustration of an AAV capsid protein where arrows indicate the exposed loops into which the peptides are inserted. Panel 1B is a diagram of the AAV serotype

backbones that the peptides were inserted into. Silent mutations were made in the regions surrounding the peptide insertion sites (shown as grey boxes adjacent to the inserted peptide region, “peptide”) to enable the use of the same universal Next-Generation Sequencing (NGS) primers to amplify the diversified region and quantify variant performance in a head to head comparison. A single insertion region is depicted (VR-VIII) as a representative example, but the same strategy is generalizable to other capsid regions targeted for diversification.

[0084] **Fig. 2** illustrates an example of the method used to generate capsid libraries with high diversity. Panel A shows the fragments used to build the capsid encoding genes, where two fragments, left and right, were joined by Gibson assembly of two PCR amplification products and a pre-digested plasmid backbone. Panel B is a blow up of a primer pair (Reverse: SEQ ID NO: 204 and Forward: SEQ ID NO: 205) used to join the two fragments by Gibson assembly and also depicts the diversified sequence included in the RF Fwd primer, where X can be between 12 and 45 nucleotides in length.

[0085] **Fig. 3A and Fig. 3B** are drawings of the various library constructs that contain the variant capsid library in *cis* with an expression cassette, both flanked by viral ITRs for encapsidation of the viral genome. Panel A is a construct where the variant capsid gene “Cap” is regulated by the p40 promoter and the transcript is terminated by a polyadenylation signal sequence (“polyA”). The construct also comprises an EGFP reporter gene regulated by the CMV promoter where the EGFP is linked to an SV40 nuclear localization sequence (“SV40 NLS”) on its N-terminus. The construct also comprises a bovine growth hormone polyA signal sequence BGH and the 5’ and 3’ ITR sequences. Panel B is similar to that in Panel A except in that it has an mCherry reporter. Panel C shows the same design for the variant capsid gene, and further comprises an EGFP reporter gene regulated by the CMV promoter wherein the EGFP gene is fused to a KASH nuclear envelope binding domain (“KASH”). Panel D shows a construct similar to Panel C except that an mCherry reporter is used. Panel E shows a construct with the same variant capsid expression construct but has a synapsin promoter (“hSyn1”) driving expression of an EGFP reporter fused to a histone 2B DNA binding domain (“H2B”) on its 3’ end. The construct also comprises an SV40 polyadenylation signal sequence. Panels F and G are similar to Panel E except that Panel F uses an mClover3 reporter and Panel G uses an mRuby3 reporter.

[0086] **Fig. 4A and Fig. 4B** illustrate the steps for Method 1 for bioinformatically linking each variant capsid sequence with a randomly generated or specified barcode. In step 1, a short piece of DNA is synthesized comprising a randomly generated or specified barcode and a randomly generated or specified capsid variant region, as well as two regions used for Gibson assembly. Step 2 comprises amplification of capsid sequence 3' of the diversified region. Step 3 is the Gibson assembly reaction where the 5' ITR and SV40 polyadenylation sequences are fused to the barcode on the 5' end, and the second Gibson assembly region is fused to the 3' end of the capsid gene and the polyA signal for the capsid gene and the 3' ITR. Step 4 comprises performing ILLUMINA[®] sequencing across the barcode and the variant capsid sequences. Step 5 comprises digestion with the BsaI restriction enzyme. Step 6 is a PCR amplification step where the H2B, EGFP, hSyn1 and p40 promoters, and the 5' end of the capsid gene are prepared. Alternatively, the fragment comprising the H2B, EGFP, hSyn1, p40 promoter, and 5' end of the capsid gene may be pre-assembled in a donor plasmid, digested with BsaI, and gel purified. Step 7 is the final golden gate cloning step to create the final construct.

[0087] **Fig. 4C and Fig. 4D** illustrate an alternate approach to Method 1 for bioinformatically linking each variant capsid sequence with a randomly generated barcode. In step 1 two DNA fragments are synthesized. Fragment A comprises Gibson assembly region #1, a BsaI site, the variable capsid region, and a region homologous to the capsid gene that is used as a PCR primer. Fragment B comprises Gibson assembly region #2, a random barcode, a BsaI site, and Gibson assembly region #1. Next, a PCR procedure is performed where the 3' sequence of capsid gene is amplified using fragment A synthesized in step 1 as a PCR primer. Next, an intermediate AAV construct is generated by Gibson assembly where the construct comprises in a 5' to 3' order the 5' ITR, the SV40 poly A signal, the barcode, the two restriction endonuclease sites, the variant capsid sequences, the 3' region of the capsid protein, the polyA sequence for the capsid expression construct and the 3' ITR (step 3). Step 4 comprises performing ILLUMINA[®] sequencing across the barcode and the variant capsid sequences. Step 5 comprises digestion with the BsaI restriction enzyme. Step 6 is a PCR amplification step where the H2B, EGFP, hSyn1 and p40 promoters, and the 5' end of the capsid gene are prepared. Alternatively, the fragment comprising the H2B, EGFP, hSyn1, p40 promoter, and 5' end of the capsid gene may be pre-assembled in a donor

plasmid, digested with BsaI, and gel purified. Step 7 is the final golden gate cloning step to create the final construct.

[0088] **Fig. 5** illustrates the steps for Method 2 for bioinformatically linking each mutated capsid sequence with a randomly generated barcode. First, two sets of ILLUMINA® sequencing primers are used to separately sequence the random barcode and mutated capsid sequence with high fidelity. Next, OXFORD NANOPORE® sequencing is performed to sequence the entire construct. The Nanopore sequencing is less accurate than ILLUMINA® sequencing, but can be used to link the two ILLUMINA® sequences to one molecule via bioinformatic analysis.

10 [0089] **Fig. 6** is a plot of the AAV variants isolated from primary mouse cortical neurons following transduction with the AAV variant libraries. The Y axis indicates the log2 fold change in variant frequency after selection and recovery from transduced cells as compared with the variant frequency in administered library prior to transduction. The data demonstrates that the AAV serotypes tended to cluster with variants based on AAV1 being the most enriched in the primary mouse neurons as compared with variants based on insertions into other AAV serotypes.

[0090] **Fig. 7A and Fig. 7B** are plots of either the AAV1 variants (Fig. 7A) or the AAV2 variants (Fig. 7B). In Fig. 7A, wild type AAV1, lacking any inserted peptide in the capsid sequence, is labeled. The data demonstrates that many of the inserted peptide sequences caused an enrichment of the variants as compared to the wild type AAV1. In Fig. 7B, wild type AAV2, lacking any inserted peptide in the capsid sequence, is labeled. The data demonstrates that many of the inserted peptide sequences caused an enrichment of the variants in nuclei as compared to the wild type AAV2.

[0091] **Fig. 8** depicts two plots showing the enriched AAV variants as assayed by either reverse transcription of the RNA isolated from the target cells and amplification of the barcodes (plot on left side) or by isolation of nuclei from the treated cells and sequencing of the inserted nucleotides encoding the peptides inserted into the capsid gene (plot on right side). The data demonstrates that very similar results were obtained by both analysis methods. Left and right plots each disclose SEQ ID NOS: 199-203, respectively, in order of appearance (top to bottom in each panel).

[0092] **Fig. 9** shows micrographs of HEK293 cells transduced with the different reporter gene constructs. Panel A shows HEK293 cells transduced with AAV variants comprising the EGFP reporter alone, while Panel B shows the results when HEK293 cells are transduced with constructs comprising the SV40 nuclear localization sequence

(NLS) fused to the EGFP gene, causing accumulation of the reporter in the nucleus. Panel C shows the results of HEK293 cells transduced with the AAV construct comprising the KASH-linked EGFP sequence and Panel D shows HEK293 cells transduced with the AAV construct comprising the mCherry reporter. Panel E shows the results when the AAV construct comprised the mCherry fused to the SV40 NLS, and Panel F shows the results when mCherry is fused to KASH.

[0093] **Fig. 10A and Fig. 10B** are immunohistochemistry micrographs from mouse brain tissues depicting nuclear localized neuronal reporter expression (cortex, hippocampus, thalamus) of the AAV variant library comprising the EGFP-H2B fusion (Panels A and B) following injection. Panel C shows mouse brain tissue depicting nuclear localized neuronal reporter expression (cortex, hippocampus, thalamus) of the AAV variant library comprising the mClover3-H2B fusion following injection. Panels D and E show mouse brain tissue depicting nuclear envelope localized neuronal reporter expression (cortex, hippocampus, thalamus) of the AAV variant library comprising the EGFP-KASH fusion following injection. Panel F shows mouse brain tissue depicting nuclear localized neuronal reporter expression (cortex, hippocampus, thalamus) of the AAV variant library comprising the mRuby3-H2B fusion following injection. Images in Panel F are native fluorescence in fixed brain sections.

[0094] **Fig. 11** depicts FACS analysis of nuclei isolated from neuronal tissue in mice treated with AAV variants comprising the EGFP-H2B reporter. In mice injected with formulation buffer alone (Formulation) examined brain tissues did not exhibit any EGFP fluorescence (depicted in graph is the cortex tissue). In comparison, for nuclei isolated from mice treated with the AAV variants, reporter signaling could be detected in the thoracic spinal cord (7.68% of total events), the thalamus (16.53% of total events) and the cortex (6.54% of total events).

[0095] **Fig. 12** depicts FACS analysis of nuclei isolated from mice treated with AAV variants comprising the mClover3 reporter construct or the EGFP-KASH reporter. With both types of AAV variants, reporter signal was seen in the thalamus for mClover3 (14.72% of total events) and in the cortex for EGFP-KASH (4.88%).

[0096] **Fig. 13** depicts FACS analysis of nuclei isolated from mice treated with AAV variants comprising the mRuby3 reporter construct where reporter signal was detected in the cortex as shown (7.62% of total events).

[0097] **Fig. 14** depicts FACS analysis of nuclei isolated from non-CNS tissues when the reporter gene is driven by the hSyn1 promoter (neuron specific). Panel A shows

the comparison in signal from liver tissue in mice treated with AAV variants comprising the EGFP-H2B construct in comparison with formulation buffer, while Panel B shows the same comparison in cardiac tissue. No off-target expression from the hSyn1 promoter was observed.

5 [0098] **Fig. 15A, Fig. 15B and Fig. 15C** depict a series of graphs supporting a clear dose response of EGFP reporter signal when the AAV variant library comprising the EGFP-H2B construct driven by the liver-specific TTR promoter are introduced into HepG2 cells *in vitro* at different doses (3×10^3 (Panel B); 1×10^4 (Panel C); 3×10^4 (Panel D); 1×10^5 (Panel E); 3×10^5 (Panel F) and 1×10^6 (Panel G) compared to mock (Panel A)).

10 [0099] **Fig. 16** depicts the reporter signal detected in NHP (Non-Human Primate) nuclei isolated from liver tissue following injection of the animals with the AAV variant library (Panel A). Panel B shows immunohistochemical analysis of the liver tissue and demonstrates that nuclear localized reporter signal (brown staining of nuclei) is detected

15 in the liver in both the male and female NHP.

[00100] **Fig. 17A and Fig. 17B** show the distribution of the top 2500 fold enriched AAV variants according to which parent serotype the peptide insertion was made in. Data were obtained from sorting and sequencing. EGFP positive nuclei isolated from HepG2 (Panel A) and primary human hepatocytes *in vitro* (Panel B) in comparison with

20 mouse (Panel C) and NHP liver tissue *in vivo* (Panel D). As can be seen in the figure, there are significant differences in the parent serotypes of AAV variants that are successful when challenged with different selective pressures.

[00101] **Fig. 18** shows a sampling of highly enriched AAV variants and the sequences of peptides inserted ("Peptide", SEQ ID NOs 1 to 32) identified from the second round of screening from NHP liver tissue. As can be seen, the variants are based on insertions

25 into AAV1, AAV2, AAV3B, AAV9, AAV6 and AAV5 serotypes, where the peptide sequences were inserted into the following amino acid positions in each serotype indicated: AAV1 (590), AAV2 (588), AAV3B (589), AAV5 (578), AAV6 (454), AAV8 (591), AAV9 (589). The data shows the enrichment of the individual variants

30 through a second screening round as measured by analysis of AAV library derived barcoded mRNA transcripts isolated from liver tissue ("Round 2 mRNA), viral genomic DNA sequenced from nuclei isolated on the basis of EGFP-H2B reporter signal using FACS ("Round 2 nuclei"), viral genomic DNA sequenced from total liver genomic DNA in round 2 ("Round 2 Total gDNA"), and viral genomic DNA sequenced

from total liver genomic DNA in round 1 ("Round 1 Total gDNA"). Also shown is the relative yield of the AAV variant when produced by transient transfection into HEK293 cells. The degree of enrichment of the individual variant when isolated from the tissue as compared to its percentage in the library prior to injection is indicated by the size of the circle. For example, the AAV3B serotype variant with the inserted peptide sequence QGALAQV (SEQ ID NO: 8) has a log₂ fold enrichment of 6.1 in mRNA barcode frequency when isolated from the NHP tissue as compared with the starting library. The darkness of the color of the circles also relates to the scale shown in the bottom right showing the relative variability in performance across multiple animals and tissue punches for a particular variant.

[00102] **Fig. 19** is a bubble plot of the AAV library variants recovered after infection of Neuro2A cells. The log₂ fold change represents the change in variant frequency after infection and recovery of transcripts expressed in transduced Neuro2A cells as compared with the variant frequency in the administered library. The performance of wild type serotypes is indicated as well as that for variants 1-43 (SEQ ID NO: 68-110) listed in Figs. 29A-D.

[00103] **Fig. 20** is a bubble plot of the AAV library variants recovered after infection of primary mouse cortical neurons. The log₂ fold change represents the change in variant frequency after infection and recovery of transcripts expressed in transduced neurons as compared with the variant frequency in the administered library. The performance of wild type serotypes is indicated as well as that of variants 1-43 (SEQ ID NO: 68-110) listed in Fig. 29A-D.

[00104] **Fig. 21** is a bubble plot of the AAV library variants recovered after infection of iCell human neurons derived from human induced pluripotent stem cells. The log₂ fold change represents the change in variant frequency after infection and recovery of transcripts expressed in transduced neurons as compared with the variant frequency in the administered library. The performance of wild type serotypes is indicated as well as that of variants 1-43 (SEQ ID NO: 68-110) listed in Fig. 29A-D.

[00105] **Fig. 22** is a bubble plot of the AAV library variants recovered from C57BL/6J mouse CNS tissues after intracerebroventricular administration of the AAV variant library. Tissue regions included in the analysis were striatum, hippocampus, cerebellum, thalamus, hypothalamus, midbrain, brain stem, motor cortex, somatosensory cortex, rest of cortex, cervical spinal cord, thoracic spinal cord, and lumbar spinal cord. The log₂ fold change represents the change in variant frequency

after infection and recovery of transcripts expressed in transduced neurons as compared with the variant frequency in the administered library. The performance of wild type serotypes is indicated as well as that of variants 1-43 (SEQ ID NO: 68-110) listed in Fig. 29A-D.

5 [00106] **Fig. 23** is a bubble plot of the AAV library variants recovered from non-human primate CNS tissues after intrathecal administration of the AAV variant library. Tissue regions included in this analysis were hippocampus, entorhinal cortex, temporal cortex, frontal cortex, and parietal cortex. The log₂ fold change represents the change in variant frequency after infection and recovery of viral genomic DNA from tissue as compared with the variant frequency in the administered library. The performance of wild type serotypes is indicated as well as that of variants 1-43 (SEQ ID NO: 68-110) listed in Fig. 29A-D.

[00107] **Fig. 24** is a bubble plot of the AAV library variants recovered from non-human primate CNS tissues after intrathecal administration of the AAV variant library. Tissue regions included in this analysis were pons, medulla, cerebellum, and motor cortex. The log₂ fold change represents the change in variant frequency after infection and recovery of viral genomic DNA from tissue as compared with the variant frequency in the administered library. The performance of wild type serotypes is indicated as well as that of variants 1-43 (SEQ ID NO: 68-110) listed in Fig. 29A-D.

20 [00108] **Fig. 25** is a bubble plot of the AAV library variants recovered from non-human primate spinal cord after intrathecal administration of the AAV variant library. The log₂ fold change represents the change in variant frequency after infection and recovery of viral genomic DNA from tissue as compared with the variant frequency in the administered library. The performance of wild type serotypes is indicated as well as that of variants 1-43 (SEQ ID NO: 68-110) listed in Fig. 29A-D.

[00109] **Fig. 26** is a bubble plot of the AAV library variants recovered from non-human primate CNS tissues after intrathecal administration of the AAV variant library. Tissue regions included in this analysis were hippocampus, entorhinal cortex, temporal cortex, frontal cortex, and parietal cortex. The log₂ fold change represents the change in variant frequency after infection and recovery of transcripts expressed in transduced neurons as compared with the variant frequency in the administered library. The performance of wild type serotypes is indicated as well as that of variants 1-43 (SEQ ID NO: 68-110) listed in Fig. 29A-D.

[00110] **Fig. 27** is a bubble plot of the AAV library variants recovered from non-human primate CNS tissues after intrathecal administration of the AAV variant library. Tissue regions included in this analysis were pons, medulla, cerebellum, substantia nigra, and motor cortex. The log₂ fold change represents the change in variant frequency after infection and recovery of transcripts expressed in transduced neurons as compared with the variant frequency in the administered library. The performance of wild type serotypes is indicated as well as that of variants 1-43 (SEQ ID NO: 68-110) listed in Fig. 29.

[00111] **Fig. 28** is a bubble plot of the AAV library variants recovered from non-human primate spinal cord after intrathecal administration of the AAV variant library. The log₂ fold change represents the change in variant frequency after infection and recovery of transcripts expressed in transduced neurons as compared with the variant frequency in the administered library. The performance of wild type serotypes is indicated as well as that of variants 1-43 (SEQ ID NO: 68-110) listed in Fig. 29.

[00112] **Fig. 29A, Fig. 29B, Fig. 29C and Fig. 29D** show highly enriched AAV variants and the sequences of peptides inserted ("Peptide", SEQ ID NOs 68-110) identified from the second round of screening from NHP CNS tissue. The variants are based on insertions into AAV1, AAV2, AAV3B, and AAV9 serotypes, where the peptide sequences were inserted into the following amino acid positions in each serotype indicated: AAV1 (590), AAV2 (588), AAV3B (589), AAV9 (589). The number to the left of each variant (1 through 43 (SEQ ID NO: 68-110)) corresponds to the numbers used for plotting in Figs. 19 through 28. The data shows the enrichment of the individual variants through a second screening round in multiple cell lines or species as measured by quantification of AAV library barcoded mRNA transcripts or vector genomic DNA isolated from cells or CNS tissues. The degree of enrichment of each individual variant when isolated from the cells or tissue as compared to its percentage in the library prior to injection is indicated by the size of the circle. The darkness of the color of the circles also relates to the scale shown in the bottom right of Fig. 29D showing the relative variability in performance across multiple replicates, animals and/or tissue punches for a particular variant.

[00113] **Fig. 30** is a schematic of the vector genome cassette employed for pooled evaluation of barcoded AAV variants. The cassette contains an RNA polymerase II promoter to quantify expression of barcoded transcripts in a target cell population, for example neurons or hepatocytes. In addition, there is an RNA polymerase III promoter

(e.g. hU6) which drives ubiquitous expression in all cell types. The combination of these promoters enables ranking of AAV variant transduction in both an individual targeted cell type and bulk tissue.

[00114] **Fig. 31** shows the results of a pooled evaluation of a subset of the AAV variants in Figs. 29A-D (variants 2, 3, 4, 5, 6, 9, 10, 11, 12, 13, 14, 16, 18, 19, 20, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 49). Control serotypes include wild-type AAV9, PHP.B, and AAV2_HSPGKO. The barcoded AAV variants were evaluated *in vitro* in Neuro2A cells (ATCC CCL-131), primary mouse cortical neurons (Gibco), and iCell human neurons derived from human induced pluripotent stem cells. The AAV expression cassette described in Fig. 30 was employed for the pooled evaluation and the distinct barcode quantifications from the pol II neuron-specific hSyn1 promoter and the pol III hU6 ubiquitous promoter were labeled. The values in the heat maps represent the percentage of NGS reads derived from each AAV variant and are rounded to the nearest tenth of a percent. These results were normalized by the frequency of each AAV variant in the pool that was used for infection. The parental serotype of each AAV variant is colored according to the accompanying figure legend.

[00115] **Fig. 32** shows the evaluation of the barcoded AAV variants (variants 2, 3, 4, 5, 6, 9, 10, 11, 12, 13, 14, 16, 18, 19, 20, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 49) and control serotypes wild-type AAV9, PHP.B, and AAV2_HSPGKO *in vitro* in iCell human astrocytes and endothelial cells derived from human induced pluripotent stem cells. The vector genome expression cassette described in Fig. 30 was employed for the pooled evaluation, data are presented for the pol III hU6 ubiquitous promoter, hSyn1 barcode measurements were not performed because the promoter has minimal activity in non-neuronal cell types. The values in the heat maps represent the percentage of NGS reads derived from each AAV variant and are rounded to the nearest tenth of a percent. These results were normalized by the frequency of each AAV variant in the pool that was used for infection. The parental serotype of each AAV variant is colored according to the accompanying figure legend.

[00116] **Fig. 33** shows the evaluation of the barcoded AAV variants (variants 2, 3, 4, 5, 6, 9, 10, 11, 12, 13, 14, 16, 18, 19, 20, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 49) and control serotypes wild-type AAV9, PHP.B, and AAV2_HSPGKO *in vivo* after unilateral intracerebroventricular administration in C57BL/6J mice. Data are aggregated according to the following CNS regions:

brainstem (brainstem, midbrain), cerebellum, cortex (motor cortex, sensory cortex, rest of cortex), deep brain regions (hippocampus, hypothalamus, striatum, thalamus) and spinal cord (cervical, thoracic, and lumbar). The AAV expression cassette described in Fig. 30 was employed for the pooled evaluation and the distinct barcode quantifications from the pol II neuron-specific hSyn1 promoter and the pol III hU6 ubiquitous promoter are labeled. The values in the heat maps represent the percentage of NGS reads derived from each AAV variant and are rounded to the nearest tenth of a percent. These results were normalized by the frequency of each AAV variant in the pool that was administered. The parental serotype of each AAV variant is colored according to the accompanying figure legend.

[00117] **Fig. 34** shows the evaluation of the barcoded AAV variants (variants 2, 3, 4, 5, 6, 9, 10, 11, 12, 13, 14, 16, 18, 19, 20, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 49) and control serotypes wild-type AAV9, PHP.B, and AAV2_HSPGKO *in vivo* after unilateral intracerebroventricular administration in Sprague-Dawley rats. Data are aggregated according to the following CNS regions: brainstem (brainstem, midbrain), cerebellum, cortex (motor cortex, sensory cortex, rest of cortex), deep brain regions (hippocampus, hypothalamus, striatum, thalamus) and spinal cord (cervical, thoracic, and lumbar). The AAV expression cassette described in Fig. 30 was employed for the pooled evaluation and the distinct barcode quantifications from the pol II neuron-specific hSyn1 promoter and the pol III hU6 ubiquitous promoter are labeled. The values in the heat maps represent the percentage of NGS reads derived from each AAV variant and are rounded to the nearest tenth of a percent. These results were normalized by the frequency of each AAV variant in the pool that was administered. The parental serotype of each AAV variant is colored according to the accompanying figure legend.

[00118] **Fig. 35** shows the evaluation of the barcoded AAV variants (variants 2, 3, 4, 5, 6, 9, 10, 11, 12, 13, 14, 16, 18, 19, 20, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 49) and control serotypes wild-type AAV9, PHP.B, and AAV2_HSPGKO *in vivo* after intrathecal administration in non-human primates (cynomolgus macaques). Data shown are from analysis of total RNA isolated from NHP tissues. The data are aggregated according to the following CNS regions: brainstem (medulla, midbrain, pons, substantia nigra), cerebellum (cerebellum, cerebellar vermis), cortex (entorhinal cortex, frontal cortex, fronto-orbital gyrus,

fusiform gyrus, lateral orbital gyrus, medial orbital gyrus, motor cortex, parahippocampal gyrus, parietal cortex, parietal-visual cortex, posterior cingulate gyrus, sensory cortex, somatosensory cortex, temporal cortex, visual cortex), deep brain regions (amygdala, caudate nucleus, hippocampus, hypothalamus, putamen, thalamus) and spinal cord (cervical, thoracic, and lumbar). The AAV expression cassette described in Fig. 30 was employed for the pooled evaluation and the distinct barcode quantifications from the pol II neuron-specific hSyn1 promoter and the pol III hU6 ubiquitous promoter are labeled. The values in the heat maps represent the percentage of NGS reads derived from each AAV variant and are rounded to the nearest tenth of a percent. These results were normalized by the frequency of each AAV variant in the pool that was administered. The parental serotype of each AAV variant is colored according to the accompanying figure legend.

[00119] **Fig. 36** shows the evaluation of the barcoded AAV variants and control serotypes wild-type AAV9, PHP.B, and AAV2_HSPGKO *in vivo* after intrathecal administration in non-human primates (cynomolgus macaques). Data shown are from analysis of genomic DNA isolated from NHP tissues. The data are aggregated according to the following CNS regions: brainstem (medulla, pons, substantia nigra), cerebellum, cortex (entorhinal cortex, frontal cortex, motor cortex, parietal cortex, somatosensory cortex, temporal cortex), deep brain regions (caudate nucleus, hippocampus, hypothalamus, putamen, thalamus) and spinal cord (cervical, thoracic, and lumbar). The AAV expression cassette described in Fig. 30 was employed for the pooled evaluation and the distinct barcode quantifications from the pol II neuron-specific hSyn1 promoter and the pol III hU6 ubiquitous promoter are labeled. The values in the heat maps represent the percentage of NGS reads derived from each AAV variant and are rounded to the nearest tenth of a percent. These results were normalized by the frequency of each AAV variant in the pool that was administered. The parental serotype of each AAV variant is colored according to the accompanying figure legend.

[00120] **Fig. 37** shows the evaluation of the barcoded AAV variants and control serotypes wild-type AAV9, PHP.B, and AAV2_HSPGKO *in vivo* after intrathecal administration in non-human primates (cynomolgus macaques). Data shown are from analysis of total RNA isolated from NHP tissues. The data are aggregated according to the following CNS regions: brainstem (medulla, midbrain, pons, substantia nigra), cerebellum (cerebellum, cerebellar vermis), and cortex (entorhinal cortex, frontal cortex, fronto-orbital gyrus, fusiform gyrus, lateral orbital gyrus, medial orbital gyrus,

motor cortex, parahippocampal gyrus, parietal cortex, parietal-visual cortex, posterior cingulate gyrus, sensory cortex, somatosensory cortex, temporal cortex, visual cortex). The plotted results show the fold increase in the normalized percentage of reads for each serotype compared to wild-type AAV9.

5 [00121] **Fig. 38** shows the evaluation of the barcoded AAV variants and control serotypes wild-type AAV9, PHP.B, and AAV2_HSPGKO *in vivo* after intrathecal administration in non-human primates (cynomolgus macaques). Data shown are from analysis of total RNA isolated from NHP tissues. The data are aggregated according to the following CNS regions: deep brain regions (amygdala, caudate nucleus,
10 hippocampus, hypothalamus, putamen, thalamus) and spinal cord (cervical, thoracic, and lumbar). The plotted results show the fold increase in the normalized percentage of reads for each serotype compared to wild-type AAV9.

[00122] **Fig. 39** shows the evaluation of the barcoded AAV variants and control serotypes wild-type AAV9, PHP.B, and AAV2_HSPGKO *in vivo* after intrathecal
15 administration in non-human primates (cynomolgus macaques). Data shown are from analysis of genomic DNA isolated from NHP tissues. The data are aggregated according to the following CNS regions: brainstem (medulla, pons, substantia nigra), cerebellum, and cortex (entorhinal cortex, frontal cortex, motor cortex, parietal cortex, somatosensory cortex, temporal cortex). The plotted results show the fold increase in
20 the normalized percentage of reads for each serotype compared to wild-type AAV9.

[00123] **Fig. 40** shows the evaluation of the barcoded AAV variants and control serotypes wild-type AAV9, PHP.B, and AAV2_HSPGKO *in vivo* after intrathecal administration in non-human primates (cynomolgus macaques). Data shown are from analysis of genomic DNA isolated from NHP tissues. The data are aggregated
25 according to the following CNS regions: deep brain regions (caudate nucleus, hippocampus, hypothalamus, putamen, thalamus) and spinal cord (cervical, thoracic, and lumbar). The plotted results show the fold increase in the normalized percentage of reads for each serotype compared to wild-type AAV9.

[00124] **Fig. 41** shows a summary of serotype performance across different species.
30 Data presented are for the hSyn1 barcode RNA analysis and serotypes are ordered according to performance in the non-human primate CNS.

[00125] **Fig. 42** shows a summary of serotype performance across different species. Data presented are for the hU6 barcode RNA analysis and serotypes are ordered according to performance in the non-human primate CNS.

DETAILED DESCRIPTION

[00126] The present disclosure provides methods and compositions to develop AAV capsids with a desired characteristic compared to a natural AAV serotype. These capsids are useful, for example, for the delivery of genome engineering molecules and gene therapy molecules to a target cell, cell line, or tissue (*e.g., in vitro* or *in vivo*) for the treatment of a subject in need thereof.

[00127] Many tissues are highly heterogeneous and contain biological barriers that limit adeno-associated virus (AAV) transduction. A functional selection strategy enables selection of AAV variants from a library that are capable of transducing specific cell types within a tissue. Moreover, the selective pressure is designed to identify variants that excel in mediating post-entry steps and driving transgene expression. In order to establish a functional selection strategy that is applicable to all species and tissues, several modifications were introduced in the AAV viral genome. Herein we describe methods for the generation of AAV variant libraries and methods of functional selection of variants capable of transducing desired tissues, cells and/or organelles. These methods are applicable to the development of AAV variants suitable for all species, cell types and target organelles.

General

[00128] Practice of the methods, as well as preparation and use of the compositions disclosed herein employ, unless otherwise indicated, conventional techniques in molecular biology, biochemistry, chromatin structure and analysis, computational chemistry, cell culture, recombinant DNA and related fields as are within the skill of the art. These techniques are fully explained in the literature. *See*, for example, Sambrook *et al.* MOLECULAR CLONING: A LABORATORY MANUAL, Second edition, Cold Spring Harbor Laboratory Press, 1989 and Third edition, 2001; Ausubel *et al.*, CURRENT PROTOCOLS IN MOLECULAR BIOLOGY, John Wiley & Sons, New York, 1987 and periodic updates; the series METHODS IN ENZYMOLOGY, Academic Press, San Diego; Wolffe, CHROMATIN STRUCTURE AND FUNCTION, Third edition, Academic Press, San Diego, 1998; METHODS IN ENZYMOLOGY, Vol. 304, "Chromatin" (P.M. Wassarman and A. P. Wolffe, eds.), Academic Press, San Diego, 1999; and METHODS IN MOLECULAR BIOLOGY, Vol. 119, "Chromatin Protocols" (P.B. Becker, ed.) Humana Press, Totowa, 1999.

Definitions

[00129] The term "herein" means the entire application.

[00130] Unless otherwise defined herein, scientific and technical terms used in this application shall have the meanings that are commonly understood by those of ordinary skill in the art to which this invention belongs. Generally, nomenclature used in connection with the compounds, composition and methods described herein, are those well-known and commonly used in the art.

[00131] It should be understood that any of the embodiments described herein, including those described under different aspects of the disclosure and different parts of the specification (including embodiments described only in the Examples) can be combined with one or more other embodiments of the invention, unless explicitly disclaimed or improper. Combination of embodiments are not limited to those specific combinations claimed via the multiple dependent claims.

[00132] All of the above, and any other publications, patents and published patent applications referred to in this application are specifically incorporated by reference herein. In case of conflict, the present specification, including its specific definitions, will control.

[00133] Throughout this specification, the word “comprise” or variations such as “comprises” or “comprising” will be understood to imply the inclusion of a stated integer (or components) or group of integers (or components), but not the exclusion of any other integer (or components) or group of integers (or components).

[00134] Throughout the specification, where compositions are described as having, including, or comprising (or variations thereof), specific components, it is contemplated that compositions also may consist essentially of, or consist of, the recited components. Similarly, where methods or processes are described as having, including, or comprising specific process steps, the processes also may consist essentially of, or consist of, the recited processing steps. Further, it should be understood that the order of steps or order for performing certain actions is immaterial so long as the compositions and methods described herein remains operable. Moreover, two or more steps or actions can be conducted simultaneously.

[00135] The term “including” is used to mean “including but not limited to.” “Including” and “including but not limited to” are used interchangeably.

[00136] As used herein, “about” or “approximately” means within an acceptable error range for the particular value as determined by one of ordinary skill in the art, which will depend in part on how the value is measured or determined, *i.e.*, the limitations of the measurement system.

[00137] The use of the terms “a” and “an” and “the” and similar referents in the context of describing the elements (especially in the context of the following claims) are to be construed to cover both the singular and the plural, unless otherwise indicated herein or clearly contradicted by context.

- 5 [00138] The term “or” as used herein should be understood to mean “and/or,” unless the context clearly indicates otherwise.

[00139] Recitation of ranges of values herein are merely intended to serve as a shorthand method of referring individually to each separate value falling within the range, unless otherwise indicated herein, and each separate value is incorporated into
10 the specification as if it were individually recited herein. All methods described herein can be performed in any suitable order unless otherwise indicated herein or otherwise clearly contradicted by context. The use of any and all examples, or exemplary language (e.g., “such as”) provided herein, is intended merely to better illuminate the embodiments and does not pose a limitation on the scope of the claims unless otherwise
15 stated. No language in the specification should be construed as indicating any non-claimed element as essential.

[00140] The terms “nucleic acid,” “polynucleotide,” and “oligonucleotide” are used interchangeably and refer to a deoxyribonucleotide or ribonucleotide polymer, in linear or circular conformation, and in either single- or double-stranded form. For the
20 purposes of the present disclosure, these terms are not to be construed as limiting with respect to the length of a polymer. The terms can encompass known analogues of natural nucleotides, as well as nucleotides that are modified in the base, sugar and/or phosphate moieties (e.g., phosphorothioate backbones). In general, an analogue of a particular nucleotide has the same base-pairing specificity; *i.e.*, an analogue of A will
25 base-pair with T.

[00141] The terms “polypeptide,” “peptide” and “protein” are used interchangeably to refer to a polymer of amino acid residues. The term also applies to amino acid polymers in which one or more amino acids are chemical analogues or modified derivatives of a corresponding naturally-occurring amino acids.

- 30 [00142] “Binding” refers to a sequence-specific, non-covalent interaction between macromolecules (e.g., between a protein and a nucleic acid). Not all components of a binding interaction need be sequence-specific (e.g., contacts with phosphate residues in a DNA backbone), as long as the interaction as a whole is sequence-specific. Such interactions are generally characterized by a dissociation constant (K_d) of 10^{-6} M^{-1} or

lower. “Affinity” refers to the strength of binding: increased binding affinity being correlated with a lower K_d . “Non-specific binding” refers to, non-covalent interactions that occur between any molecule of interest (*e.g.* an engineered nuclease) and a macromolecule (*e.g.* DNA) that are not dependent on-target sequence.

5 [00143] A “binding protein” is a protein that is able to bind non-covalently to another molecule. A binding protein can bind to, for example, a DNA molecule (a DNA-binding protein), an RNA molecule (an RNA-binding protein) and/or a protein molecule (a protein-binding protein). In the case of a protein-binding protein, it can bind to itself (to form homodimers, homotrimers, *etc.*) and/or it can bind to one or more
10 molecules of a different protein or proteins. A binding protein can have more than one type of binding activity. For example, zinc finger proteins have DNA-binding, RNA-binding and protein-binding activity. In the case of an RNA-guided nuclease system, the RNA guide is heterologous to the nuclease component (Cas9 or Cfp1) and both may be engineered.

15 [00144] A “DNA binding molecule” is a molecule that can bind to DNA. Such DNA binding molecule can be a polypeptide, a domain of a protein, a domain within a larger protein or a polynucleotide. In some embodiments, the polynucleotide is DNA, while in other embodiments, the polynucleotide is RNA. In some embodiments, the DNA binding molecule is a protein domain of a nuclease (*e.g.* the *FokI* domain), while in
20 other embodiments, the DNA binding molecule is a guide RNA component of an RNA-guided nuclease (*e.g.* Cas9 or Cpf1).

[00145] A “DNA binding protein” (or binding domain) is a protein, or a domain within a larger protein, that binds DNA in a sequence-specific manner, for example through one or more zinc fingers or through interaction with one or more RVDs in a zinc finger
25 protein or TALE, respectively. The term zinc finger DNA binding protein is often abbreviated as zinc finger protein or ZFP.

[00146] A “zinc finger DNA binding protein” (or binding domain) is a protein, or a domain within a larger protein, that binds DNA in a sequence-specific manner through one or more zinc fingers, which are regions of amino acid sequence within the binding
30 domain whose structure is stabilized through coordination of a zinc ion. The term zinc finger DNA binding protein is often abbreviated as zinc finger protein or ZFP.

[00147] A “TALE DNA binding domain” or “TALE” is a polypeptide comprising one or more TALE repeat domains/units. The repeat domains are involved in binding of the TALE to its cognate target DNA sequence. A single “repeat unit” (also referred to

as a “repeat”) is typically 33-35 amino acids in length and exhibits at least some sequence homology with other TALE repeat sequences within a naturally occurring TALE protein. *See, e.g.*, U.S. Patent No. 8,586,526, incorporated by reference herein in its entirety.

5 [00148] “TtAgo” is a prokaryotic Argonaute protein thought to be involved in gene silencing. TtAgo is derived from the bacteria *Thermus thermophilus*. *See, e.g.* Swarts, *et al.*, *ibid*; G. Sheng, *et al.* (2013) *Proc. Natl. Acad. Sci. U.S.A.* 111, 652). A “TtAgo system” is all the components required including e.g. guide DNAs for cleavage by a TtAgo enzyme.

10 [00149] “Cleavage” refers to the breakage of the covalent backbone of a DNA molecule. Cleavage can be initiated by a variety of methods including, but not limited to, enzymatic or chemical hydrolysis of a phosphodiester bond. Both single-stranded cleavage and double-stranded cleavage are possible, and double-stranded cleavage can occur as a result of two distinct single-stranded cleavage events. DNA cleavage can
15 result in the production of either blunt ends or staggered ends. In certain embodiments, fusion polypeptides are used for targeted double-stranded DNA cleavage.

[00150] The term “editing” as used herein refers to a process wherein a nucleotide base is modified such that point mutations are introduced into a DNA strand. Introduction of the point mutation in the DNA will necessarily reproduce the change in any mRNA
20 that is transcribed from the edited DNA. Adenine and cytidine deaminases remove an amino group from their respective nucleotide targets, converting them into inosine and uridine respectively. During DNA repair or replication, inosine is recognized as guanine and uridine is recognized as thymine by polymerase enzymes, resulting in conversion of an A:T base pair into a G:C base pair, or C:G base pair into a T:A base
25 pair in the double stranded DNA that has been edited.

[00151] The term “sequence” refers to a nucleotide sequence of any length, which can be DNA or RNA; can be linear, circular or branched and can be either single-stranded or double stranded. The term “transgene” refers to a nucleotide sequence that is inserted into a genome. A transgene can be of any length, for example between 2 and
30 100,000,000 nucleotides in length (or any integer value therebetween or thereabove), between about 100 and 100,000 nucleotides in length (or any integer therebetween), between about 2000 and 20,000 nucleotides in length (or any value therebetween) or between about 5 and 15 kb (or any value therebetween).

[00152] A “chromosome,” is a chromatin complex comprising all or a portion of the genome of a cell. The genome of a cell is often characterized by its karyotype, which is the collection of all the chromosomes that comprise the genome of the cell. The genome of a cell can comprise one or more chromosomes.

5 [00153] An “episome” is a replicating nucleic acid, nucleoprotein complex or other structure comprising a nucleic acid that is not part of the chromosomal karyotype of a cell. Examples of episomes include plasmids, minicircles and certain viral genomes. The liver specific constructs described herein may be episomally maintained or, alternatively, may be stably integrated into the cell.

10 [00154] An “exogenous” molecule is a molecule that is not normally present in a cell, but can be introduced into a cell by one or more genetic, biochemical or other methods. “Normal presence in the cell” is determined with respect to the particular developmental stage and environmental conditions of the cell. Thus, for example, a molecule that is present only during embryonic development of muscle is an exogenous
15 molecule with respect to an adult muscle cell. Similarly, a molecule induced by heat shock is an exogenous molecule with respect to a non-heat-shocked cell. An exogenous molecule can comprise, for example, a functioning version of a malfunctioning endogenous molecule or a malfunctioning version of a normally-functioning endogenous molecule.

20 [00155] An exogenous molecule can be, among other things, a small molecule, such as is generated by a combinatorial chemistry process, or a macromolecule such as a protein, nucleic acid, carbohydrate, lipid, glycoprotein, lipoprotein, polysaccharide, any modified derivative of the above molecules, or any complex comprising one or more of the above molecules. Nucleic acids include DNA and RNA, can be single- or double-
25 stranded; can be linear, branched or circular; and can be of any length. Nucleic acids include those capable of forming duplexes, as well as triplex-forming nucleic acids. See, for example, U.S. Patent Nos. 5,176,996 and 5,422,251. Proteins include, but are not limited to, DNA-binding proteins, transcription factors, chromatin remodeling factors, methylated DNA binding proteins, polymerases, methylases, demethylases,
30 acetylases, deacetylases, kinases, phosphatases, ligases, deubiquitinases, integrases, recombinases, ligases, topoisomerases, gyrases and helicases.

[00156] An exogenous molecule can be the same type of molecule as an endogenous molecule, e.g., an exogenous protein or nucleic acid. For example, an exogenous nucleic acid can comprise an infecting viral genome, a plasmid or episome introduced

- into a cell, or a chromosome that is not normally present in the cell. Methods for the introduction of exogenous molecules into cells are known to those of skill in the art and include, but are not limited to, lipid-mediated transfer (i.e., liposomes, including neutral and cationic lipids), electroporation, direct injection, cell fusion, particle bombardment, calcium phosphate co-precipitation, DEAE-dextran-mediated transfer and viral vector-mediated transfer. An exogenous molecule can also be the same type of molecule as an endogenous molecule but derived from a different species than the cell is derived from. For example, a human nucleic acid sequence may be introduced into a cell line originally derived from a mouse or hamster.
- 5
- 10 [00157] By contrast, an “endogenous” molecule is one that is normally present in a particular cell at a particular developmental stage under particular environmental conditions. For example, an endogenous nucleic acid can comprise a chromosome, the genome of a mitochondrion, chloroplast or other organelle, or a naturally-occurring episomal nucleic acid. Additional endogenous molecules can include proteins, for example, transcription factors and enzymes.
- 15 [00158] As used herein, the term “product of an exogenous nucleic acid” includes both polynucleotide and polypeptide products, for example, transcription products (polynucleotides such as RNA) and translation products (polypeptides).
- 20 [00159] The term “heterologous” means derived from a genotypically distinct entity from that of the rest of the entity to which it is being compared. For example, a polynucleotide introduced by genetic engineering techniques into a plasmid or vector derived from a different species is a heterologous polynucleotide. A promoter removed from its native coding sequence and operatively linked to a coding sequence with which it is not naturally found linked is a heterologous promoter. Thus, for example, an rAAV that includes a heterologous nucleic acid sequence encoding a heterologous gene product is an rAAV that includes a polynucleotide not normally included in a naturally-occurring, wild-type AAV, and the encoded heterologous gene product is a gene product not normally encoded by a naturally-occurring, wild type AAV.
- 25 [00160] The terms “fusion,” “fused” molecule or variations thereof refer to is a molecule in which two or more subunit molecules are linked, preferably covalently. The subunit molecules can be the same chemical type of molecule, or can be different chemical types of molecules. Examples of fusion molecules include, but are not limited to, fusion proteins (for example, a fusion between a protein DNA-binding domain and a cleavage domain), fusions between a polynucleotide DNA-binding domain (*e.g.*,
- 30

sgRNA) operatively associated with a cleavage domain, and fusion nucleic acids (for example, a nucleic acid encoding the fusion protein).

[00161] Expression of a fusion protein in a cell can result from delivery of the fusion protein to the cell or by delivery of a polynucleotide encoding the fusion protein to a cell, wherein the polynucleotide is transcribed, and the transcript is translated, to generate the fusion protein. Trans-splicing, polypeptide cleavage and polypeptide ligation can also be involved in expression of a protein in a cell. Methods for polynucleotide and polypeptide delivery to cells are presented elsewhere in this disclosure.

10 [00162] A “gene,” for the purposes of the present disclosure, includes a DNA region encoding a gene product (see *infra*), as well as all DNA regions which regulate the production of the gene product, whether or not such regulatory sequences are adjacent to coding and/or transcribed sequences. Accordingly, a gene includes, but is not necessarily limited to, promoter sequences, terminators, translational regulatory sequences such as ribosome binding sites and internal ribosome entry sites, enhancers, silencers, insulators, boundary elements, replication origins, matrix attachment sites and locus control regions.

[00163] “Gene expression” refers to the conversion of the information contained in a gene, into a gene product. A gene product can be the direct transcriptional product of a gene (e.g., mRNA, tRNA, rRNA, antisense RNA, ribozyme, structural RNA or any other type of RNA) or a protein produced by translation of an mRNA. Gene products also include RNAs which are modified, by processes such as capping, polyadenylation, methylation, and editing, and proteins modified by, for example, methylation, acetylation, phosphorylation, ubiquitination, ADP-ribosylation, myristoylation, and glycosylation.

[00164] “Modulation” of gene expression refers to a change in the activity of a gene. Modulation of expression can include, but is not limited to, gene activation and gene repression. Genome editing (e.g., cleavage, alteration, inactivation, random mutation) can be used to modulate expression. Gene inactivation refers to any reduction in gene expression as compared to a cell that does not include a ZFP, TALE or CRISPR/Cas system as described herein. Thus, gene inactivation may be partial or complete.

[00165] A “region of interest” is any region of cellular chromatin, such as, for example, a gene or a non-coding sequence within or adjacent to a gene, in which it is desirable to bind an exogenous molecule. Binding can be for the purposes of targeted

DNA cleavage and/or targeted recombination. A region of interest can be present in a chromosome, an episome, an organellar genome (e.g., mitochondrial, chloroplast), or an infecting viral genome, for example. A region of interest can be within the coding region of a gene, within transcribed non-coding regions such as, for example, leader sequences, trailer sequences or introns, or within non-transcribed regions, either upstream or downstream of the coding region. A region of interest can be as small as a single nucleotide pair or up to 2,000 nucleotide pairs in length, or any integral value of nucleotide pairs.

[00166] A “reporter gene” or “reporter sequence” refers to any sequence that produces a protein product (a “reporter protein”) that is easily measured, in an assay. The assay may be, but is not necessarily, routine. Suitable reporter genes include, but are not limited to, sequences encoding proteins that mediate antibiotic resistance (e.g., ampicillin resistance, neomycin resistance, G418 resistance, puromycin resistance), sequences encoding colored or fluorescent or luminescent proteins (e.g., green fluorescent protein, enhanced green fluorescent protein, red fluorescent protein, luciferase), and proteins which mediate enhanced cell growth and/or gene amplification (e.g., dihydrofolate reductase). Epitope tags include, for example, one or more copies of FLAG, His, myc, Tap, HA or any detectable amino acid sequence. “Expression tags” include sequences that encode reporters that may be operably linked to a desired gene sequence in order to monitor expression of the gene of interest.

[00167] “Eukaryotic” cells include, but are not limited to, fungal cells (such as yeast), plant cells, animal cells, mammalian cells and human cells (e.g., T-cells), including stem cells (pluripotent and multipotent).

[00168] The term “barcode”, as used herein, refers to a unique oligonucleotide sequence (e.g., 5, 6, 7, 8, 9, 10, 12, 15, 20, 25, 30, 50, 75, 100 nucleotides) having a particular sequence, that is used as a means of identifying a nucleic acid sequence in which it is incorporated. The barcode is used as a means of distinguishing or identifying individual members (e.g., variants) in a library.

[00169] The terms “operative linkage” and “operatively linked” (or “operably linked”) are used interchangeably with reference to a juxtaposition of two or more components (such as sequence elements), in which the components are arranged such that both components function normally and allow the possibility that at least one of the components can mediate a function that is exerted upon at least one of the other components. By way of illustration, a transcriptional regulatory sequence, such as a

promoter, is operatively linked to a coding sequence if the transcriptional regulatory sequence controls the level of transcription of the coding sequence in response to the presence or absence of one or more transcriptional regulatory factors. A transcriptional regulatory sequence is generally operatively linked in cis with a coding sequence, but
5 need not be directly adjacent to it. For example, an enhancer is a transcriptional regulatory sequence that is operatively linked to a coding sequence, even though they are not contiguous.

[00170] A “functional fragment” of a protein, polypeptide or nucleic acid is a protein, polypeptide or nucleic acid whose sequence is not identical to the full-length protein,
10 polypeptide or nucleic acid, yet retains the same function as the full-length protein, polypeptide or nucleic acid. A functional fragment can possess more, fewer, or the same number of residues as the corresponding native molecule, and/or can contain one or more amino acid or nucleotide substitutions. Methods for determining the function of a nucleic acid or protein (e.g., coding function, ability to hybridize to another nucleic
15 acid, enzymatic activity assays) are well-known in the art.

[00171] A polynucleotide “vector” or “construct” is capable of transferring gene sequences to target cells. Typically, “vector construct,” “expression vector,” “expression construct,” “expression cassette,” and “gene transfer vector,” mean any nucleic acid construct capable of directing the expression of a gene of interest and
20 which can transfer gene sequences to target cells. Thus, the term includes cloning, and expression vehicles, as well as integrating vectors.

[00172] The terms “subject” and “patient” are used interchangeably and refer to mammals including, but not limited to, human patients and non-human primates, as well as experimental animals such as rabbits, dogs, cats, rats, mice, and other animals.
25 Accordingly, the term “subject” or “patient” as used herein means any mammalian patient or subject to which the expression cassettes of the invention can be administered. Subjects of the present invention include those with a disorder.

[00173] The terms “treating” and “treatment” as used herein refer to reduction in severity and/or frequency of symptoms, elimination of symptoms and/or underlying
30 cause, prevention of the occurrence of symptoms and/or their underlying cause, and improvement or remediation of damage. Cancer, monogenic diseases and graft versus host disease are non-limiting examples of conditions that may be treated using the compositions and methods described herein.

[00174] The term "effective amount" as used herein is an amount sufficient to effect beneficial or desired clinical results. An effective amount can be administered in one or more administrations. For purposes of this disclosure, an effective amount of a compound (*e.g.*, an infectious rAAV virion) is an amount that is sufficient to palliate, ameliorate, stabilize, reverse, prevent, slow or delay the progression of (and/or symptoms associated with) a particular disease state (*e.g.*, a muscle disease). Accordingly, an effective amount of an infectious rAAV virion is an amount of the infectious rAAV virion that is able to effectively deliver a heterologous nucleic acid to a target cell (or target cells) of the individual. Effective amounts may be determined preclinically by, *e.g.*, detecting in the cell or tissue the gene product (RNA, protein) that is encoded by the heterologous nucleic acid sequence using techniques that are well understood in the art, *e.g.* RT-PCR, western blotting, ELISA, fluorescence or other reporter readouts, and the like. Effective amounts may be determined clinically by, *e.g.* detecting a change in the onset or progression of disease using methods known in the art, *e.g.* 6-minute walk test, left ventricular ejection fraction, hand-held dynamometry, Vignos Scale and the like as described herein and as known in the art.

[00175] "Chromatin" is the nucleoprotein structure comprising the cellular genome. Cellular chromatin comprises nucleic acid, primarily DNA, and protein, including histones and non-histone chromosomal proteins. The majority of eukaryotic cellular chromatin exists in the form of nucleosomes, wherein a nucleosome core comprises approximately 150 base pairs of DNA associated with an octamer comprising two each of histones H2A, H2B, H3 and H4; and linker DNA (of variable length depending on the organism) extends between nucleosome cores. A molecule of histone H1 is generally associated with the linker DNA. For the purposes of the present disclosure, the term "chromatin" is meant to encompass all types of cellular nucleoprotein, both prokaryotic and eukaryotic. Cellular chromatin includes both chromosomal and episomal chromatin.

[00176] The term "virus genome" refers to a nucleic acid sequence that is flanked by cis acting nucleic acid sequences that mediate the packaging of the nucleic acid into a viral capsid. For AAVs and parvoviruses, for example it is known that the "inverted terminal repeats" (ITRs) that are located at the 5' and 3' end of the viral genome have this function and that the ITRs can mediate the packaging of heterologous, for example, non-wild type virus genomes, into a viral capsid.

[00177] The term “element” refers to a separate or distinct part of something, for example, a nucleic acid sequence with a separate function within a longer nucleic acid sequence. The term “regulatory element” and “expression control element” are used interchangeably herein and refer to nucleic acid molecules that can influence the expression of an operably linked coding sequence in a particular host organism. These terms are used broadly to and cover all elements that promote or regulate transcription, including promoters, core elements required for basic interaction of RNA polymerase and transcription factors, upstream elements, enhancers, and response elements (see, e.g., Lewin, “Genes V” (Oxford University Press, Oxford) pages 847-873). Exemplary regulatory elements in prokaryotes include promoters, operator sequences and a ribosome binding sites. Regulatory elements that are used in eukaryotic cells can include, without limitation, transcriptional and translational control sequences, such as promoters, enhancers, splicing signals, polyadenylation signals, terminators, protein degradation signals, internal ribosome-entry element (IRES), 2A sequences, and the like, that provide for and/or regulate expression of a coding sequence and/or production of an encoded polypeptide in a host cell.

[00178] As used herein, the term “variant” refers to a polynucleotide or polypeptide having a sequence substantially similar to a reference polynucleotide or polypeptide. In the case of a polynucleotide, a variant can have deletions, substitutions, additions of one or more nucleotides at the 5' end, 3' end, and/or one or more internal sites in comparison to the reference polynucleotide. Similarities and/or differences in sequences between a variant and the reference polynucleotide can be detected using conventional techniques known in the art, for example polymerase chain reaction (PCR) and hybridization techniques. Variant polynucleotides also include synthetically derived polynucleotides, such as those generated, for example, by using site-directed mutagenesis. Generally, a variant of a polynucleotide, including, but not limited to, a DNA, can have at least about 50%, about 55%, about 60%, about 65%, about 70%, about 75%, about 80%, about 85%, about 90%, about 91%, about 92%, about 93%, about 94%, about 95%, about 96%, about 97%, about 98%, about 99% or more sequence identity to the reference polynucleotide as determined by sequence alignment programs known by skilled artisans. In the case of a polypeptide, a variant can have deletions, substitutions, additions of one or more amino acids in comparison to the reference polypeptide. Similarities and/or differences in sequences between a variant and the reference polypeptide can be detected using conventional techniques known in

the art, for example Western blot. Generally, a variant of a polypeptide, can have at least about 60%, about 65%, about 70%, about 75%, about 80%, about 85%, about 90%, about 91%, about 92%, about 93%, about 94%, about 95%, about 96%, about 97%, about 98%, about 99% or more sequence identity to the reference polypeptide as determined by sequence alignment programs known by skilled artisans. In some instances, the term "variant" may also be used to describe an AAV comprising a variant capsid sequence.

[00179] The term "AAV" or "adeno-associated virus" refers to a Dependoparvovirus within the Parvoviridae genus of viruses. For example, the AAV can be an AAV derived from a naturally occurring "wild-type" virus, an AAV derived from a rAAV genome packaged into a capsid derived from capsid proteins encoded by a naturally occurring cap gene and/or a rAAV genome packaged into a capsid derived from capsid proteins encoded by a non-natural capsid cap gene. For the purposes of the disclosure herein, the term "AAV" is an abbreviation for adeno-associated virus, including, without limitation, the virus itself and derivatives thereof. Except where otherwise indicated, the term refers to all subtypes or serotypes and both replication-competent and recombinant forms. The term "AAV" includes, without limitation, AAV type 1 (AAV-1 or AAV1), AAV type 2 (AAV-2 or AAV2), AAV type 3A (AAV-3A or AAV3A), AAV type 3B (AAV-3B or AAV3B), AAV type 4 (AAV-4 or AAV4), AAV type 5 (AAV-5 or AAV5), AAV type 6 (AAV-6 or AAV6), AAV type 7 (AAV-7 or AAV7), AAV type 8 (AAV-8 or AAV8), AAV type 9 (AAV-9 or AAV9), AAV type 10 (AAV-10 or AAV10 or AAVrh10), avian AAV, bovine AAV, canine AAV, caprine AAV, equine AAV, primate AAV, non-primate AAV, and ovine AAV. "Primate AAV" refers to AAV that infect primates, "non-primate AAV" refers to AAV that infect non-primate mammals, "bovine AAV" refers to AAV that infect bovine mammals, etc.

[00180] The genomic sequences of various serotypes of AAV, as well as the sequences of the native terminal repeats (TRs), Rep proteins, and capsid subunits are known in the art. Such sequences may be found in the literature or in public databases such as GenBank. See, e.g., GenBank Accession Numbers NC_002077.1 (AAV1), AF063497.1 (AAV1), NC_001401.2 (AAV2), AF043303.1 (AAV2), J01901.1 (AAV2), U48704.1 (AAV3A), NC_001729.1 (AAV3A), AF028705.1 (AAV3B), NC_001829.1 (AAV4), U89790.1 (AAV4), NC_006152.1 (AA5), AF085716.1 (AAV-5), AF028704.1 (AAV6), NC_006260.1 (AAV7), AF513851.1 (AAV7), AF513852.1 (AAV8) NC_006261.1 (AAV-8), AY530579.1 (AAV9), AAT46337 (AAV10) and AAO88208

(AAVrh10); the disclosures of which are incorporated by reference herein for teaching AAV nucleic acid and amino acid sequences. See also, *e.g.*, Srivastava *et al.* (1983) *J. Virology* 45 :555; Morini *et al.* (1998) *J. Virology* 71 :6823; Chiorini *et al.* (1999) *J. Virology* 73 : 1309; Bantel-Schaal *et al.* (1999) *J. Virology* 73:939; Xiao *et al.* (1999) *J. Virology* 73 :3994; Muramatsu *et al.* (1996) *Virology* 221 :208; Shade *et al.* (1986) *J. Virol.* 58:921; Gao *et al.* (2002) *Proc. Nat. Acad. Sci. USA* 99: 11854; Moris *et al.* (2004) *Virology* 33 :375-383; international patent publications WO 00/28061, WO 99/61601, WO 98/11244; and U.S. Pat. No. 6,156,303.

[00181] The term "rAAV" refers to a "recombinant AAV". In some embodiments, a recombinant AAV has an AAV genome in which part or all of the rep and cap genes have been replaced with heterologous sequences. If an AAV virion comprises a heterologous polynucleotide (i.e. a polynucleotide other than a wild-type AAV genome, *e.g.*, a transgene to be delivered to a target cell, a nuclease system, an RNAi agent or CRISPR agent to be delivered to a target cell, etc.), it is typically referred to as a "recombinant AAV (rAAV) virion" or an "rAAV viral particle." In general, the heterologous polynucleotide is flanked by at least one, and generally by two, AAV inverted terminal repeat sequences (ITRs).

[00182] The term "cap gene" or "capsid gene" refers to the nucleic acid sequences that encode capsid proteins that form, or contribute to the formation of, the capsid, or protein shell, of the virus. In the case of AAV, the capsid protein may be VP1, VP2, or VP3. For other parvoviruses, the names and numbers of the capsid proteins can differ.

[00183] The term "rep gene" refers to the nucleic acid sequences that encode the non-structural proteins (rep78, rep68, rep52 and rep40) required for the replication and production of virus.

[00184] The term "packaging" refers to a series of intracellular events that result in the assembly and encapsidation of an AAV particle. AAV "rep" and "cap" genes refer to polynucleotide sequences encoding replication and encapsidation proteins of adeno-associated virus. AAV rep and cap are referred to herein as AAV "packaging genes."

[00185] The term "helper virus" for AAV refers to a virus that allows AAV (*e.g.* wild-type AAV) to be replicated and packaged by a mammalian cell. A variety of such helper viruses for AAV are known in the art, including adenoviruses, herpesviruses and poxviruses such as vaccinia. The adenoviruses encompass a number of different subgroups, although Adenovirus type 5 of subgroup C is most commonly used. Numerous adenoviruses of human, non-human mammalian and avian origin are known

and available from depositories such as the ATCC. Viruses of the herpes family include, for example, herpes simplex viruses (HSV) and Epstein-Barr viruses (EBV), as well as cytomegaloviruses (CMV) and pseudorabies viruses (PRV); which are also available from depositories such as ATCC.

5 [00186] The term "helper virus function(s)" refers to function(s) encoded in a helper virus genome which allow AAV replication and packaging (in conjunction with other requirements for replication and packaging described herein). As described herein, "helper virus function" may be provided in a number of ways, including by providing helper virus or providing, for example, polynucleotide sequences encoding the requisite
10 function(s) to a producer cell in trans. For example, a plasmid or other expression vector comprising nucleotide sequences encoding one or more adenoviral proteins is transfected into a producer cell along with an rAAV vector.

[00187] The term "infectious" virus or viral particle is one that comprises a competently assembled viral capsid and is capable of delivering a polynucleotide
15 component into a cell for which the viral species is tropic. The term does not necessarily imply any replication capacity of the virus. Assays for counting infectious viral particles are described elsewhere in this disclosure and in the art. Viral infectivity can be expressed as the ratio of infectious viral particles to total viral particles. Methods of determining the ratio of infectious viral particle to total viral particle are known in
20 the art. See, *e.g.*, Grainger *et al.* (2005) *Mol. Ther.* 11: S337 (describing a TCID50 infectious titer assay); and Zolotukhin *et al.* (1999) *Gene Ther.* 6:973.

[00188] The term "tropism" as used herein refers to the preferential targeting by a virus (*e.g.*, an AAV) of cells of a particular host species or of particular cell types within a host species. For example, a virus that can infect cells of the heart, lung, liver, and
25 muscle has a broader (*i.e.*, increased) tropism relative to a virus that can infect only lung and muscle cells. Tropism can also include the dependence of a virus on particular types of cell surface molecules of the host. For example, some viruses can infect only cells with surface glycosaminoglycans, while other viruses can infect only cells with sialic acid (such dependencies can be tested using various cells lines deficient in
30 particular classes of molecules as potential host cells for viral infection). In some cases, the tropism of a virus describes the virus's relative preferences. For example, a first virus may be able to infect all cell types but is much more successful in infecting those cells with surface glycosaminoglycans. A second virus can be considered to have a similar (or identical) tropism as the first virus if the second virus also prefers the same

characteristics (*e.g.*, the second virus is also more successful in infecting those cells with surface glycosaminoglycans), even if the absolute transduction efficiencies are not similar. For example, the second virus might be more efficient than the first virus at infecting every given cell type tested, but if the relative preferences are similar (or identical), the second virus can still be considered to have a similar (or identical) tropism as the first virus. In some embodiments, the tropism of a virion comprising a subject variant AAV capsid protein is not altered relative to a naturally occurring virion. In some embodiments, the tropism of a virion comprising a subject variant AAV capsid protein is expanded (*i.e.*, broadened) relative to a naturally occurring virion. In some embodiments, the tropism of a virion comprising a subject variant AAV capsid protein is reduced relative to a naturally occurring virion.

[00189] The term "replication-competent" virus (*e.g.* a replication-competent AAV) refers to a phenotypically wild-type virus that is infectious, and is also capable of being replicated in an infected cell (*i.e.* in the presence of a helper virus or helper virus functions). In the case of AAV, replication competence generally requires the presence of functional AAV packaging genes. In general, rAAV vectors as described herein are replication-incompetent in mammalian cells (especially in human cells) by virtue of the lack of one or more AAV packaging genes. Typically, such rAAV vectors lack any AAV packaging gene sequences in order to minimize the possibility that replication competent AAV are generated by recombination between AAV packaging genes and an incoming rAAV vector. In many embodiments, rAAV vector preparations as described herein are those which contain few if any replication competent AAV (rcAAV, also referred to as RCA) (*e.g.*, less than about 1 rcAAV per 10^2 rAAV particles, less than about 1 rcAAV per 10^4 rAAV particles, less than about 1 rcAAV per 10^6 rAAV particles, less than about 1 rcAAV per 10^{12} rAAV particles, or no rcAAV).

[00190] A "library" may be in the form of a multiplicity of linear nucleic acids, plasmids, viral particles or viral vectors, etc. A library will include at least two nucleic acids, plasmids, viral particles, viral vectors, etc.

Libraries of AAV Variants

[00191] In one aspect, the subject matter disclosed herein relates to the development of libraries encoding AAV capsid proteins with a desired characteristic compared to a natural AAV serotype. Thus, described herein are libraries of AAV variants used to develop AAV capsids with a desired characteristic compared to a natural AAV serotype. In some embodiments, the desired characteristic is enhanced cell or tissue

tropism as compared to the natural AAV serotype. In some embodiments, the desired characteristic is the evasion of a pre-existing host antibody response. In some embodiments, the desired characteristic is reduced immunogenicity so as to not provoke a host response.

5 [00192] In some embodiments, each member of a library of the disclosure comprises a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein; and one or more of: b) one or more silent mutations in the nucleic acid sequence flanking the peptide insertion site in the AAV variant capsid protein of a); c) a nucleic acid encoding a localization signal; d) a nucleic acid comprising a barcode; and e) a
10 nucleic acid encoding a reporter protein.

[00193] In some embodiments, each member of a library of the disclosure comprises a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid
15 protein; and two or more of: b) one or more silent mutations in the nucleic acid sequence flanking the peptide insertion site in the AAV variant capsid protein of a); c) a nucleic acid encoding a localization signal; d) a nucleic acid comprising a barcode; and e) a nucleic acid encoding a reporter protein.

[00194] In some embodiments, each member of a library of the disclosure comprises
20 a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein; and three or more of: b) one or more silent mutations in the nucleic acid sequence flanking the peptide insertion site in the AAV variant capsid protein of a); c) a nucleic acid encoding a localization signal; d) a nucleic acid comprising a barcode; and e) a nucleic acid encoding a reporter protein.
25

[00195] In some embodiments, each member of a library of the disclosure comprises a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein; and b) one or more silent mutations in the nucleic acid sequence flanking the
30 peptide insertion site in the AAV variant capsid protein of a); c) a nucleic acid encoding a localization signal; d) a nucleic acid comprising a barcode; and e) a nucleic acid encoding a reporter protein.

[00196] In some embodiments, each member of a library of the disclosure comprises a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable

and/or surface-exposed loop of the variant capsid protein; and one or more of: b) one or more silent mutations in the nucleic acid encoding the AAV variant capsid protein of a) in the nucleic acid sequence flanking the peptide insertion site; c) a nucleic acid encoding a localization signal; d) a nucleic acid comprising a barcode; and e) a nucleic acid encoding a reporter protein.

5 [00197] In some embodiments, each member of a library of the disclosure comprises a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein; and two or more of: b) one or more silent mutations in the nucleic acid encoding the AAV variant capsid protein of a) in the nucleic acid sequence flanking the peptide insertion site; c) a nucleic acid encoding a localization signal; d) a nucleic acid comprising a barcode; and e) a nucleic acid encoding a reporter protein.

10 [00198] In some embodiments, each member of a library of the disclosure comprises a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein; and three or more of: b) one or more silent mutations in the nucleic acid encoding the AAV variant capsid protein of a) in the nucleic acid sequence flanking the peptide insertion site; c) a nucleic acid encoding a localization signal; d) a nucleic acid comprising a barcode; and e) a nucleic acid encoding a reporter protein.

15 [00199] In some embodiments, each member of a library of the disclosure comprises a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein; b) one or more silent mutations in the nucleic acid encoding the AAV variant capsid protein of a) in the nucleic acid sequence flanking the peptide insertion site; c) a nucleic acid encoding a localization signal; d) a nucleic acid comprising a barcode; and e) a nucleic acid encoding a reporter protein.

20 [00200] In some embodiments, each member of the library comprises a nucleic acid encoding a localization signal. In some embodiments, each member of the library comprises a nucleic acid encoding a localization signal. In some embodiments, each member of the library comprises a nucleic acid comprising a barcode. In some embodiments, each member of the library comprises a nucleic acid comprising two or more barcodes. In some embodiments, each member of the library comprises a nucleic acid encoding a reporter protein.

[00201] In any of the above embodiments, the nucleic acid encoding an AAV variant capsid protein, the nucleic acid encoding a localization signal, the nucleic acid comprising a barcode, and/or the nucleic acid encoding a reporter protein, are present on separate nucleic acid molecules. In some embodiments, the nucleic acid encoding an AAV variant capsid protein, the nucleic acid encoding a localization signal, the nucleic acid comprising a barcode, and/or the nucleic acid encoding a reporter protein, are present on a single nucleic acid molecule. In some embodiments, the nucleic acid encoding an AAV variant capsid protein, and the nucleic acid encoding a localization signal, the nucleic acid comprising a barcode, and/or the nucleic acid encoding a reporter protein, are linked to each other in any order. In some embodiments, each member of the library comprises a 5'ITR sequence, the nucleic acid comprising a barcode, the nucleic acid encoding a reporter protein, the nucleic acid encoding an AAV variant capsid protein, and a 3'ITR sequence, in that order.

[00202] In some embodiments, the AAV variant capsid proteins are derived from AAV1, AAV2, AAV3B, AAV5, AAV6, AAV8 and AAV9. In some embodiments, the AAV variant capsid proteins are derived from less well characterized AAV serotypes, including but not limited to AAV3, AAV4, AAV7, AAV11, AAVrh10, AAVrh39, and AAVrh74. In some embodiments, a library of AAV variants comprises AAV variant capsid proteins derived from a single AAV serotype. In some embodiments, a library of AAV variants comprises AAV variant capsid proteins derived from 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, or more AAV serotypes. In some embodiments, the AAV variant capsid proteins derived from 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, or more AAV serotypes are combined once individual serotype libraries are developed. In some embodiments, combinatorial libraries are generated by modifying nucleic acids encoding AAV capsid proteins from 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, or more serotypes in the same pool.

[00203] In some embodiments, mutations (e.g., insertions, deletions and/or substitutions) are introduced into a DNA sequence encoding an exposed loop in the capsid protein. In some embodiments, a peptide is inserted into exposed loops (e.g. hypervariable regions) in the AAV capsid. In some embodiments, the peptide comprises 6, 7, 8, 9, 10, 11, 12, 13, 14, 15 or more amino acids. In some embodiments, the HI loop is targeted (mutated) while in others, the DE loop is targeted (mutated). In some embodiments, mutations (e.g., insertions, deletions and/or substitutions) are made in both loops. In further embodiments, mutations (e.g., insertions, deletions and/or

substitutions) are introduced into the VR region of a surface loop, including into VR-I, VR-II, VR-III, VR-IV, VR-V, VR-VI, VR-VII, VR-VIII and or VR-IX. In yet other embodiments, mutations (e.g., insertions, deletions and/or substitutions) are made in VR-I, VR-VIII and or VR-IV. In some embodiments, the mutations (e.g., insertions, deletions and/or substitutions) are introduced into the AAV capsid proteins VP1, VP2 or VP3, or in two of the capsid proteins in any combination, or in all three. In some embodiments, the mutations are introduced into VP1. In some embodiments, the mutations are introduced into VP2. In some embodiments, the mutations are introduced into VP3. In some embodiments, the mutations are introduced into VP1 and VP2. In some embodiments, the mutations are introduced into VP1 and VP3. In some embodiments, the mutations are introduced into VP2 and VP3. In some embodiments, the mutations are introduced into VP1, VP2, and VP3. In some embodiments, a single mutation (e.g., an insertion, a deletion and/or a substitution) is introduced at a single site in a gene encoding a capsid protein, while in other embodiments, more than 1, 2, 3, 4, 5, 6, 7, 10, 20, 30, 40, 50, 100 or more (including any number between 1 and 100 or more) mutations (e.g., insertions, deletions and/or substitutions) are introduced in a gene encoding a capsid protein.

[00204] In some exemplary embodiments, a peptide is introduced into the variable regions VR-I, VR-IV, or VR-VIII of the capsid protein. In some embodiments, the peptide is introduced at a location between positions 450 and 600 of the capsid protein. In some embodiments, the peptide is introduced at position 590 if the capsid protein corresponds to AAV1. In some embodiments, the peptide is introduced into position 454 or 590 if an AAV6 capsid is being modified. In some embodiments, the peptide introduced at position 588 if an AAV2 capsid is being modified. In some embodiments, the peptide is introduced into position 589 if an AAV3B capsid is used. In some embodiments, the peptide is introduced into position 578 if an AAV5 capsid is used. In some embodiments, the peptide is introduced into position 591 if an AAV8 capsid is used. In some embodiments the peptide is introduced into position 266, 455, and/or 589 if an AAV9 capsid is used. It is understood that other sites in the capsid proteins may be selected for insertion.

[00205] In some embodiments of the AAV libraries disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO:1-32 is inserted at amino acid position 590 of the capsid protein of an AAV1 serotype. In some embodiments of the AAV libraries disclosed herein, a peptide comprising the amino acid sequence of

any one of SEQ ID NO:68-110 is inserted at amino acid position 590 of the capsid protein of an AAV1 serotype. In some embodiments of the AAV libraries disclosed herein, the peptide inserted at position 590 of the capsid protein of an AAV1 serotype comprises an amino acid sequence selected from the group consisting of any one of

5 SEQ ID NO: 68 to SEQ ID NO: 75. In some embodiments of the AAV libraries disclosed herein, the peptide inserted at position 590 of the capsid protein of an AAV1 serotype comprises the amino acid sequence SEQ ID NO: 71. In some embodiments of the AAV libraries disclosed herein, the peptide inserted at position 590 of the capsid protein of an AAV1 serotype comprises an amino acid sequence selected from the

10 group consisting of any one of SEQ ID NO: 1, SEQ ID NO: 2 and SEQ ID NO: 3.

[00206] In some embodiments of the AAV libraries disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO:1-32 is inserted at amino acid position 454 of the capsid protein of an AAV6 serotype. In some embodiments of the AAV libraries disclosed herein, a peptide comprising the amino acid sequence of

15 any one of SEQ ID NO:68-110 is inserted at amino acid position 454 of the capsid protein of an AAV6 serotype. In some embodiments of the AAV libraries disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO:1-32 is inserted at amino acid position 590 of the capsid protein of an AAV6 serotype. In some embodiments of the AAV libraries disclosed herein, a peptide comprising the

20 amino acid sequence of any one of SEQ ID NO:68-110 is inserted at amino acid position 590 of the capsid protein of an AAV6 serotype. In some embodiments of the AAV libraries disclosed here, the peptide inserted at position 454 of the capsid protein of an AAV6 serotype comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 19 to SEQ ID NO: 27. In some embodiments of

25 the AAV libraries disclosed here, the peptide inserted at position 590 of the capsid protein of an AAV6 serotype comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 19 to SEQ ID NO: 27.

[00207] In some embodiments of the AAV libraries disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO:1-32 is inserted at amino

30 acid position 588 of the capsid protein of an AAV2 serotype. In some embodiments of the AAV libraries disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO:68-110 is inserted at amino acid position 588 of the capsid protein of an AAV2 serotype. In some embodiments of the AAV libraries disclosed here, the peptide inserted at position 588 of the capsid protein of an AAV2 serotype

comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 90 to SEQ ID NO: 110. In some embodiments of the AAV libraries disclosed here, the peptide inserted at position 588 of the capsid protein of an AAV2 serotype comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 95, SEQ ID NO: 94, SEQ ID NO: 96, SEQ ID NO: 101, SEQ ID NO: 103, SEQ ID NO: 106, SEQ ID NO: 91 and SEQ ID NO: 102. . In some embodiments of the AAV libraries disclosed here, the peptide inserted at position 588 of the capsid protein of an AAV2 serotype comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 4-7.

10 [00208] In some embodiments of the AAV libraries disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO:1-32 is inserted at amino acid position 589 of the capsid protein of an AAV3B serotype. In some embodiments of the AAV libraries disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO:68-110 is inserted at amino acid position 589 of the capsid protein of an AAV3B serotype. In some embodiments of the AAV libraries disclosed here, the peptide inserted at position 589 of the capsid protein of an AAV3B serotype comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 76- 85. In some embodiments of the AAV libraries disclosed here, the peptide inserted at position 589 of the capsid protein of an AAV3B serotype comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 78, SEQ ID NO: 80, SEQ ID NO: 77, SEQ ID NO: 79, SEQ ID NO: 76 and SEQ ID NO: 83. In some embodiments of the AAV libraries disclosed here, the peptide inserted at position 589 of the capsid protein of an AAV3B serotype comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 8 to SEQ ID NO: 11.

25 [00209] In some embodiments of the AAV libraries disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO:1-32 is inserted at amino acid position 578 of the capsid protein of an AAV5 serotype. In some embodiments of the AAV libraries disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO:68-110 is inserted at amino acid position 578 of the capsid protein of an AAV5 serotype. In some embodiments of the AAV libraries disclosed here, the peptide inserted at position 578 of the capsid protein of an AAV5 serotype comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 28 to SEQ ID NO: 32.

[00210] In some embodiments of the AAV libraries disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO:1-32 is inserted at amino acid position 591 of the capsid protein of an AAV8 serotype. In some embodiments of the AAV libraries disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO:68-110 is inserted at amino acid position 591 of the capsid protein of an AAV8 serotype.

[00211] In some embodiments of the AAV libraries disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO:1-32 is inserted at amino acid position 266 of the capsid protein of an AAV9 serotype. In some embodiments of the AAV libraries disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO:68-110 is inserted at amino acid position 266 of the capsid protein of an AAV9 serotype. In some embodiments of the AAV libraries disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO:1-32 is inserted at amino acid position 455 of the capsid protein of an AAV9 serotype.

In some embodiments of the AAV libraries disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO:68-110 is inserted at amino acid position 455 of the capsid protein of an AAV9 serotype. In some embodiments of the AAV libraries disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO:1-32 is inserted at amino acid position 589 of the capsid protein of an AAV9 serotype. In some embodiments of the AAV libraries disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO:68-110 is inserted at amino acid position 589 of the capsid protein of an AAV9 serotype. In some embodiments of the AAV libraries disclosed here, the peptide inserted at position 266 of the capsid protein of an AAV9 serotype comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 12 to SEQ ID NO: 18. In some embodiments of the AAV libraries disclosed here, the peptide inserted at position 266 of the capsid protein of an AAV9 serotype comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 86 to SEQ ID NO: 89. In some embodiments of the AAV libraries disclosed here, the peptide inserted at position 266 of the capsid protein of an AAV9 serotype comprises an amino acid sequence of SEQ ID NO: 89. In some embodiments of the AAV libraries disclosed here, the peptide inserted at position 455 of the capsid protein of an AAV9 serotype comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 12 to SEQ ID NO: 18. In some embodiments of the AAV libraries disclosed here, the peptide

inserted at position 455 of the capsid protein of an AAV9 serotype comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 86 to SEQ ID NO: 89. In some embodiments of the AAV libraries disclosed here, the peptide inserted at position 455 of the capsid protein of an AAV9 serotype comprises an amino acid sequence of SEQ ID NO: 89. In some embodiments of the AAV libraries disclosed here, the peptide inserted at position 455 of the capsid protein of an AAV9 serotype comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 12 to SEQ ID NO: 18. In some embodiments of the AAV libraries disclosed here, the peptide inserted at position 589 of the capsid protein of an AAV9 serotype comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 86 to SEQ ID NO: 89. In some embodiments of the AAV libraries disclosed here, the peptide inserted at position 589 of the capsid protein of an AAV9 serotype comprises an amino acid sequence of SEQ ID NO: 89.

[00212] In some embodiments, the inserted peptide is 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15 or more amino acids long. In some embodiments, the peptide is 7 amino acids long. In some embodiments, the peptide is 10 amino acids long. In some embodiments, the peptide is 15 amino acids long. In some embodiments, the peptides are introduced during amplification of the fragment of the capsid gene that is 3' of the insertion site by PCR. Thus, in some embodiments, the capsid gene is diversified using PCR. In some embodiments, the introduced sequences are introduced during amplification of the fragment of the capsid gene that is 3' of the insertion site.

[00213] In some embodiments, silent mutations are introduced into regions of the capsid gene flanking the region into which the peptides are introduced so that all capsid serotype genes have the same nucleotide sequence in these flanking regions. The flanking region may include 10 or more, 20 or more, 30 or more, 40 or more, 50 or more, 100 or more, 150 or more, or 200 or more nucleotides on either side of the peptide insertion site. In this way the same primer sequences can be used for PCR amplification and next-generation sequencing (NGS) for all serotype libraries. This allows for faster screening of libraries based on 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, or more serotypes. In some embodiments, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15 or more silent mutations are introduced to bring the flanking sequences into alignment with two common sequences (one at the 5' end of the diversified region and one at the 3' end of the diversified region). In some embodiments, the silent mutations are introduced at one or more of position 571, 612, and 617 if the capsid protein corresponds to AAV1.

In some embodiments, the silent mutations are introduced at one or more of position 568, 569, 572, 573, 574, 610, 611, 613, 615, 616, and 617 if the capsid protein corresponds to AAV2. In some embodiments, the silent mutations are introduced at one or more of position 569, 570, 571, 573, 574, 575, 612, 614, 615, and 616 if the capsid protein corresponds to AAV3B. In some embodiments, the silent mutations are introduced at one or more of position 573, 575, 576, 577, 614, and 619 if the capsid protein corresponds to AAV8. In some embodiments, the silent mutations are introduced at one or more of position 571, 572, 573, 574, 575, 611, 612, 615, 616, and 617 if the capsid protein corresponds to AAV9. It is understood that other sites in the capsid proteins may be selected for insertion.

[00214] In some embodiments, the payload or genome of each AAV variant in a library further comprises a reporter gene. In some embodiments, the protein encoded by the reporter is fluorescent. Exemplary, non-limiting reporter genes include EGFP, mCherry, mClover3 and mRuby3. Other exemplary non-limiting reporter genes include mApple, iRFP, tdTomato, mVenus, YFP, RFP, firefly luciferase, and nanoluciferase.

[00215] In some embodiments, the capsid gene and the reporter gene are under the control of separate promoters. In some embodiments, the capsid gene and the reporter gene are each independently operatively linked to a promoter.

[00216] In some embodiments, the reporter gene is controlled by a cell type and/or tissue specific promoter. In some embodiments, the reporter gene is operatively linked to a cell type and/or tissue specific promoter. In some embodiments, the reporter gene is operatively linked to a cell-type specific RNA polymerase II promoter. Exemplary cell type and/or tissue specific promoters include the human synapsin promoter (hSyn1), only expressed in neurons, or the transthyretin promoter (TTR), expressed in hepatocytes. Other non-limiting cell type and/or tissue specific promoters for use in the methods and compositions of the invention include cytokeratin 18 and 19 (epithelial cell specific, Zheng and Baum (2008) *Methods Mol Biol* 434:205-219), unc45b or unc45 myosin chaperon B (muscle specific, Rudeck *et al* (2016) *Genesis* 54(8):431-8), cardiac troponin T (cTnT) (cardiomyocyte specific, Ma *et al* (2004) *Am J Physiol Cell Physiol* 286(3):556-64), glial fibrillary acidic protein (GFAP) (astrocyte specific, Lee *et al* (2008) *Glia* 56(5):481-93), myelin basic protein (MBP) (oligodendrocyte specific, Wei *et al* (2003) *Gene* 313:161-7), methyl CpG-binding protein 2 (MeCP2) (neuron specific, Adachi *et al* (2005) *Hum Mol Genetics* 14(23):3709-22), and other brain or

eye specific rAAV-compatible MiniPromoters (Leeuw *et al* (2016) *Molecular Brain* 9(1):52).

[00217] In some embodiments, the payload or genome of each AAV variant in a library further comprise a nucleic acid encoding a localization signal. In some
5 embodiments, the reporter gene is fused to the nucleic acid encoding a localization signal. In some embodiments, the reporter genes are fused to domains to increase movement of the reporter into organelles. In some embodiments, the reporter genes are fused to domains to increase movement of the reporter into the nucleus. In some
10 embodiments, the reporter genes are fused to a nucleic acid encoding a nuclear localization signal (NLS) (for example the SV40 large T-antigen nuclear localization signal). Non-limiting examples of NLSs include an NLS sequence derived from: the NLS of the SV40 virus large T-antigen; the NLS from nucleoplasmin; a c-myc NLS; the hRNPA1 M9 NLS; the IBB domain from importin-alpha; the myoma T protein NLS; human p53 NLS; mouse c-abl IV NLS; influenza virus NS1 NLS; Hepatitis virus
15 delta antigen NLS; the mouse Mx1 protein NLS; the human poly(ADP-ribose) polymerase NLS; and steroid hormone receptors (human) glucocorticoid NLS. Other NLSs are known in the art. In some embodiments, the reporter proteins are fused to a protein that localizes to the nuclear envelope (for example KASH domains). In some
20 embodiments, the reporter proteins are fused to a histone binding domain (for example histone 2B binding domain, H2B). Other non-limiting histones include those in the H1, H2A, H3, and H4 families. It is understood that both N and C terminal fusions to a reporter gene support nuclear localization. In some embodiments, the reporter protein is fused to more than one localization signal. In some embodiments, the multiple
25 localization signals are in tandem. In some embodiments, the reporter protein is fused to one or more localization signals at its N-terminus and one or more localization signals at its C-terminus.

[00218] In some embodiments, a nucleic acid comprising a barcode is added to the payload or genome of each AAV variant in a library. In some embodiments, the barcode is bioinformatically linked to the peptide introduced into the variant capsid
30 protein. In some embodiments, the DNA sequences comprising the variant DNA sequences encoding the inserted peptide are synthesized to further comprise a random or specified barcode. The barcode may comprise 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18 or more nucleotides. In some embodiments, the nucleic acid comprising a barcode is selected from any one of sequences SEQ ID NO: 111-154 or 155-198. In

some embodiments, the nucleic acid comprising a barcode is selected from SEQ ID NO: 111-154. In some embodiments, the nucleic acid comprising a barcode is selected from SEQ ID NO: 155-198. In some embodiments, the nucleic acid comprising the barcode comprises a sequence selected from any one of sequences SEQ ID NO: 111-154. In some embodiments, the nucleic acid comprising the barcode comprises a sequence selected from any one of sequences SEQ ID NO: 155-198. The synthesized DNA may also comprise restriction sites and or nucleic acid sequences used for molecular cloning by Gibson assembly. In some embodiments an intron is included in the expression cassette to confirm that sequenced transcripts are derived from mRNA and not vector genomic DNA. In further embodiments, the AAV payload or genome is assembled via Gibson assembly where the 3' end of the capsid gene is linked to the random or specified insertion sequences at the insertion site, and the barcode is linked to a polyA sequence and 5' ITR. In some embodiments, ILLUMINA® sequencing (or any other sequencing technique) is performed across the barcode and the inserted variable region in the capsid gene to bioinformatically link the two random sequences. In further embodiments, the reporter construct, reporter-specific promoter, capsid-specific promoter and 5' end of the capsid gene are assembled to create the final payload construct. In some embodiments, the expression cassette relative to the *cap* gene is in the sense orientation.

[00219] In some embodiments, each member of the library comprises a nucleic acid comprising more than one barcode sequences. In some embodiments, each member of the library comprises two or more nucleic acids each comprising a barcode sequence. In some embodiments, each member of the library comprises a first nucleic acid comprising a first barcode and a second nucleic acid comprising a second barcode. In some embodiments, the first nucleic acid comprising the first barcode and the second nucleic acid comprising the second barcode are different. In some embodiments, the first nucleic acid comprising the first barcode sequence comprises a sequence selected from any one of sequences SEQ ID NO: 111-154. In some embodiments, the first barcode sequence is selected from any one of sequences SEQ ID NO: 111-154. In some embodiments, the second nucleic acid comprising the second barcode sequence comprises a sequence selected from any one of sequences SEQ ID NO: 155-198. In some embodiments, the second nucleic acid comprising the second barcode sequence is selected from any one of sequences SEQ ID NO: 155-198. In some embodiments, each of the first nucleic acid comprising the first barcode and the second nucleic acid

comprising the second barcode is independently operatively linked to a promoter. In some embodiments, the promoter operatively linked to the first nucleic acid comprising the first barcode and the promoter operatively linked to the second nucleic acid comprising the second barcode is each independently an RNA Pol II promoter. In some

5 embodiments, the promoter operatively linked to the first nucleic acid comprising the first barcode and the promoter operatively linked to the second nucleic acid comprising the second barcode is each independently an RNA Pol III promoter (e.g., a promoter selected from the group of U6 promoter, H1 promoter and 7SK promoter). In some

10 embodiments, the promoter operatively linked to the first nucleic acid comprising the first barcode is operatively linked to an RNA Pol II promoter and the promoter operatively linked to the second nucleic acid comprising the second barcode is an RNA Pol III promoter (e.g., a promoter selected from the group of human synapsin promoter (hSyn1), transthyretin promoter (TTR), cytokeratin 18, cytokeratin 19, unc-45 myosin chaperon B (unc45b) promoter, cardiac troponin T (cTnT) promoter, glial fibrillary

15 acidic protein (GFAP) promoter, myelin basic protein (MBP) promoter, and methyl CpG-binding protein 2 (MeCP2) promoter.

[00220] In some embodiments, a short piece of DNA is synthesized comprising a randomly generated or specified barcode and a randomly generated or specified capsid

20 variant region, as well as two regions used for Gibson assembly. Next, capsid sequence 3' of the diversified region are amplified. In further embodiments, a Gibson assembly reaction where the 5' ITR and polyadenylation sequences are fused to the barcode on the 5' end, and a second Gibson assembly region is fused to the 3' end of the capsid gene and the polyA signal for the capsid gene and the 3' ITR are performed. In further

25 embodiments, ILLUMINA® sequencing is performed across the barcode and the variant capsid sequences. In further embodiments, digestion with a restriction enzyme is carried out. In further embodiments, a PCR amplification step where the reporter, localization signal, promoter(s), and the 5' end of the capsid gene are prepared. Alternatively, the fragment comprising the reporter, the localization signal, the

30 promoter(s), and 5' end of the capsid gene may be pre-assembled in a donor plasmid, digested with BsaI, and gel purified. In further embodiments, golden gate cloning step is performed to create the final construct.

[00221] In some embodiments, two DNA fragments are synthesized. Fragment A comprises Gibson assembly region #1, a restriction enzyme site, the variable capsid

region, and a region homologous to the capsid gene that is used as a PCR primer. Fragment B comprises Gibson assembly region #2, a random barcode, a restriction enzyme site, and Gibson assembly region #1. Next, a PCR procedure is performed where the 3' sequence of capsid gene is amplified using fragment A synthesized in step 1 as a PCR primer. In further embodiments, an intermediate AAV construct is generated by Gibson assembly where the construct comprises in a 5' to 3' order the 5' ITR, the SV40 poly A signal, the barcode, the two restriction endonuclease sites, the variant capsid sequences, the 3' region of the capsid protein, the polyA sequence for the capsid expression construct and the 3' ITR. In further embodiments, ILLUMINA® sequencing is performed across the barcode and the variant capsid sequences. In further embodiments, digestion with a restriction enzyme is carried out. In further embodiments, a PCR amplification step where the reporter, localization signal, promoter(s), and the 5' end of the capsid gene are prepared is performed. Alternatively, the fragment comprising the reporter, localization signal, promoter(s), and 5' end of the capsid gene may be pre-assembled in a donor plasmid, digested with BsaI, and gel purified. In further embodiments, a golden gate cloning step is performed to create the final construct.

[00222] In some embodiments, each inserted peptide may be encoded by multiple nucleic acid molecules, each having a different sequence (due to codon degeneracy). Each nucleic acid sequence is linked to a unique bar code such that performance (*e.g.* enrichment) of an inserted peptide can be verified when two or more variants are identified having the same inserted peptide sequence, but wherein the inserted peptides are encoded by different nucleic acid sequences.

[00223] In some embodiments, the barcode is linked to the reporter gene, the polyA sequence and the 5' ITR through standard cloning techniques. In further embodiments, the variant sequences encoding the peptide are inserted into the capsid gene through standard techniques, and then specific promoter(s) are added, and the 5' end of the capsid gene is added. ILLUMINA® sequencing (or any other highly reliable sequencing technique) is then performed in two separate reactions where the barcode and the inserted nucleotide sequences are sequenced. Finally, OXFORD NANOPORE® sequencing (or any other long read sequencing technique, for example PACBIO® SMRT sequencing) is performed such that the long-read length sequence comprises both the barcode and inserted nucleotide sequences.

[00224] In some embodiments, a 'look up' table is created linking each barcode to each nucleotide sequence that has been inserted into the capsid gene.

[00225] A library of the disclosure may comprise 10^2 , 10^3 , 10^4 , 10^5 , 10^6 , 10^7 , or 10^8 or more unique AAV variants. In some embodiments, a library may comprise 10^2 - 10^3 ,
5 10^3 - 10^4 , 10^4 - 10^5 , 10^5 - 10^6 , 10^6 - 10^7 , or 10^7 - 10^8 unique AAV variants.

[00226] Any of the foregoing libraries of AAV variants may be used in the methods disclosed herein.

Methods of Identifying AAV Capsid Variants

[00227] The present disclosure provides methods and compositions to develop AAV
10 capsids with a desired characteristic compared to a natural AAV serotype. These capsids are useful, for example, for the delivery of genome engineering molecules and gene therapy molecules to a target cell, cell line, or tissue (*e.g.*, *in vitro* or *in vivo*) for the treatment of a subject in need thereof. In some embodiments, the capsids are used to deliver a payload to a desired tissue, cell or organelle.

15 [00228] In another aspect, disclosed herein are methods for directed evolution of AAV capsid proteins and identification of an AAV capsid variant with a desired characteristic compared to a natural AAV serotype.

[00229] In some embodiments, the method of identifying an AAV capsid variant with a desired characteristic compared to a natural AAV serotype comprises: (i) contacting
20 a cell, cell line, or tissue *in vitro* or *in vivo* with any one of the libraries of AAV variants disclosed herein, (ii) allowing the AAV variants in said library to transduce the cell, cell line, or tissue; (iii) recovering from the cell, cell line, or tissue the AAV variant; and (iv) identifying the AAV capsid variant with the desired characteristic.

[00230] In some embodiments, the method of identifying an AAV capsid variant with
25 a desired characteristic compared to a natural AAV serotype, comprises: (i) inserting a plurality of nucleic acids encoding peptides, into a population of nucleic acids encoding a hypervariable and/or surface-exposed loop of an AAV capsid protein to create a library of nucleic acids encoding AAV variant capsid proteins; (ii) linking each nucleic acid encoding an AAV variant capsid protein in said library to one or more of: (a) a
30 nucleic acid comprising a barcode, (b) a nucleic acid encoding a reporter protein, and (c) a nucleic acid encoding a localization signal, to form a payload construct; (iii) manufacturing a library of AAV variants in producer cells by providing adenovirus helper and AAV rep functions *in trans*; (iv) purifying the library of AAV variants; (v) contacting a cell, cell line, or tissue *in vitro* or *in vivo* with the library of AAV variants;

(vi) recovering the AAV variants from the target cell, cell line, or tissue; and (vii) identifying the AAV capsid variant with the desired characteristic.

[00231] In some embodiments, the method of identifying an AAV capsid variant with a desired characteristic compared to a natural AAV serotype, comprises: (i) inserting a plurality of nucleic acids encoding peptides, into a population of nucleic acids encoding a hypervariable and/or surface-exposed loop of an AAV capsid protein to create a library of nucleic acids encoding AAV variant capsid proteins; (ii) linking each nucleic acid encoding an AAV variant capsid protein in said library to two or more of: (a) a nucleic acid comprising a barcode, (b) a nucleic acid encoding a reporter protein, and (c) a nucleic acid encoding a localization signal, to form a payload construct; (iii) manufacturing a library of AAV variants in producer cells by providing adenovirus helper and AAV rep functions in trans; (iv) purifying the library of AAV variants; (v) contacting a cell, cell line, or tissue in vitro or in vivo with the library of AAV variants; (vi) recovering the AAV variants from the target cell, cell line, or tissue; and (vii) identifying the AAV capsid variant with the desired characteristic.

[00232] In some embodiments, the method of identifying an AAV capsid variant with a desired characteristic compared to a natural AAV serotype, comprises: (i) inserting a plurality of nucleic acids encoding peptides, into a population of nucleic acids encoding a hypervariable and/or surface-exposed loop of an AAV capsid protein to create a library of nucleic acids encoding AAV variant capsid proteins; (ii) linking each nucleic acid encoding an AAV variant capsid protein in said library to (a) a nucleic acid comprising a barcode, (b) a nucleic acid encoding a reporter protein, and (c) a nucleic acid encoding a localization signal, to form a payload construct; (iii) manufacturing a library of AAV variants in producer cells by providing adenovirus helper and AAV rep functions in trans; (iv) purifying the library of AAV variants; (v) contacting a cell, cell line, or tissue in vitro or in vivo with the library of AAV variants; (vi) recovering the AAV variants from the target cell, cell line, or tissue; and (vii) identifying the AAV capsid variant with the desired characteristic.

[00233] In some embodiments, the steps for directed evolution of AAV capsid proteins to identify AAV capsid variants with a desired characteristic compared to a natural AAV serotype comprise (i) insertion of peptides into hypervariable and/or surface-exposed loops in capsid proteins from one or more AAV serotypes creating libraries of modified variant capsids for each AAV serotype; (ii) packaging of the variant AAVs in producer cells wherein adenovirus helper and AAV *rep* functions are supplied in trans;

(iii) purification of viral capsid library pools; (iv) administration of the pools *in vitro* or *in vivo*; (v) recovery of AAV variants from target tissues or cell lines; (vi) next-generation sequencing to determine the identity of the engineered variant capsid sequences; (vii) repeated rounds of *in vitro* or *in vivo* selection where variants are isolated from a target tissue or cell line; and (viii) full evaluation of enriched variants.

[00234] In some embodiments, the desired characteristic is enhanced cell or tissue tropism as compared to the natural AAV serotype. These methods may also be adapted for selecting AAV capsid variants that evade a pre-existing host antibody response and/or the development of AAV variants that will not provoke a host response.

[00235] In some embodiments, capsid proteins, for example from AAV1, AAV2, AAV3B, AAV5, AAV6, AAV8 and AAV9 are chosen for starting points. In some embodiments, capsid proteins from less well characterized AAV serotypes are chosen, including but not limited to AAV3, AAV4, AAV7, AAV11, AAVrh10, AAVrh39, and AAVrh74. In some embodiments, a library of AAV variants comprises AAV variant capsid proteins derived from a single AAV serotype. In some embodiments, a library of AAV variants comprises AAV variant capsid proteins derived from 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, or more AAV serotypes. In some embodiments, the AAV variant capsid proteins derived from 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, or more AAV serotypes are combined once individual serotype libraries are developed. In some embodiments, combinatorial libraries are generated by modifying nucleic acids encoding AAV capsid proteins from 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, or more serotypes in the same pool.

[00236] In some embodiments, directed evolution comprises mutating the AAV capsid (*e.g.*, insertions, deletions and/or substitutions). In some embodiments, the mutations (*e.g.*, insertions, deletions and/or substitutions) are introduced into a DNA sequence encoding an exposed loop in the capsid protein. In some embodiments, directed evolution comprises insertion of peptides into exposed loops (*e.g.* hypervariable regions) in the AAV capsid.

[00237] In some embodiments, the libraries are packaged in HEK293 cells where the helper functions (*e.g.* E2A, E4, VA, E1A and E1B) are supplied in *trans*. In some embodiments, the AAV rep function comprises rep78, rep 68, rep 52, and rep40 genes. In some embodiments, the rep genes are supplied in *trans*. In some embodiments, the start codon of the rep78 and/or the rep68 gene is altered from ACG to ATG to increase replication of the capsid library construct containing inverted terminal repeats (ITRs),

thereby improving AAV library manufacturing yield. In some embodiments, the *cap* genes are supplied as payload to the manufactured AAVs. In some embodiments, the capsid gene is controlled by the p40 promoter such that it is only expressed during manufacturing in HEK293 cells in the presence of helper virus functions.

5 [00238] In some embodiments, the libraries are selected in cells. In some embodiments, the individual serotype libraries are combined to generate a single library comprising 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, or more serotypes where each AAV variant also comprises the peptide inserted into the AAV variant capsid. In some
10 embodiments, single serotype libraries are used wherein each AAV in that serotype library comprises a peptide inserted into the AAV variant capsid. In some embodiments, the cells are treated with the libraries and then monitored for the expression of the reporter gene in the cytoplasm of the cell or in the organelle of interest. In some embodiments, the organelle of interest is the nucleus. In some embodiments, the organelles comprising the AAV payload or genome as evidenced by the expression
15 of the reporter gene are isolated from the cells. In some embodiments, the organelle is the nucleus. In some embodiments, the nucleic acid is extracted from the organelle (*e.g.* nucleus). In some embodiments, the nucleic acid extracted is RNA, while in some embodiments, the nucleic acid extracted is DNA. In some embodiments, the extracted RNA is subject to reverse transcription to generate cDNA which is then amplified using
20 primers specific to the barcoded region and sequenced. In some embodiments, the extracted DNA is amplified and sequenced using the primers specific for the introduced variable sequence. In some embodiments, enrichment of specific AAV variants is observed following selection in cells.

[00239] In some embodiments, the cell used includes, but is not limited to, a cell from
25 the CNS, heart, lung, trachea, esophagus, muscle, bone, cartilage, stomach, pancreas, intestine, liver, bladder, kidney, ureter, urethra, uterus, fallopian tube, ovary, testes, prostate, eye, blood, lymph, or oral mucosa.

[00240] In some embodiments, the cell includes, but is not limited to, neurons, glial
30 cells, astrocytes, oligodendroglia, microglia, Schwann cells, ependymal cells, hepatocytes, stellate fat storing cells, Kupffer cells, liver endothelial cells, epithelial cells, cardiomyocytes, smooth muscle cells, T-cells, B cells, hematopoietic stem cells, and embryonic stem cells.

[00241] In some embodiments, the libraries are selected in animals. In some embodiments, the individual serotype libraries are combined to generate a single library

comprising 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, or more serotypes where each AAV also comprises the peptide inserted into the AAV variant capsid. In some embodiments, single serotype libraries are used wherein each AAV in that serotype library comprises a peptide inserted into the AAV variant capsid. In some
5 embodiments, the animals are treated with the libraries *via* intravenous, intracranial, or intrathecal injection, or by injection by some other route (*e.g.* nasal, hepatic, intracerebroventricular, intracisternal, intravitreal, intracochlear, etc.). Following a sufficient time for the AAV to traffic to the desired tissue or organ (for example, 7, 10, 14, 18, 21, 24, 28, 30 days or more), the animal is sacrificed, and the tissue/organ of
10 interest is harvested. In some embodiments, the cells in the tissues are monitored for the expression of the reporter gene in the cytoplasm of the cell or in the organelle of interest. In some embodiments, the organelle of interest is the nucleus. In some embodiments, the organelles comprising the AAV payload as evidenced by the expression of the reporter gene are isolated from the tissue. In some embodiments, the
15 organelle is the nucleus. In some embodiments, the nucleic acid is extracted from the organelle (*e.g.* nucleus). In some embodiments, the nucleic acid extracted is RNA, while in some embodiments, the nucleic acid extracted is DNA. In some embodiments, the extracted RNA is subject to reverse transcription to generate cDNA which is then amplified using primers specific to the barcoded region and sequenced. In some
20 embodiments, the extracted DNA is amplified and sequenced using the primers specific for the introduced variable sequence. In some embodiments, enrichment of specific AAV variants is observed following selection *in vivo*.

[00242] In either of these embodiments, the selection of AAV variants through cells or *in vivo* may be performed in 1, 2, 3, 4, 5 or more rounds, in each case pooling the
25 AAV variants obtained from the previous round or synthesizing a subset of variants that were enriched and re-selecting in the cells or *in vivo*.

[00243] In some embodiments, following the desired number of selection rounds, the variants are analyzed. In some embodiments, the individual variants are used to deliver a transgene to a desired cell or organ *in vivo*. After analysis of the delivery capability
30 of the variants, the best candidates are selected for future use.

[00244] In some embodiments, each member of the library comprises a nucleic acid comprising two barcode sequences. In some embodiments, each member of the library comprises a first nucleic acid comprising a first barcode and a second nucleic acid comprising a second barcode. In some embodiments, the first nucleic acid comprising

the first barcode and the second nucleic acid comprising the second barcode are different. In some embodiments, the first nucleic acid comprising the first barcode comprises a sequence selected from any one of sequences SEQ ID NO: 111-154 or is selected from any one of sequences SEQ ID NO: 111-154. In some embodiments of the method, library of AAV variants, AAV variant, or nucleic acid disclosed herein, the second nucleic acid comprising the second barcode comprises a sequence selected from any one of sequences SEQ ID NO: 155-198 or is selected from any one of sequences SEQ ID NO: 155-198. In some embodiments, the first nucleic acid comprising the first barcode comprises a sequence selected from any one of sequences SEQ ID NO: 111-154 or is selected from any one of sequences SEQ ID NO: 111-154 and the second nucleic acid comprising the second barcode comprises a sequence selected from any one of sequences SEQ ID NO: 155-198 or is selected from any one of sequences SEQ ID NO: 155-198. In some embodiments, each of the first nucleic acid comprising the first barcode and the second nucleic acid comprising the second barcode is independently operatively linked to a promoter. In some embodiments, said promoter is different for each of the first barcode and the second barcode. In some embodiments, each of the first nucleic acid comprising the first barcode and the second nucleic acid are independently controlled under a different promoter. In some embodiments, the promoter operatively linked to the first nucleic acid comprising the first barcode and the promoter operatively linked to the second nucleic acid comprising the second barcode is each independently an RNA Pol II promoter (e.g., human synapsin promoter (hSyn1), transthyretin promoter (TTR), cytokeratin 18, cytokeratin 19, unc-45 myosin chaperon B (unc45b) promoter, cardiac troponin T (cTnT) promoter, glial fibrillary acidic protein (GFAP) promoter, myelin basic protein (MBP) promoter, or methyl CpG-binding protein 2 (MeCP2) promoter). In some embodiments, the promoter operatively linked to the first nucleic acid comprising the first barcode and the promoter operatively linked to the second nucleic acid comprising the second barcode is each independently an RNA Pol III promoter (e.g., U6 promoter, H1 promoter or 7SK promoter). In some embodiments, the promoter operatively linked to the first nucleic acid comprising the first barcode is an RNA Pol II promoter and the promoter operatively linked to the second nucleic acid comprising the second barcode is an RNA Pol III promoter. In some embodiments, the nucleic acid comprising the barcode further comprises a reporter gene, a nuclear localization signal and a polyadenylation signal.

AAV Variants

[00245] Described herein are AAV variants used to develop AAV capsids with a desired characteristic compared to a natural AAV serotype. In some embodiments, the desired characteristic is enhanced cell or tissue tropism as compared to the natural AAV serotype. In some embodiments, the desired characteristic is the evasion of a pre-existing host antibody response. In some embodiments, the desired characteristic is reduced immunogenicity so as to not provoke a host response.

[00246] In some embodiments, an AAV variant of the disclosure comprises: a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein; and one or more of: b) one or more silent mutations in the nucleic acid sequence flanking the peptide insertion site in the AAV variant capsid protein of a); c) a nucleic acid encoding a localization signal; d) a nucleic acid comprising a barcode; and e) a nucleic acid encoding a reporter protein.

[00247] In some embodiments, an AAV variant of the disclosure comprises: a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein; and two or more of: b) one or more silent mutations in the nucleic acid sequence flanking the peptide insertion site in the AAV variant capsid protein of a); c) a nucleic acid encoding a localization signal; d) a nucleic acid comprising a barcode; and e) a nucleic acid encoding a reporter protein.

[00248] In some embodiments, an AAV variant of the disclosure comprises: a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein; and three or more of: b) one or more silent mutations in the nucleic acid sequence flanking the peptide insertion site in the AAV variant capsid protein of a); c) a nucleic acid encoding a localization signal; d) a nucleic acid comprising a barcode; and e) a nucleic acid encoding a reporter protein.

[00249] In some embodiments, an AAV variant of the disclosure comprises: a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein; b) one or more silent mutations in the nucleic acid sequence flanking the peptide insertion site in the AAV variant capsid protein of a); c) a nucleic acid encoding a

localization signal; d) a nucleic acid comprising a barcode; and e) a nucleic acid encoding a reporter protein.

[00250] In some embodiments, an AAV variant of the disclosure comprises: a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein; and one or more of: b) one or more silent mutations in the nucleic acid encoding the AAV variant capsid protein of a) in the nucleic acid sequence flanking the peptide insertion site; c) a nucleic acid encoding a localization signal; d) a nucleic acid comprising a barcode; and e) a nucleic acid encoding a reporter protein.

10 [00251] In some embodiments, an AAV variant of the disclosure comprises: a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein; and two or more of: b) one or more silent mutations in the nucleic acid encoding the AAV variant capsid protein of a) in the nucleic acid sequence flanking the peptide insertion site; c) a nucleic acid encoding a localization signal; d) a nucleic acid comprising a barcode; and e) a nucleic acid encoding a reporter protein.

[00252] In some embodiments, an AAV variant of the disclosure comprises: a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein; and three or more of: b) one or more silent mutations in the nucleic acid encoding the AAV variant capsid protein of a) in the nucleic acid sequence flanking the peptide insertion site; c) a nucleic acid encoding a localization signal; d) a nucleic acid comprising a barcode; and e) a nucleic acid encoding a reporter protein.

25 [00253] In some embodiments, an AAV variant of the disclosure comprises: a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein; b) one or more silent mutations in the nucleic acid encoding the AAV variant capsid protein of a) in the nucleic acid sequence flanking the peptide insertion site; c) a nucleic acid encoding a localization signal; d) a nucleic acid comprising a barcode; and e) a nucleic acid encoding a reporter protein.

30 [00254] In any of the above embodiments, the nucleic acid encoding an AAV variant capsid protein, the nucleic acid encoding a localization signal, the nucleic acid comprising a barcode, and/or the nucleic acid encoding a reporter protein, are present on separate nucleic acid molecules. In some embodiments, the nucleic acid encoding

an AAV variant capsid protein, the nucleic acid encoding a localization signal, the nucleic acid comprising a barcode, and/or the nucleic acid encoding a reporter protein, are present on a single nucleic acid molecule. In some embodiments, the nucleic acid encoding an AAV variant capsid protein, and the nucleic acid encoding a localization signal, the nucleic acid comprising a barcode, and/or the nucleic acid encoding a reporter protein, are linked to each other in any order. In some embodiments, each member of the library comprises a 5'ITR sequence, the nucleic acid comprising a barcode, the nucleic acid encoding a reporter protein, the nucleic acid encoding an AAV variant capsid protein, and a 3'ITR sequence, in that order.

10 [00255] The various components of the AAV variants (e.g., AAV variant capsid protein, inserted peptides, silent mutations flanking the peptide insertion site, localization signal, barcode, reporter protein, promoter(s) or related nucleic acid sequences, etc.) are disclosed elsewhere herein.

[00256] In another aspect, the present disclosure provides a nucleic acid molecule encoding an AAV variant disclosed herein. In some embodiments, the nucleic acid molecule comprises a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein; and one or more of: b) a nucleic acid sequence encoding a variant capsid protein comprising one or more silent mutations in the nucleotide sequence flanking the peptide insertion site in the hypervariable and/or surface-exposed loop of the variant capsid protein; c) a nucleic acid sequence encoding a localization signal; d) a nucleic acid sequence comprising a barcode; and e) a nucleic acid sequence encoding a reporter protein.

[00257] In some embodiments, the present disclosure provides a nucleic acid molecule comprising two or more of: a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein; and two or more of: b) a nucleic acid sequence encoding a variant capsid protein comprising one or more silent mutations in the nucleotide sequence flanking the peptide insertion site in the hypervariable and/or surface-exposed loop of the variant capsid protein; c) a nucleic acid sequence encoding a localization signal; d) a nucleic acid sequence comprising a barcode; and e) a nucleic acid sequence encoding a reporter protein.

[00258] In some embodiments, the present disclosure provides a nucleic acid molecule comprising a) a nucleic acid sequence encoding an AAV variant capsid protein

comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein; and three or more of: b) a nucleic acid sequence encoding a variant capsid protein comprising one or more silent mutations in the nucleotide sequence flanking the peptide insertion site in the hypervariable and/or surface-exposed loop of the variant capsid protein; c) a nucleic acid sequence encoding a localization signal; d) a nucleic acid sequence comprising a barcode; and e) a nucleic acid sequence encoding a reporter protein.

[00259] In some embodiments, the present disclosure provides a nucleic acid molecule comprising a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein; b) a nucleic acid sequence encoding a variant capsid protein comprising one or more silent mutations in the nucleotide sequence flanking the peptide insertion site in the hypervariable and/or surface-exposed loop of the variant capsid protein; c) a nucleic acid sequence encoding a localization signal; d) a nucleic acid sequence comprising a barcode; and e) a nucleic acid sequence encoding a reporter protein.

[00260] In some embodiments, the barcode nucleic acid sequence comprises more than one barcode sequences. In some embodiments, the barcode nucleic acid sequence comprises two or more barcode sequences. In some embodiments, the barcode nucleic acid sequence comprises a first nucleic acid comprising a first barcode and a second nucleic acid comprising a second barcode. In some embodiments, the first nucleic acid comprising the first barcode and the second nucleic acid comprising the second barcode are different. In some embodiments, the first nucleic acid comprising the first barcode sequence comprises a sequence selected from any one of sequences SEQ ID NO: 111-154. In some embodiments, the first barcode sequence is selected from any one of sequences SEQ ID NO: 111-154. In some embodiments, the second nucleic acid comprising the second barcode sequence comprises a sequence selected from any one of sequences SEQ ID NO: 155-198. In some embodiments, the second nucleic acid comprising the second barcode sequence is selected from any one of sequences SEQ ID NO: 155-198. In some embodiments, each of the first nucleic acid comprising the first barcode and the second nucleic acid comprising the second barcode is independently operatively linked to a promoter. In some embodiments, the promoter operatively linked to the first nucleic acid comprising the first barcode and the promoter operatively linked to the second nucleic acid comprising the second barcode is each

independently an RNA Pol II promoter. In some embodiments, the promoter operatively linked to the first nucleic acid comprising the first barcode and the promoter operatively linked to the second nucleic acid comprising the second barcode is each independently an RNA Pol III promoter (e.g., a promoter selected from the group of U6 promoter, H1 promoter and 7SK promoter). In some embodiments, the promoter operatively linked to the first nucleic acid comprising the first barcode is operatively linked to an RNA Pol II promoter and the promoter operatively linked to the second nucleic acid comprising the second barcode is an RNA Pol III promoter (e.g., a promoter selected from the group of human synapsin promoter (hSyn1), transthyretin promoter (TTR), cytokeratin 18, cytokeratin 19, unc-45 myosin chaperon B (unc45b) promoter, cardiac troponin T (cTnT) promoter, glial fibrillary acidic protein (GFAP) promoter, myelin basic protein (MBP) promoter, and methyl CpG-binding protein 2 (Mecp2) promoter.

[00261] In some embodiments, the AAV variant is selected from any one the following: (i) the AAV serotype is AAV1 and the peptide is inserted at amino acid position 590 of the capsid protein, (ii) the AAV serotype is AAV6 and the peptide is inserted at amino acid position 454 or 590 of the capsid protein, (iii) the AAV serotype is AAV2 and the peptide is inserted at amino acid position 588 of the capsid protein, (iv) the AAV serotype is AAV3B and the peptide is inserted at amino acid position 589 of the capsid protein, (v) the AAV serotype is AAV5 and the peptide is inserted at amino acid position 578 of the capsid protein, (vi) the AAV serotype is AAV8 and the peptide is inserted at amino acid position 591 of the capsid protein, or (vii) the AAV serotype is AAV9 and the peptide is inserted at amino acid position 266, 455, or 589 of the capsid protein, wherein the positions correspond to the numbering of VP1 in the AAV serotype.

[00262] In some embodiments of the AAV variants disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO. 1-32 is inserted at amino acid position 590 of the capsid protein of an AAV1 serotype. In some embodiments of the AAV variants disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO. 68-110 is inserted at amino acid position 590 of the capsid protein of an AAV1 serotype. In some embodiments of the AAV variants disclosed herein, the peptide inserted at position 590 of the capsid protein of an AAV1 serotype comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 68 to SEQ ID NO: 75. In some embodiments of the AAV variants

disclosed herein, the peptide inserted at position 590 of the capsid protein of an AAV1 serotype comprises the amino acid sequence SEQ ID NO: 71. In some embodiments of the AAV variants disclosed herein, the peptide inserted at position 590 of the capsid protein of an AAV1 serotype comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 1, SEQ ID NO: 2 and SEQ ID NO: 3.

5 [00263] In some embodiments of the AAV variants disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO. 1-32 is inserted at amino acid position 454 of the capsid protein of an AAV6 serotype. In some embodiments of the AAV variants disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO. 68-110 is inserted at amino acid position 454 of the capsid protein of an AAV6 serotype. In some embodiments of the AAV variants disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO. 1-32 is inserted at amino acid position 590 of the capsid protein of an AAV6 serotype. In some embodiments of the AAV variants disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO. 68-110 is inserted at amino acid position 590 of the capsid protein of an AAV6 serotype. In some embodiments of the AAV variants disclosed here, the peptide inserted at position 454 of the capsid protein of an AAV6 serotype comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 19 to SEQ ID NO: 27. In some

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[00264] In some embodiments of the AAV variants disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO. 1-32 is inserted at amino acid position 588 of the capsid protein of an AAV2 serotype. In some embodiments of the AAV variants disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO. 68-110 is inserted at amino acid position 588 of the capsid protein of an AAV2 serotype. In some embodiments of the AAV variants disclosed here, the peptide inserted at position 588 of the capsid protein of an AAV2 serotype comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 90 to SEQ ID NO: 110. In some embodiments of the AAV variants disclosed here, the peptide inserted at position 588 of the capsid protein of an AAV2 serotype comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 95, SEQ ID NO: 94, SEQ ID NO: 96, SEQ ID NO: 101, SEQ ID

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NO: 103, SEQ ID NO: 106, SEQ ID NO: 91 and SEQ ID NO: 102. In some embodiments of the AAV variants disclosed here, the peptide inserted at position 588 of the capsid protein of an AAV2 serotype comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 4-7.

- 5 [00265] In some embodiments of the AAV variants disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO. 1-32 is inserted at amino acid position 589 of the capsid protein of an AAV3B serotype. In some embodiments of the AAV variants disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO. 68-110 is inserted at amino acid position 589
- 10 of the capsid protein of an AAV3B serotype. In some embodiments of the AAV variants disclosed here, the peptide inserted at position 589 of the capsid protein of an AAV3B serotype comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 76- 85. In some embodiments of the AAV variants disclosed here, the peptide inserted at position 589 of the capsid protein of an AAV3B serotype
- 15 comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 78, SEQ ID NO: 80, SEQ ID NO: 77, SEQ ID NO: 79, SEQ ID NO: 76 and SEQ ID NO: 83. In some embodiments of the AAV variants disclosed here, the peptide inserted at position 589 of the capsid protein of an AAV3B serotype comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO:
- 20 8 to SEQ ID NO: 11.

- [00266] In some embodiments of the AAV variants disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO. 1-32 is inserted at amino acid position 578 of the capsid protein of an AAV5 serotype. In some embodiments of the AAV variants disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO. 68-110 is inserted at amino acid position 578
- 25 of the capsid protein of an AAV5 serotype. In some embodiments of the AAV variants disclosed here, the peptide inserted at position 578 of the capsid protein of an AAV5 serotype comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 28 to SEQ ID NO: 32.

- 30 [00267] In some embodiments of the AAV variants disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO. 1-32 is inserted at amino acid position 591 of the capsid protein of an AAV8 serotype. In some embodiments of the AAV variants disclosed herein, a peptide comprising the amino

acid sequence of any one of SEQ ID NO. 68-110 is inserted at amino acid position 591 of the capsid protein of an AAV8 serotype.

[00268] In some embodiments of the AAV variants disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO. 1-32 is inserted at
5 amino acid position 266 of the capsid protein of an AAV9 serotype. In some embodiments of the AAV variants disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO. 68-110 is inserted at amino acid position 266 of the capsid protein of an AAV9 serotype. In some embodiments of the AAV variants disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID
10 NO. 1-32 is inserted at amino acid position 455 of the capsid protein of an AAV9 serotype. In some embodiments of the AAV variants disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO. 68-110 is inserted at amino acid position 455 of the capsid protein of an AAV9 serotype. In some embodiments of the AAV variants disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO. 1-32 is inserted at amino acid position 589 of
15 the capsid protein of an AAV9 serotype. In some embodiments of the AAV variants disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO. 68-110 is inserted at amino acid position 589 of the capsid protein of an AAV9 serotype. In some embodiments of the AAV variants disclosed here, the peptide inserted at position 266 of the capsid protein of an AAV9 serotype comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 12 to SEQ ID NO: 18. In some embodiments of the AAV variants disclosed here, the peptide inserted at position 266 of the capsid protein of an AAV9 serotype comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 86 to SEQ
20 ID NO: 89. In some embodiments of the AAV variants disclosed here, the peptide inserted at position 266 of the capsid protein of an AAV9 serotype comprises an amino acid sequence of SEQ ID NO: 89. In some embodiments of the AAV variants disclosed here, the peptide inserted at position 455 of the capsid protein of an AAV9 serotype comprises an amino acid sequence selected from the group consisting of any one of
25 SEQ ID NO: 12 to SEQ ID NO: 18. In some embodiments of the AAV variants disclosed here, the peptide inserted at position 455 of the capsid protein of an AAV9 serotype comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 86 to SEQ ID NO: 89. In some embodiments of the AAV variants disclosed here, the peptide inserted at position 455 of the capsid protein of an AAV9
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serotype comprises an amino acid sequence of SEQ ID NO: 89. In some embodiments of the AAV variants disclosed here, the peptide inserted at position 455 of the capsid protein of an AAV9 serotype comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 12 to SEQ ID NO: 18. In some
5 embodiments of the AAV variants disclosed here, the peptide inserted at position 589 of the capsid protein of an AAV9 serotype comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 86 to SEQ ID NO: 89. In some
10 embodiments of the AAV variants disclosed here, the peptide inserted at position 589 of the capsid protein of an AAV9 serotype comprises an amino acid sequence of SEQ ID NO: 89.

[00269] In some embodiments, an AAV3B variant comprises a peptide comprising any one of the sequences selected from the group consisting of EQFRNLA (SEQ ID NO: 78), TDFRSPQ (SEQ ID NO: 80), TGAFSST (SEQ ID NO: 77), FNSPVIQ (SEQ ID NO: 79), PYASITG (SEQ ID NO: 76) and YGSRSD (SEQ ID NO: 83). In some
15 embodiments, an AAV3B variant comprises a peptide sequence selected from the group consisting of sequences EQFRNLA (SEQ ID NO: 78), TDFRSPQ (SEQ ID NO: 80), TGAFSST (SEQ ID NO: 77), FNSPVIQ (SEQ ID NO: 79), PYASITG (SEQ ID NO: 76) and YGSRSD (SEQ ID NO: 83).

[00270] In some embodiments, an AAV1 variant comprises a peptide comprising the
20 sequence SVVVSSDSSKRPNL (SEQ ID NO: 71). In some embodiments, an AAV1 variant comprises the peptide sequence SVVVSSDSSKRPNL (SEQ ID NO: 71).

[00271] In some embodiments, an AAV2 variant comprises a peptide comprising any one of the sequences selected from the group consisting of RPLTAND (SEQ ID NO: 95), PRDTFNG (SEQ ID NO: 94), PLRMVNE (SEQ ID NO: 96), ENFSKVA (SEQ ID NO: 101), LGNGKMTVQP (SEQ ID NO: 103), GRNTVGLSSA (SEQ ID NO: 106), TSNSRTE (SEQ ID NO: 91) and RDALSGLRPE (SEQ ID NO: 102). In some
25 embodiments, an AAV2 variant comprises a peptide sequence selected from the group consisting of RPLTAND (SEQ ID NO: 95), PRDTFNG (SEQ ID NO: 94), PLRMVNE (SEQ ID NO: 96), ENFSKVA (SEQ ID NO: 101), LGNGKMTVQP (SEQ ID NO: 103), GRNTVGLSSA (SEQ ID NO: 106), TSNSRTE (SEQ ID NO: 91) and RDALSGLRPE (SEQ ID NO: 102). In some
30 embodiments, an AAV2 variant comprises a peptide comprising any one of the sequences selected from the group consisting of RPLTAND (SEQ ID NO: 95), PRDTFNG (SEQ ID NO: 94), and PLRMVNE (SEQ ID NO: 96). In some embodiments, an AAV2 variant comprises a

peptide comprising any one of the sequences selected from the group consisting of ENFSKVA (SEQ ID NO: 101), LGNGKMTVQP (SEQ ID NO: 103), GRNTVGLSSA (SEQ ID NO: 106), TSNSRTE (SEQ ID NO: 91) and RDALSGLRPE (SEQ ID NO: 102). In some embodiments, an AAV2 variant comprises a peptide sequence selected from the group consisting of RPLTAND (SEQ ID NO: 95), PRDTFNG (SEQ ID NO: 94), and PLRMVNE (SEQ ID NO: 96). In some embodiments, an AAV2 variant comprises a peptide sequence selected from the group consisting of ENFSKVA (SEQ ID NO: 101), LGNGKMTVQP (SEQ ID NO: 103), GRNTVGLSSA (SEQ ID NO: 106), TSNSRTE (SEQ ID NO: 91) and RDALSGLRPE (SEQ ID NO: 102).

5 [00272] In some embodiments, an AAV9 variant comprises a peptide comprising the sequence NIPKAYG (SEQ ID NO: 89). In some embodiments, an AAV9 variant comprises the peptide sequence NIPKAYG (SEQ ID NO: 89).

[00273] In some embodiments, an AAV3B variant comprises a peptide comprising the amino acid sequence EQFRNLA (SEQ ID NO: 78). In some embodiments, an AAV3B variant comprises a peptide comprising the amino acid sequence TDFRSPQ (SEQ ID NO: 80). In some embodiments, an AAV3B variant comprises a peptide comprising the amino acid sequence TGAFSST (SEQ ID NO: 77). In some embodiments, an AAV3B variant comprises a peptide comprising the amino acid sequence FNSPVIQ (SEQ ID NO: 79). In some embodiments, an AAV3B variant comprises a peptide comprising the amino acid sequence PYASITG (SEQ ID NO: 76). In some embodiments, an AAV3B variant comprises a peptide comprising an amino acid sequence YGSRSD (SEQ ID NO: 83).

15 [00274] In some embodiments, an AAV2 variant comprises a peptide comprising the amino acid sequence RPLTAND (SEQ ID NO: 95). In some embodiments, an AAV2 variant comprises a peptide comprising the amino acid sequence PRDTFNG (SEQ ID NO: 94). In some embodiments, the peptide comprises amino acid sequence PLRMVNE (SEQ ID NO: 96). In some embodiments, an AAV2 variant comprises a peptide comprising the amino acid sequence ENFSKVA (SEQ ID NO: 101). In some embodiments, an AAV2 variant comprises a peptide comprising the amino acid sequence LGNGKMTVQP (SEQ ID NO: 103). In some embodiments, an AAV2 variant comprises a peptide comprising the amino acid sequence GRNTVGLSSA (SEQ ID NO: 106). In some embodiments, an AAV2 variant comprises a peptide comprising the amino acid sequence TSNSRTE (SEQ ID NO: 91). In some embodiments, an AAV2

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variant comprises a peptide comprising an amino acid sequence RDALSGLRPE (SEQ ID NO: 102).

[00275] In some embodiments, an AAV1 variant comprises a peptide comprising an amino acid sequence selected from the group consisting of KSPQSKV (SEQ ID NO:1),
5 SDLRSKV (SEQ ID NO:2) and TTTVRKV (SEQ ID NO:3). In some embodiments, an AAV1 variant comprises a peptide selected from the group consisting of KSPQSKV (SEQ ID NO:1), SDLRSKV (SEQ ID NO:2) and TTTVRKV (SEQ ID NO:3).

[00276] In some embodiments, an AAV1 variant comprises a peptide comprising an amino acid sequence selected from the group consisting of AALRDIR (SEQ ID
10 NO:68), PAIKTYS (SEQ ID NO: 69), TGDRISSRTL (SEQ ID NO: 70), SVVVSSDSSKRPRNL (SEQ ID NO: 71), VGARLSA (SEQ ID NO: 72), IEKPNTSTKK (SEQ ID NO: 73), DTVRSKN (SEQ ID NO: 74), and KELNKAR (SEQ ID NO: 75). In some embodiments, an AAV1 variant comprises a peptide selected from the group consisting of AALRDIR (SEQ ID NO:68), PAIKTYS (SEQ
15 ID NO: 69), TGDRISSRTL (SEQ ID NO: 70), SVVVSSDSSKRPRNL (SEQ ID NO: 71), VGARLSA (SEQ ID NO: 72), IEKPNTSTKK (SEQ ID NO: 73), DTVRSKN (SEQ ID NO: 74), and KELNKAR (SEQ ID NO: 75).

[00277] In some embodiments, an AAV2 variant comprises a peptide comprising an amino acid sequence selected from the group consisting of GRSDMAG (SEQ ID NO:
20 4), LLSSERS (SEQ ID NO: 5), EQRPNVS (SEQ ID NO: 6) and TRQISSD (SEQ ID NO: 7). In some embodiments, an AAV2 variant comprises a peptide selected from the group consisting of GRSDMAG (SEQ ID NO: 4), LLSSERS (SEQ ID NO: 5), EQRPNVS (SEQ ID NO: 6) and TRQISSD (SEQ ID NO: 7).

[00278] In some embodiments, an AAV2 variant comprises a peptide comprising an amino acid sequence selected from the group consisting of MTLTRQE (SEQ ID NO:
25 90), TSNSRTE (SEQ ID NO: 91), EVRGGPS (SEQ ID NO: 92), VISDRSS (SEQ ID NO: 93), PRDTFNG (SEQ ID NO: 94), RPLTAND (SEQ ID NO: 95), PLRMVNE (SEQ ID NO: 96), DVGIRPS (SEQ ID NO: 97), KDSTAFG (SEQ ID NO: 98), YPGRNPD (SEQ ID NO: 99), ISDTRIS (SEQ ID NO: 100), ENFSKVA (SEQ ID NO:
30 101), RDALSGLRPE (SEQ ID NO: 102), LGNGKMTVQP (SEQ ID NO: 103), VSNPLNQ (SEQ ID NO: 104), LNERGLG (SEQ ID NO: 105), GRNTVGLSSA (SEQ ID NO: 106), VGHAGNP (SEQ ID NO: 107), SRAGTVP (SEQ ID NO: 108), GLVAKLP (SEQ ID NO: 109), and AESLRTP (SEQ ID NO: 110). In some

embodiments, an AAV2 variant comprises a peptide selected from the group consisting of MTLTRQE (SEQ ID NO: 90), TSNSRTE (SEQ ID NO: 91), EVRGGPS (SEQ ID NO: 92), VISDRSS (SEQ ID NO: 93), PRDTFNG (SEQ ID NO: 94), RPLTAND (SEQ ID NO: 95), PLRMVNE (SEQ ID NO: 96), DVGIRPS (SEQ ID NO: 97), KDSTAFG (SEQ ID NO: 98), YPGRNPD (SEQ ID NO: 99), ISDTRIS (SEQ ID NO: 100), ENFSKVA (SEQ ID NO: 101), RDALSGLRPE (SEQ ID NO: 102), LGNGKMTVQP (SEQ ID NO: 103), VSNPLNQ (SEQ ID NO: 104), LNERGLG (SEQ ID NO: 105), GRNTVGLSSA (SEQ ID NO: 106), VGHAGNP (SEQ ID NO: 107), SRAGTVP (SEQ ID NO: 108), GLVAKLP (SEQ ID NO: 109), and AESLRTP (SEQ ID NO: 110).

10 [00279] In some embodiments, an AAV3B variant comprises a peptide comprising an amino acid sequence selected from the group consisting of QGALAQV (SEQ ID NO: 8), YPSSNTP (SEQ ID NO: 9), MLNPRTE (SEQ ID NO: 10) and QMRTRDE (SEQ ID NO: 11). In some embodiments, an AAV3B variant comprises a peptide selected from the group consisting of QGALAQV (SEQ ID NO: 8), YPSSNTP (SEQ ID NO: 9), MLNPRTE (SEQ ID NO: 10) and QMRTRDE (SEQ ID NO: 11).

[00280] In some embodiments, an AAV3B variant comprises a peptide comprising an amino acid sequence selected from the group consisting of PYASITG (SEQ ID NO: 76), TGAFSST (SEQ ID NO: 77), EQFRNLA (SEQ ID NO: 78), FNSPVIQ (SEQ ID NO: 79), TDFRSPQ (SEQ ID NO: 80), MYSLMKD (SEQ ID NO: 81), LYLSSAS (SEQ ID NO: 82), YGSRSD (SEQ ID NO: 83), LYSHQVS (SEQ ID NO: 84), and ISTHSPP (SEQ ID NO: 85). In some embodiments, an AAV3B variant comprises a peptide selected from the group consisting of PYASITG (SEQ ID NO: 76), TGAFSST (SEQ ID NO: 77), EQFRNLA (SEQ ID NO: 78), FNSPVIQ (SEQ ID NO: 79), TDFRSPQ (SEQ ID NO: 80), MYSLMKD (SEQ ID NO: 81), LYLSSAS (SEQ ID NO: 82), YGSRSD (SEQ ID NO: 83), LYSHQVS (SEQ ID NO: 84), and ISTHSPP (SEQ ID NO: 85).

[00281] In some embodiments, an AAV9 variant comprises a peptide comprising an amino acid sequence selected from the group consisting of MPGRAPI (SEQ ID NO: 12), LGRLTAN (SEQ ID NO: 13), SYSTSRS (SEQ ID NO: 14), TRPSSTN (SEQ ID NO: 15), VPQSSSR (SEQ ID NO: 16), VSRSYPA (SEQ ID NO: 17) and QRARPDT (SEQ ID NO: 18). In some embodiments, an AAV9 variant comprises a peptide selected from the group consisting of MPGRAPI (SEQ ID NO: 12), LGRLTAN (SEQ

ID NO: 13), SYSTSRs (SEQ ID NO: 14), TRPSSTN (SEQ ID NO: 15), VPQSSSR (SEQ ID NO: 16), VRSYPA (SEQ ID NO: 17) and QRARPDT (SEQ ID NO: 18).

[00282] In some embodiments, an AAV9 variant comprises a peptide comprising an amino acid sequence selected from the group consisting of RQPTTIP (SEQ ID NO: 86), RSTSSL (SEQ ID NO: 87), FRLSSPQ (SEQ ID NO: 88), and NIPKAYG (SEQ ID NO: 89). In some embodiments, an AAV9 variant comprises a peptide selected from the group consisting of RQPTTIP (SEQ ID NO: 86), RSTSSL (SEQ ID NO: 87), FRLSSPQ (SEQ ID NO: 88), and NIPKAYG (SEQ ID NO: 89).

[00283] In some embodiments, an AAV6 variant comprises a peptide comprising an amino acid sequence selected from the group consisting of SQLTPHS (SEQ ID NO: 19), LGSHLPS (SEQ ID NO: 20), YTLSSGQ (SEQ ID NO: 21), SSRIPPD (SEQ ID NO: 22), WTETIPR (SEQ ID NO: 23), HGLQGVA (SEQ ID NO: 24), TMRVSDQ (SEQ ID NO: 25), GSSKVVM (SEQ ID NO: 26), and SALDRGV (SEQ ID NO: 27). In some embodiments, an AAV6 variant comprises a peptide selected from the group consisting of SQLTPHS (SEQ ID NO: 19), LGSHLPS (SEQ ID NO: 20), YTLSSGQ (SEQ ID NO: 21), SSRIPPD (SEQ ID NO: 22), WTETIPR (SEQ ID NO: 23), HGLQGVA (SEQ ID NO: 24), TMRVSDQ (SEQ ID NO: 25), GSSKVVM (SEQ ID NO: 26), and SALDRGV (SEQ ID NO: 27).

[00284] In some embodiments, an AAV5 variant comprises a peptide comprising an amino acid sequence selected from the group consisting of KELGTQR (SEQ ID NO: 28), RSSDVQR (SEQ ID NO: 29), PSAPKTF (SEQ ID NO: 30), HTKRSEY (SEQ ID NO: 31), and IKGSNLP (SEQ ID NO: 32). In some embodiments, an AAV5 variant comprises a peptide selected from the group consisting of KELGTQR (SEQ ID NO: 28), RSSDVQR (SEQ ID NO: 29), PSAPKTF (SEQ ID NO: 30), HTKRSEY (SEQ ID NO: 31), and IKGSNLP (SEQ ID NO: 32).

Peptides

[00285] Described herein are inserted peptides identified using the methods of the present disclosure that confer a desired characteristic to an AAV variant compared to a natural AAV serotype. In some embodiments, the desired characteristic is enhanced cell or tissue tropism as compared to the natural AAV serotype. In some embodiments, an inserted peptide of the disclosure allows an AAV variant to evade a pre-existing host antibody response. In some embodiments, an inserted peptide of the disclosure renders

an AAV variant less immunogenic such that it will not provoke a host response. In some embodiments, the inserted peptides are capable of directing an AAV vector to a particular target cell or tissue.

[00286] An inserted peptide can be 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 20, 25, 30, or more amino acids in length or a range between any two of these values. In some embodiments, the peptide is 7 amino acids long. In some embodiments, the peptide is 10 amino acids long. In some embodiments, the peptide is 15 amino acids long.

[00287] In some embodiments, the inserted peptide comprises at least 4 contiguous amino acids of an amino acid sequence set forth in SEQ ID Nos. 1-32. In some embodiments, the peptide comprises at least 5 contiguous amino acids of an amino acid sequence set forth in SEQ ID Nos. 1-32. In some embodiments, the peptide comprises at least 6 contiguous amino acids of an amino acid sequence set forth in SEQ ID Nos. 1-32. In some embodiments, the peptide comprises an amino acid sequence set forth in SEQ ID Nos. 1-32. In some embodiments, the peptide comprises an amino acid sequence with at least about 60%, about 65%, about 70%, about 75%, about 80%, about 85%, about 90%, about 91%, about 92%, about 93%, about 94%, about 95%, about 96%, about 97%, about 98%, about 99% or more sequence identity to an amino acid sequence set forth in SEQ ID Nos. 1-32. In some embodiments, the inserted peptide comprises at least 4 contiguous amino acids of an amino acid sequence set forth in SEQ ID Nos. 68-110. In some embodiments, the peptide comprises at least 5 contiguous amino acids of an amino acid sequence set forth in SEQ ID Nos. 68-110. In some embodiments, the peptide comprises at least 6 contiguous amino acids of an amino acid sequence set forth in SEQ ID Nos. 68-110. In some embodiments, the peptide comprises an amino acid sequence set forth in SEQ ID Nos. 68-110. In some embodiments, the peptide comprises an amino acid sequence with at least about 60%, about 65%, about 70%, about 75%, about 80%, about 85%, about 90%, about 91%, about 92%, about 93%, about 94%, about 95%, about 96%, about 97%, about 98%, about 99% or more sequence identity to an amino acid sequence set forth in SEQ ID Nos. 68-110.

[00288] In some embodiments, the peptide comprises any one of the sequences selected from the group consisting of EQFRNLA (SEQ ID NO: 78), TDFRSPQ (SEQ ID NO: 80), TGAFSST (SEQ ID NO: 77), FNSPVIQ (SEQ ID NO: 79), PYASITG (SEQ ID NO: 76) and YGSRSDV (SEQ ID NO: 83). In some embodiments, the peptide sequence is selected from the group consisting of sequences EQFRNLA (SEQ ID NO:

78), TDFRSPQ (SEQ ID NO: 80), TGAFSST (SEQ ID NO: 77), FNSPVIQ (SEQ ID NO: 79), PYASITG (SEQ ID NO: 76) and YGSRSD (SEQ ID NO: 83). In some embodiments, the peptide comprises sequence SVVVSSDSSKRPNL (SEQ ID NO: 71). In some embodiments, the peptide sequence is SVVVSSDSSKRPNL (SEQ ID NO: 71). In some embodiments, the peptide comprises any one of the sequences selected from the group consisting of RPLTAND (SEQ ID NO: 95), PRDTFNG (SEQ ID NO: 94), PLRMVNE (SEQ ID NO: 96), ENFSKVA (SEQ ID NO: 101), LGNGKMTVQP (SEQ ID NO: 103), GRNTVGLSSA (SEQ ID NO: 106), TSNSRTE (SEQ ID NO: 91) and RDALSGLRPE (SEQ ID NO: 102). In some embodiments, the peptide sequence is selected from the group consisting of sequences RPLTAND (SEQ ID NO: 95), PRDTFNG (SEQ ID NO: 94), PLRMVNE (SEQ ID NO: 96), ENFSKVA (SEQ ID NO: 101), LGNGKMTVQP (SEQ ID NO: 103), GRNTVGLSSA (SEQ ID NO: 106), TSNSRTE (SEQ ID NO: 91) and RDALSGLRPE (SEQ ID NO: 102). In some embodiments, the peptide comprises sequence NIPKAYG (SEQ ID NO: 89). In some embodiments, the peptide sequence is NIPKAYG (SEQ ID NO: 89).

[00289] In some embodiments, the peptide comprises an amino acid sequence selected from the group consisting of EQFRNLA (SEQ ID NO: 78), TDFRSPQ (SEQ ID NO: 80), TGAFSST (SEQ ID NO: 77), FNSPVIQ (SEQ ID NO: 79), PYASITG (SEQ ID NO: 76), YGSRSD (SEQ ID NO: 83), SVVVSSDSSKRPNL (SEQ ID NO: 71), RPLTAND (SEQ ID NO: 95), PRDTFNG (SEQ ID NO: 94) and PLRMVNE (SEQ ID NO: 96). In some embodiments, the peptide sequence is selected from the group consisting of EQFRNLA (SEQ ID NO: 78), TDFRSPQ (SEQ ID NO: 80), TGAFSST (SEQ ID NO: 77), FNSPVIQ (SEQ ID NO: 79), PYASITG (SEQ ID NO: 76), YGSRSD (SEQ ID NO: 83), SVVVSSDSSKRPNL (SEQ ID NO: 71), RPLTAND (SEQ ID NO: 95), PRDTFNG (SEQ ID NO: 94) and PLRMVNE (SEQ ID NO: 96).

[00290] In some embodiments, the peptide comprises an amino acid sequence selected from the group consisting of ENFSKVA (SEQ ID NO: 101), LGNGKMTVQP, GRNTVGLSSA (SEQ ID NO: 103), TSNSRTE (SEQ ID NO: 91), RDALSGLRPE (SEQ ID NO: 102) and NIPKAYG (SEQ ID NO: 89). In some embodiments, the peptide sequence is selected from the group consisting of EQFRNLA (SEQ ID NO: 78), TDFRSPQ (SEQ ID NO: 80), TGAFSST (SEQ ID NO: 77), FNSPVIQ (SEQ ID NO: 79), PYASITG (SEQ ID NO: 76), YGSRSD (SEQ ID NO: 83), SVVVSSDSSKRPNL (SEQ ID NO: 71), RPLTAND (SEQ ID NO: 95), PRDTFNG (SEQ ID NO: 94) and PLRMVNE (SEQ ID NO: 96).

[00291] In some embodiments, the peptide comprises amino acid sequence EQFRNLA (SEQ ID NO: 78). In some embodiments, the peptide comprises amino acid sequence TDFRSPQ (SEQ ID NO: 80). In some embodiments, the peptide comprises amino acid sequence TGAFSST (SEQ ID NO: 77). In some embodiments, the peptide
5 comprises amino acid sequence FNSPVIQ (SEQ ID NO: 79). In some embodiments, the peptide comprises amino acid sequence PYASITG (SEQ ID NO: 76). In some embodiments, the peptide comprises amino acid sequence YGSRSD (SEQ ID NO: 83). In some embodiments, the peptide comprises amino acid sequence RPLTAND (SEQ ID NO: 95). In some embodiments, the peptide comprises amino acid sequence
10 PRDTFNG (SEQ ID NO: 94). In some embodiments, the peptide comprises amino acid sequence PLRMVNE (SEQ ID NO: 96). In some embodiments, the peptide comprises amino acid sequence ENFSKVA (SEQ ID NO: 101). In some embodiments, the peptide comprises amino acid sequence LGNGKMTVQP (SEQ ID NO: 103). In some
15 embodiments, the peptide comprises amino acid sequence GRNTVGLSSA (SEQ ID NO: 106). In some embodiments, the peptide comprises amino acid sequence TSNRTE (SEQ ID NO: 91). In some embodiments, the peptide comprises amino acid sequence RDALSGLRPE (SEQ ID NO: 102).

[00292] In some embodiments, the peptide comprises an amino acid sequence selected from the group consisting of KSPQSKV (SEQ ID NO:1), SDLRSKV (SEQ ID NO:2)
20 and TTTVRKV (SEQ ID NO:3). In some embodiments, the peptide is selected from the group consisting of KSPQSKV (SEQ ID NO:1), SDLRSKV (SEQ ID NO:2) and TTTVRKV (SEQ ID NO:3).

[00293] In some embodiments, the peptide comprises an amino acid sequence selected from the group consisting of AALRDIR (SEQ ID NO:68), PAIKTYS (SEQ ID NO:
25 69), TGDRISSRTL (SEQ ID NO: 70), SVVVSSDSSKRPRNL (SEQ ID NO: 71), VGARLSA (SEQ ID NO: 72), IEKPNTSTKK (SEQ ID NO: 73), DTVRSKN (SEQ ID NO: 74), and KELNKAR (SEQ ID NO: 75). In some embodiments, the peptide is selected from the group consisting of AALRDIR (SEQ ID NO:68), PAIKTYS (SEQ
ID NO: 69), TGDRISSRTL (SEQ ID NO: 70), SVVVSSDSSKRPRNL (SEQ ID NO:
30 71), VGARLSA (SEQ ID NO: 72), IEKPNTSTKK (SEQ ID NO: 73), DTVRSKN (SEQ ID NO: 74), and KELNKAR (SEQ ID NO: 75).

[00294] In some embodiments, the peptide comprises an amino acid sequence selected from the group consisting of GRSDMAG (SEQ ID NO: 4), LLSSERS (SEQ ID NO:

5), EQRPNVS (SEQ ID NO: 6) and TRQISSD (SEQ ID NO: 7). In some embodiments, the peptide is selected from the group consisting of GRSDMAG (SEQ ID NO: 4), LLSSERS (SEQ ID NO: 5), EQRPNVS (SEQ ID NO: 6) and TRQISSD (SEQ ID NO: 7).

5 [00295] In some embodiments, the peptide comprises an amino acid sequence selected from the group consisting of MTLTRQE (SEQ ID NO: 90), TSNSRTE (SEQ ID NO: 91), EVRGGPS (SEQ ID NO: 92), VISDRSS (SEQ ID NO: 93), PRDTFNG (SEQ ID NO: 94), RPLTAND (SEQ ID NO: 95), PLRMVNE (SEQ ID NO: 96), DVGIRPS (SEQ ID NO: 97), KDSTAFG (SEQ ID NO: 98), YPGRNPD (SEQ ID NO: 99),
 10 ISDTRIS (SEQ ID NO: 100), ENFSKVA (SEQ ID NO: 101), RDALSGLRPE (SEQ ID NO: 102), LGNGKMTVQP (SEQ ID NO: 103), VSNPLNQ (SEQ ID NO: 104), LNERGLG (SEQ ID NO: 105), GRNTVGLSSA (SEQ ID NO: 106), VGHAGNP (SEQ ID NO: 107), SRAGTVP (SEQ ID NO: 108), GLVAKLP (SEQ ID NO: 109), and AESLRTP (SEQ ID NO: 110). In some embodiments, the peptide is selected from
 15 the group consisting of MTLTRQE (SEQ ID NO: 90), TSNSRTE (SEQ ID NO: 91), EVRGGPS (SEQ ID NO: 92), VISDRSS (SEQ ID NO: 93), PRDTFNG (SEQ ID NO: 94), RPLTAND (SEQ ID NO: 95), PLRMVNE (SEQ ID NO: 96), DVGIRPS (SEQ ID NO: 97), KDSTAFG (SEQ ID NO: 98), YPGRNPD (SEQ ID NO: 99), ISDTRIS (SEQ ID NO: 100), ENFSKVA (SEQ ID NO: 101), RDALSGLRPE (SEQ ID NO: 102),
 20 LGNGKMTVQP (SEQ ID NO: 103), VSNPLNQ (SEQ ID NO: 104), LNERGLG (SEQ ID NO: 105), GRNTVGLSSA (SEQ ID NO: 106), VGHAGNP (SEQ ID NO: 107), SRAGTVP (SEQ ID NO: 108), GLVAKLP (SEQ ID NO: 109), and AESLRTP (SEQ ID NO: 110).

[00296] In some embodiments, the peptide comprises an amino acid sequence selected
 25 from the group consisting of QGALAQV (SEQ ID NO: 8), YPSSNTP (SEQ ID NO: 9), MLNPRTE (SEQ ID NO: 10) and QMRTRDE (SEQ ID NO: 11). In some embodiments, the peptide is selected from the group consisting of QGALAQV (SEQ ID NO: 8), YPSSNTP (SEQ ID NO: 9), MLNPRTE (SEQ ID NO: 10) and QMRTRDE (SEQ ID NO: 11).

30 [00297] In some embodiments, the peptide comprises an amino acid sequence selected from the group consisting of PYASITG (SEQ ID NO: 76), TGAFSST (SEQ ID NO: 77), EQFRNLA (SEQ ID NO: 78), FNSPVIQ (SEQ ID NO: 79), TDFRSPQ (SEQ ID NO: 80), MYSLMKD (SEQ ID NO: 81), LYLSSAS (SEQ ID NO: 82), YGSRSD

(SEQ ID NO:83), LYSHQVS (SEQ ID NO: 84), and ISTHSPP (SEQ ID NO: 85). In some embodiments, the peptide is selected from the group consisting of PYASITG (SEQ ID NO: 76), TGAFSST (SEQ ID NO: 77), EQFRNLA (SEQ ID NO: 78), FNSPVIQ (SEQ ID NO: 79), TDFRSPQ (SEQ ID NO:80), MYSLMKD (SEQ ID NO:81), LYLSSAS (SEQ ID NO: 82), YGSRSD (SEQ ID NO:83), LYSHQVS (SEQ ID NO: 84), and ISTHSPP (SEQ ID NO: 85).

[00298] In some embodiments, the peptide comprises an amino acid sequence selected from the group consisting of MPGRAP (SEQ ID NO: 12), LGRLTAN (SEQ ID NO: 13), SYSTSR (SEQ ID NO: 14), TRPSSTN (SEQ ID NO: 15), VPQSSSR (SEQ ID NO: 16), VSRSYPA (SEQ ID NO: 17) and QRARPDT (SEQ ID NO: 18). In some embodiments, the peptide is selected from the group consisting of MPGRAP (SEQ ID NO: 12), LGRLTAN (SEQ ID NO: 13), SYSTSR (SEQ ID NO: 14), TRPSSTN (SEQ ID NO: 15), VPQSSSR (SEQ ID NO: 16), VSRSYPA (SEQ ID NO: 17) and QRARPDT (SEQ ID NO: 18).

[00299] In some embodiments, the peptide comprises an amino acid sequence selected from the group consisting of RQPTTIP (SEQ ID NO: 86), RSTSSL (SEQ ID NO: 87), FRLSSPQ (SEQ ID NO: 88), and NIPKAYG (SEQ ID NO: 89). In some embodiments, the peptide is selected from the group consisting of RQPTTIP (SEQ ID NO: 86), RSTSSL (SEQ ID NO: 87), FRLSSPQ (SEQ ID NO: 88), and NIPKAYG (SEQ ID NO: 89).

[00300] In some embodiments, the peptide comprises an amino acid sequence selected from the group consisting of SQLTPHS (SEQ ID NO: 19), LGSHLPS (SEQ ID NO: 20), YTLSSGQ (SEQ ID NO: 21), SSRIPPD (SEQ ID NO: 22), WTETIPR (SEQ ID NO: 23), HGLQGVA (SEQ ID NO: 24), TMRVSDQ (SEQ ID NO: 25), GSSKVVM (SEQ ID NO: 26), and SALDRGV (SEQ ID NO: 27). In some embodiments, the peptide is selected from the group consisting of SQLTPHS (SEQ ID NO: 19), LGSHLPS (SEQ ID NO: 20), YTLSSGQ (SEQ ID NO: 21), SSRIPPD (SEQ ID NO: 22), WTETIPR (SEQ ID NO: 23), HGLQGVA (SEQ ID NO: 24), TMRVSDQ (SEQ ID NO: 25), GSSKVVM (SEQ ID NO: 26), and SALDRGV (SEQ ID NO: 27).

[00301] In some embodiments, the peptide comprises an amino acid sequence selected from the group consisting of KELGTQR (SEQ ID NO: 28), RSSDVQR (SEQ ID NO: 29), PSAPKTF (SEQ ID NO: 30), HTKRSEY (SEQ ID NO: 31), and IKGSNLP (SEQ ID NO: 32). In some embodiments, the peptide is selected from the group consisting

of KELGTQR (SEQ ID NO: 28), RSSDVQR (SEQ ID NO: 29), PSAPKTF (SEQ ID NO: 30), HTKRSEY (SEQ ID NO: 31), and IKGSNLP (SEQ ID NO: 32).

[00302] In some embodiments, the disclosure provides a capsid protein comprising an inserted peptide, wherein the peptide is inserted at i) amino acid position 590 of an AAV1 capsid protein, (ii) amino acid position 454 or 590 of an AAV6 capsid protein, (iii) amino acid position 588 of an AAV2 capsid protein, (iv) amino acid position 589 of an AAV3B capsid protein, (v) amino acid position 578 of an AAV5 capsid protein, (vi) amino acid position 591 of the an AAV8 capsid protein, or (vi) amino acid position 266, 455, or 589 of an AAV9 capsid protein, wherein the positions correspond to the numbering of VP1 in the AAV serotype.

[00303] In some embodiments of the capsid proteins disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO. 1-32 is inserted at amino acid position 590 of the capsid protein of an AAV1 serotype. In some embodiments of the capsid proteins disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO. 68-110 is inserted at amino acid position 590 of the capsid protein of an AAV1 serotype. In some embodiments of the capsid proteins disclosed herein, the peptide inserted at position 590 of the capsid protein of an AAV1 serotype comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 68 to SEQ ID NO: 75. In some embodiments of the capsid proteins disclosed herein, the peptide inserted at position 590 of the capsid protein of an AAV1 serotype comprises the amino acid sequence SEQ ID NO: 71. In some embodiments of the capsid proteins disclosed herein, the peptide inserted at position 590 of the capsid protein of an AAV1 serotype comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 1, SEQ ID NO: 2 and SEQ ID NO: 3.

[00304] In some embodiments of the capsid proteins disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO. 1-32 is inserted at amino acid position 454 of the capsid protein of an AAV6 serotype. In some embodiments of the capsid proteins disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO. 68-110 is inserted at amino acid position 454 of the capsid protein of an AAV6 serotype. In some embodiments of the capsid proteins disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO. 1-32 is inserted at amino acid position 590 of the capsid protein of an AAV6 serotype. In some embodiments of the capsid proteins disclosed herein, a peptide

comprising the amino acid sequence of any one of SEQ ID NO. 68-110 is inserted at amino acid position 590 of the capsid protein of an AAV6 serotype. In some embodiments of the capsid proteins disclosed here, the peptide inserted at position 454 of the capsid protein of an AAV6 serotype comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 19 to SEQ ID NO: 27. In some embodiments of the capsid proteins disclosed here, the peptide inserted at position 590 of the capsid protein of an AAV6 serotype comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 19 to SEQ ID NO: 27.

[00305] In some embodiments of the capsid proteins disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO. 1-32 is inserted at amino acid position 588 of the capsid protein of an AAV2 serotype. In some embodiments of the capsid proteins disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO. 68-110 is inserted at amino acid position 588 of the capsid protein of an AAV2 serotype. In some embodiments of the capsid proteins disclosed here, the peptide inserted at position 588 of the capsid protein of an AAV2 serotype comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 90 to SEQ ID NO: 110. In some embodiments of the capsid proteins disclosed here, the peptide inserted at position 588 of the capsid protein of an AAV2 serotype comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 95, SEQ ID NO: 94, SEQ ID NO: 96, SEQ ID NO: 101, SEQ ID NO: 103, SEQ ID NO: 106, SEQ ID NO: 91 and SEQ ID NO: 102. In some embodiments of the capsid proteins disclosed here, the peptide inserted at position 588 of the capsid protein of an AAV2 serotype comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 4-7.

[00306] In some embodiments of the capsid proteins disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO. 1-32 is inserted at amino acid position 589 of the capsid protein of an AAV3B serotype. In some embodiments of the capsid proteins disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO. 68-110 is inserted at amino acid position 589 of the capsid protein of an AAV3B serotype. In some embodiments of the capsid proteins disclosed here, the peptide inserted at position 589 of the capsid protein of an AAV3B serotype comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 76- 85. In some embodiments of the capsid proteins

disclosed here, the peptide inserted at position 589 of the capsid protein of an AAV3B serotype comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 78, SEQ ID NO: 80, SEQ ID NO: 77, SEQ ID NO: 79, SEQ ID NO: 76 and SEQ ID NO: 83. In some embodiments of the capsid proteins disclosed
5 here, the peptide inserted at position 589 of the capsid protein of an AAV3B serotype comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 8 to SEQ ID NO: 11.

[00307] In some embodiments of the capsid proteins disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO. 1-32 is inserted at
10 amino acid position 578 of the capsid protein of an AAV5 serotype. In some embodiments of the capsid proteins disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO. 68-110 is inserted at amino acid position 578 of the capsid protein of an AAV5 serotype. In some embodiments of the capsid proteins disclosed here, the peptide inserted at position 578 of the capsid protein of an AAV5
15 serotype comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 28 to SEQ ID NO: 32.

[00308] In some embodiments of the capsid proteins disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO. 1-32 is inserted at amino acid position 591 of the capsid protein of an AAV8 serotype. In some
20 embodiments of the capsid proteins disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO. 68-110 is inserted at amino acid position 591 of the capsid protein of an AAV8 serotype.

[00309] In some embodiments of the capsid proteins disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO. 1-32 is inserted at
25 amino acid position 266 of the capsid protein of an AAV9 serotype. In some embodiments of the capsid proteins disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO. 68-110 is inserted at amino acid position 266 of the capsid protein of an AAV9 serotype. In some embodiments of the capsid proteins disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID
30 NO. 1-32 is inserted at amino acid position 455 of the capsid protein of an AAV9 serotype. In some embodiments of the capsid proteins disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO. 68-110 is inserted at

amino acid position 455 of the capsid protein of an AAV9 serotype. In some embodiments of the capsid proteins disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO. 1-32 is inserted at amino acid position 589 of the capsid protein of an AAV9 serotype. In some embodiments of the capsid proteins disclosed herein, a peptide comprising the amino acid sequence of any one of SEQ ID NO. 68-110 is inserted at amino acid position 589 of the capsid protein of an AAV9 serotype. In some embodiments of the capsid proteins disclosed here, the peptide inserted at position 266 of the capsid protein of an AAV9 serotype comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 12 to SEQ ID NO: 18. In some embodiments of the capsid proteins disclosed here, the peptide inserted at position 266 of the capsid protein of an AAV9 serotype comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 86 to SEQ ID NO: 89. In some embodiments of the capsid proteins disclosed here, the peptide inserted at position 266 of the capsid protein of an AAV9 serotype comprises an amino acid sequence of SEQ ID NO: 89. In some embodiments of the capsid proteins disclosed here, the peptide inserted at position 455 of the capsid protein of an AAV9 serotype comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 12 to SEQ ID NO: 18. In some embodiments of the capsid proteins disclosed here, the peptide inserted at position 455 of the capsid protein of an AAV9 serotype comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 86 to SEQ ID NO: 89. In some embodiments of the capsid proteins disclosed here, the peptide inserted at position 455 of the capsid protein of an AAV9 serotype comprises an amino acid sequence of SEQ ID NO: 89. In some embodiments of the capsid proteins disclosed here, the peptide inserted at position 455 of the capsid protein of an AAV9 serotype comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 12 to SEQ ID NO: 18. In some embodiments of the capsid proteins disclosed here, the peptide inserted at position 589 of the capsid protein of an AAV9 serotype comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 86 to SEQ ID NO: 89. In some embodiments of the capsid proteins disclosed here, the peptide inserted at position 589 of the capsid protein of an AAV9 serotype comprises an amino acid sequence of SEQ ID NO: 89.

[00310] Also disclosed herein are AAV capsid proteins comprising an inserted peptide as disclosed herein. In some embodiments, the capsid protein is VP1, VP2, or VP3. In

some embodiments, the peptide is inserted at a location between residues 450 and 600 of the capsid protein. In some embodiments, the peptide is inserted at (i) position 590 of an AAV1 capsid protein, (ii) position 454 or 590 of an AAV6 capsid protein, (iii) position 588 of an AAV2 capsid protein, (iv) position 589 of an AAV3B capsid protein, 5 (v) position 578 of an AAV5 capsid protein, (vi) position 591 of an AAV8 capsid protein, or (vii) position 266, 455, or 589 of an AAV9 capsid protein, wherein the positions correspond to the numbering of VP1 in the AAV serotype. In some embodiments, the peptide is inserted at position 590 of an AAV1 capsid protein. In some embodiments, the peptide is inserted at position 454 or 590 of an AAV6 capsid 10 protein. In some embodiments, the peptide is inserted at position 588 of an AAV2 capsid protein. In some embodiments, the peptide is inserted at position 589 of an AAV3B capsid protein. In some embodiments, the peptide is inserted at position 578 of an AAV5 capsid protein. In some embodiments, the peptide is inserted at position 591 of an AAV8 capsid protein. In some embodiments, the peptide is inserted at 15 position 266, 455, or 589 of an AAV9 capsid protein. It is understood that other sites in the capsid proteins may be selected for insertion. It will also be understood that the amino acid sequences may be inserted at corresponding positions of VP2 or VP3.

[00311] Also disclosed herein are nucleic acid sequences encoding the peptides, capsid proteins and AAV variants disclosed herein.

20 [00312] Further, disclosed herein are AAV vectors comprising the inserted peptides disclosed herein. In some embodiments, the peptide is part of a capsid protein of the AAV vector.

[00313] In some embodiments, the inserted peptide of the disclosure has cell or tissue tropism for a target cell or tissue. In some embodiments, the target cell or tissue 25 includes, but is not limited to, a cell from the CNS, heart, lung, trachea, esophagus, muscle, bone, cartilage, stomach, pancreas, intestine, liver, bladder, kidney, ureter, urethra, uterus, fallopian tube, ovary, testes, prostate, eye, blood, lymph, or oral mucosa. In some embodiments, the target cell or tissue is from the liver. In some embodiments, the target cell or tissue is from the CNS. In some embodiments, the 30 target cell includes, but is not limited to, neurons, glial cells, astrocytes, oligodendroglia, microglia, Schwann cells, ependymal cells, hepatocytes, stellate fat storing cells, Kupffer cells, liver endothelial cells, epithelial cells, cardiomyocytes, smooth muscle cells, T-cells, B cells, hematopoietic stem cells, and embryonic stem cells.

[00314] A vector comprising an inserted peptide of the disclosure may be used to deliver a nucleic acid to a target cell or tissue. In one aspect, the present disclosure provides a method of delivering a nucleic acid to a target cell or tissue comprising administering an AAV vector comprising the nucleic acid, wherein the AAV vector
5 comprises a targeting protein of the disclosure. In some embodiments, the target cell or tissue includes, but is not limited to, a cell from the CNS, heart, lung, trachea, esophagus, muscle, bone, cartilage, stomach, pancreas, intestine, liver, bladder, kidney, ureter, urethra, uterus, fallopian tube, ovary, testes, prostate, eye, blood, lymph, or oral mucosa. In some embodiments, the target cell or tissue is from the liver. In some
10 embodiments, the target cell or tissue is from the CNS. In some embodiments, the target cell includes, but is not limited to, neurons, glial cells, astrocytes, oligodendroglia, microglia, Schwann cells, ependymal cells, hepatocytes, stellate fat storing cells, Kupffer cells, liver endothelial cells, epithelial cells, cardiomyocytes, smooth muscle cells, T-cells, B cells, hematopoietic stem cells, and embryonic stem
15 cells.

DNA-binding molecules/domains

[00315] Described herein are compositions comprising a DNA-binding molecule/domain that specifically binds to a target site in any gene or locus of interest. Any DNA-binding molecule/domain can be used in the compositions and methods
20 disclosed herein, including but not limited to a zinc finger DNA-binding domain, a TALE DNA binding domain, the DNA-binding portion (guide or sgRNA) of a CRISPR/Cas nuclease, or a DNA-binding domain from a meganuclease. In the methods and compositions described herein, it is understood that the term “Cas” includes both Cas9 and Cpf1 proteins. Thus, as used herein, a “CRISPR/Cas system”
25 refers both CRISPR/Cas and/or CRISPR/Cpf1 systems, including both nuclease, nickase and/or transcription factor systems.

[00316] In some embodiments, other Cas proteins may be used. Some exemplary Cas proteins include Cas9, Cpf1 (also known as Cas12a), C2c1, C2c2 (also known as Cas13a), C2c3, Cas1, Cas2, Cas4, CasX and CasY; and include engineered and natural
30 variants thereof (Burstein, *et al.* (2017) *Nature* 542:237-241) for example HF1/spCas9 (Kleinstiver, *et al.* (2016) *Nature* 529: 490-495; Cebrian-Serrano and Davies (2017) *Mamm Genome* (2017) 28(7):247-261); split Cas9 systems (Zetsche, *et al.* (2015) *Nat Biotechnol* 33(2):139-142), trans-spliced Cas9 based on an intein-extein system (Truong, *et al.* (2015) *Nucl Acid Res* 43(13):6450-8); mini-SaCas9 (Ma, *et al.* (2018)

ACS Synth Biol 7(4):978-985). Thus, in the methods and compositions described herein, it is understood that the term “Cas” includes all Cas variant proteins, both natural and engineered. Thus, as used herein, a “CRISPR/Cas system” refers to any CRISPR/Cas system, including both nuclease, nickase and/or transcription factor
5 systems.

Systems

[00317] The DNA-editing complexes (or component molecules thereof) described herein may be delivered to a target cell by the methods and compositions as described herein. Delivery may be to isolated cells (which in turn may be administered to a living
10 subject for *ex vivo* cell therapy) or a living subject. Delivery of gene editing molecules to cells and subjects are known in the art.

[00318] Suitable cells include but not limited to eukaryotic and prokaryotic cells and/or cell lines. Non-limiting examples of such cells or cell lines generated from such cells include T-cells, COS, CHO (e.g., CHO-S, CHO-K1, CHO-DG44, CHO-DUXB11, CHO-DUKX, CHOK1SV), VERO, MDCK, WI38, V79, B14AF28-G3,
15 BHK, HaK, NS0, SP2/0-Ag14, HeLa, HEK293 (e.g., HEK293-F, HEK293-H, HEK293-T), and perC6 cells as well as insect cells such as *Spodoptera fugiperda* (Sf), or fungal cells such as *Saccharomyces*, *Pichia* and *Schizosaccharomyces*. In certain embodiments, the cell line is a CHO-K1, MDCK or HEK293 cell line. Suitable cells
20 also include stem cells such as, by way of example, embryonic stem cells, induced pluripotent stem cells (iPS cells), hematopoietic stem cells, neuronal stem cells and mesenchymal stem cells.

[00319] DNA-editing complexes as described herein may also be delivered using vectors of the invention containing sequences encoding one or more of the components
25 (e.g., fusion molecules). Additionally, additional nucleic acids (e.g., donors) also may be delivered via these vectors. Furthermore, it will be apparent that any of these vectors may comprise one or more DNA-binding protein-encoding sequences and/or additional nucleic acids as appropriate. Thus, when one or more DNA-binding proteins as described herein are introduced into the cell, and additional DNAs as appropriate, they
30 may be carried on the same vector or on different vectors. When multiple vectors are used, each vector may comprise a sequence encoding one or multiple DNA-binding proteins and additional nucleic acids as desired. Conventional viral and non-viral based gene transfer methods can be used to introduce nucleic acids encoding engineered DNA-binding proteins in cells (e.g., mammalian cells) and target tissues and to co-

introduce additional nucleotide sequences as desired. Such methods can also be used to administer nucleic acids (*e.g.*, encoding DNA-binding proteins and/or donors) to cells *in vitro*. In certain embodiments, nucleic acids are administered for *in vivo* or *ex vivo* gene therapy uses.

5 [00320] Packaging cells are used to form virus particles that are capable of infecting a host cell. Such cells include HEK293 cells, which package adenovirus or AAV. Viral vectors used in gene therapy are usually generated by a producer cell line that packages a nucleic acid vector into a viral particle. The vectors typically contain the minimal viral sequences required for packaging and subsequent integration into a host (if
10 applicable), other viral sequences being replaced by an expression cassette encoding the protein to be expressed. The missing viral functions are supplied in *trans* by the packaging cell line. For example, AAV vectors used in gene therapy typically only possess inverted terminal repeat (ITR) sequences from the AAV genome which are required for packaging and integration into the host genome. Viral DNA is packaged
15 in a cell line, which contains a helper plasmid encoding the other AAV genes, namely rep and cap, but lacking ITR sequences. The cell line is also infected with adenovirus as a helper. The helper virus promotes replication of the AAV vector and expression of AAV genes from the helper plasmid. The helper plasmid is not packaged in significant amounts due to a lack of ITR sequences. Contamination with adenovirus
20 can be reduced by, *e.g.*, heat treatment to which adenovirus is more sensitive than AAV. In some embodiments, baculovirus systems are used to produce the AAV (see for example Smith *et al* (2009) *Mol Ther* 434:37-54).

[00321] In many gene therapy applications, it is desirable that the gene therapy vector be delivered with a high degree of specificity to a particular tissue type. Accordingly,
25 a viral vector can be modified to have specificity for a given cell type by expressing a ligand as a fusion protein with a viral coat protein on the outer surface of the virus. The ligand is chosen to have affinity for a receptor known to be present on the cell type of interest. For example, Han, *et al.* (1995) *Proc. Natl. Acad. Sci. USA* 92:9747-9751, reported that Moloney murine leukemia virus can be modified to express human
30 heregulin fused to gp70, and the recombinant virus infects certain human breast cancer cells expressing human epidermal growth factor receptor. This principle can be extended to other virus-target cell pairs, in which the target cell expresses a receptor and the virus expresses a fusion protein comprising a ligand for the cell-surface receptor. For example, filamentous phage can be engineered to display antibody

fragments (*e.g.*, FAB or Fv) having specific binding affinity for virtually any chosen cellular receptor. Although the above description applies primarily to viral vectors, the same principles can be applied to nonviral vectors. Such vectors can be engineered to contain specific uptake sequences which favor uptake by specific target cells.

- 5 [00322] Delivery methods for CRISPR/Cas systems can comprise those methods described above. For example, in animal models, *in vitro* transcribed Cas encoding mRNA or recombinant Cas protein can be directly injected into one-cell stage embryos using glass needles to genome-edited animals. To express Cas and guide RNAs in cells *in vitro*, typically plasmids that encode them are transfected into cells via lipofection or
10 electroporation. Also, recombinant Cas protein can be complexed with *in vitro* transcribed guide RNA where the Cas-guide RNA ribonucleoprotein is taken up by the cells of interest (Kim, *et al.* (2014) *Genome Res* 24(6):1012). For therapeutic purposes, Cas and guide RNAs can be delivered by a combination of viral and non-viral techniques. For example, mRNA encoding Cas may be delivered via nanoparticle
15 delivery while the guide RNAs and any desired transgene or repair template are delivered via AAV (Yin, *et al.* (2016) *Nat Biotechnol* 34(3):328).

- [00323] Gene therapy vectors can be delivered *in vivo* by administration to an individual patient (subject), typically by systemic administration (*e.g.*, intravenous, intraperitoneal, intramuscular, subdermal, or intracranial infusion) or topical
20 application, as described below. Alternatively, vectors can be delivered to cells *ex vivo*, such as cells explanted from an individual patient (*e.g.*, lymphocytes, bone marrow aspirates, tissue biopsy) or universal donor hematopoietic stem cells, followed by re-implantation of the cells into a patient, usually after selection for cells which have incorporated the vector.

- 25 [00324] *Ex vivo* cell transfection for diagnostics, research, transplant or for gene therapy (*e.g.*, via re-infusion of the transfected cells into the host organism) is well known to those of skill in the art. In some embodiments, cells are isolated from the subject organism, transfected with a DNA-binding proteins nucleic acid (gene or cDNA), and re-infused back into the subject organism (*e.g.*, patient). Various cell types
30 suitable for *ex vivo* transfection are well known to those of skill in the art (see, *e.g.*, Freshney, *et al.*, *Culture of Animal Cells, A Manual of Basic Technique* (3rd ed. 1994))

and the references cited therein for a discussion of how to isolate and culture cells from patients).

[00325] In one embodiment, stem cells are used in *ex vivo* procedures for cell transfection and gene therapy. The advantage to using stem cells is that they can be differentiated into other cell types *in vitro*, or can be introduced into a mammal (such as the donor of the cells) where they will engraft in the bone marrow. Methods for differentiating CD34+ cells *in vitro* into clinically important immune cell types using cytokines such as GM-CSF, IFN- γ and TNF- α are known (see Inaba, *et al.* (1992) *J. Exp. Med.* 176:1693-1702).

[00326] The vectors as described herein containing therapeutic DNA-binding proteins (or nucleic acids encoding these proteins) can also be administered directly to an organism for transduction of cells *in vivo*. Administration is by any of the routes normally used for introducing a molecule into ultimate contact with blood or tissue cells including, but not limited to, injection, infusion, topical application and electroporation. Suitable methods of administering such nucleic acids are available and well known to those of skill in the art, and, although more than one route can be used to administer a particular composition, a particular route can often provide a more immediate and more effective reaction than another route.

[00327] Pharmaceutically acceptable carriers are determined in part by the particular composition being administered, as well as by the particular method used to administer the composition. Accordingly, there is a wide variety of suitable formulations of pharmaceutical compositions available, as described below (see, *e.g.*, Remington's Pharmaceutical Sciences, 17th ed., 1989).

[00328] As noted above, the disclosed methods and compositions can be used in any type of cell including, but not limited to, prokaryotic cells, fungal cells, Archaeal cells, plant cells, insect cells, animal cells, vertebrate cells, mammalian cells and human cells, including T-cells and stem cells of any type. Suitable cell lines for protein expression are known to those of skill in the art and include, but are not limited to COS, CHO (*e.g.*, CHO-S, CHO-K1, CHO-DG44, CHO-DUXB11), VERO, MDCK, WI38, V79, B14AF28-G3, BHK, HaK, NS0, SP2/0-Ag14, HeLa, HEK293 (*e.g.*, HEK293-F, HEK293-H, HEK293-T), perC6, insect cells such as *Spodoptera fugiperda* (Sf), and

fungal cells such as *Saccharomyces*, *Pichia* and *Schizosaccharomyces*. Progeny, variants and derivatives of these cell lines can also be used.

Applications

[00329] Engineered AAV capsids can be used for many different applications of *in vivo* and *ex vivo* gene therapy and genome editing. The AAV variants disclosed herein were generated through the use of directed evolution involving the use of cell and *in vivo* selections following administration. In some embodiments, the variant capsid proteins disclosed herein, when present in an AAV virion, confer increased transduction of a cell, tissue or organelle compared to the transduction of the cell, tissue or organelle by an AAV virion comprising the corresponding parental AAV capsid protein or wild-type AAV. For example, in some embodiments, the variant capsid proteins disclosed herein, when present in an AAV virion, confer more efficient transduction of cells, tissues or organelle than AAV virions comprising the corresponding parental AAV capsid protein or wild-type AAV capsid protein, *e.g.* the cells, tissues or organelles take up more AAV virions comprising the variant AAV capsid protein than AAV virions comprising the parental AAV capsid protein or wild-type AAV. In some such embodiments, the AAV variant virion or variant rAAV exhibits at least 2-fold, at least 5 -fold, at least 10-fold, at least 15 -fold, at least 20-fold, at least 25-fold, at least 30-fold, at least 40-fold, at least 50-fold, or more than 50-fold, increased transduction of a cell, tissue or organelle compared to the transduction of the cell, tissue or organelle by a wild-type AAV virion or rAAV comprising the corresponding parental AAV capsid protein. In some embodiments, the cell or tissue includes, but is not limited to, a cell or tissue from the CNS, heart, lung, trachea, esophagus, muscle, bone, cartilage, stomach, pancreas, intestine, liver, bladder, kidney, ureter, urethra, uterus, fallopian tube, ovary, testes, prostate, eye, blood, lymph, or oral mucosa. In some embodiments, the cell or tissue is from the liver. In some embodiments, the cell or tissue is from the CNS. In some embodiments, the target cell includes, but is not limited to, neurons, glial cells, astrocytes, oligodendroglia, microglia, Schwann cells, ependymal cells, hepatocytes, stellate fat storing cells, Kupffer cells, liver endothelial cells, epithelial cells, cardiomyocytes, smooth muscle cells, T-cells, B cells, hematopoietic stem cells, and embryonic stem cells. In some embodiments, the AAV variant virion or variant rAAV exhibits at least 2-fold, at least 5 -fold, at least 10-fold, at least 15-fold, at least 20-fold, at least 25-fold, at least 30-fold, at least 40-fold, at least 50-fold, at least 100-fold, at least 1000-fold or more than 1000-fold, increased transduction of a cell, tissue

or organelle compared to the transduction of the cell, tissue or organelle by a wild-type AAV1, AAV2, AAV3B, AAV4, AAV5, AAV6, AAV8 or AAV9 virion. In certain such embodiments, the variant capsid proteins disclosed herein, when present in an AAV virion, confer broader transduction of primate CNS cells than AAV virions comprising the corresponding parental AAV capsid protein or wild type AAV capsid protein. In some embodiments, the variant AAV virion transduces cell types not transduced by virions comprising the corresponding parental AAV capsid protein, and hence more types of cells in the CNS than the corresponding parental AAV virion. In some embodiments, the AAV variant virion preferentially transduces a CNS cell, *e.g.*, a rAAV virion infects a CNS cell with 2-fold, 5-fold, 10-fold, 15-fold, 20-fold, 25-fold, 50-fold, or more than 50-fold, specificity than another cell. In some embodiments, the transduced CNS cell is a neuron or glial cell, including without limitation, an astrocyte, oligodendroglia, microglia, Schwann cell, or ependymal cell.

[00330] In certain such embodiments, the variant capsid proteins disclosed herein, when present in an AAV virion, confer broader transduction of primate liver cells than AAV virions comprising the corresponding parental AAV capsid protein or wild type AAV capsid protein. In some embodiments, the variant AAV virion transduces cell types not transduced by virions comprising the corresponding parental AAV capsid protein, and hence more types of cells in the liver than the corresponding parental AAV virion. In some embodiments, the AAV variant virion preferentially transduces a liver cell, *e.g.*, a rAAV virion infects a liver cell with 2-fold, 5-fold, 10-fold, 15-fold, 20-fold, 25-fold, 50-fold, or more than 50-fold, specificity than another cell. In some embodiments, the transduced liver cell is, without limitation, a hepatocyte, stellate fat storing cell, Kupffer cell or liver endothelial cell.

[00331] An increase in transduction of a CNS or liver cell, *e.g.* increased efficiency of transduction, broader transduction, more preferential transduction, etc. may be readily assessed *in vitro* or *in vivo* by any number of methods in the art for measuring gene expression. For example, the AAV may be packaged with a genome comprising an expression cassette comprising a reporter gene, *e.g.* a fluorescent protein, under the control of or operatively linked to a ubiquitous or cell type and/or tissue specific promoter, and the extent of transduction assessed by detecting the fluorescent protein by, *e.g.*, fluorescence microscopy. As another example, the AAV may be packaged with a genome comprising a barcoded nucleic acid sequence, and the extent of transduction assessed by detecting the nucleic acid sequence by, *e.g.*, PCR. As another

example, the AAV may be packaged with a genome comprising an expression cassette comprising a therapeutic gene for the treatment of a disease, and the extent of transduction assessed by detecting the treatment of the disease in a subject in need of treatment that was administered the AAV.

- 5 [00332] Exemplary genetic diseases that may be treated and/or prevented by the compositions and methods described herein include, but are not limited to, achondroplasia, achromatopsia, acid maltase deficiency, adenosine deaminase deficiency (OMIM No.102700), adrenoleukodystrophy, aicardi syndrome, alpha-1 antitrypsin deficiency, alpha-thalassemia, androgen insensitivity syndrome, apert
10 syndrome, arrhythmogenic right ventricular, dysplasia, ataxia telangiectasia, Barth syndrome, beta-thalassemia, blue rubber bleb nevus syndrome, Canavan disease, chronic granulomatous diseases (CGD), cri du chat syndrome, cystic fibrosis, dercun's disease, ectodermal dysplasia, Fanconi anemia, fibrodysplasia ossificans progressive, fragile X syndrome, galactosemia, Gaucher's disease, generalized gangliosidoses (*e.g.*,
15 GM1), hemochromatosis, the hemoglobin C mutation in the 6th codon of beta-globin (HbC), hemophilia, Huntington's disease, Hurler Syndrome, hypophosphatasia, Klinefelter syndrome, Krabbes Disease, Langer-Giedion Syndrome, leukocyte adhesion deficiency (LAD, OMIM No. 116920), leukodystrophy, long QT syndrome, Marfan syndrome, Moebius syndrome, mucopolysaccharidosis (MPS), nail patella
20 syndrome, nephrogenic diabetes insipidus, neurofibromatosis, Neimann-Pick disease, osteogenesis imperfecta, phenylketonuria (PKU), porphyria, Prader-Willi syndrome, progeria, Proteus syndrome, retinoblastoma, Rett syndrome, Rubinstein-Taybi syndrome, Sanfilippo syndrome, severe combined immunodeficiency (SCID), Shwachman syndrome, sickle cell disease (sickle cell anemia), Smith-Magenis
25 syndrome, Stickler syndrome, Tay-Sachs disease, Thrombocytopenia Absent Radius (TAR) syndrome, Treacher Collins syndrome, trisomy, tuberous sclerosis, Turner's syndrome, urea cycle disorder, von Hippel-Landau disease, Waardenburg syndrome, Williams syndrome, Wilson's disease, Wiskott-Aldrich syndrome, X-linked lymphoproliferative syndrome (XLP, OMIM No. 308240).
- 30 [00333] Additional exemplary diseases that can be treated by targeted DNA base editing include acquired immunodeficiencies, lysosomal storage diseases (*e.g.*, Gaucher's disease, GM1, Fabry disease and Tay-Sachs disease), mucopolysaccharidosis (*e.g.* Hunter's disease, Hurler's disease), hemoglobinopathies (*e.g.*, sickle cell diseases, HbC, α -thalassemia, β -thalassemia) and hemophilias.

[00334] Such methods also allow for treatment of infections (viral or bacterial) in a host (*e.g.*, by blocking expression of viral or bacterial receptors, thereby preventing infection and/or spread in a host organism). Non-limiting examples of viruses or viral receptors that may be targeted include herpes simplex virus (HSV), such as HSV-1 and HSV-2, varicella zoster virus (VZV), Epstein-Barr virus (EBV) and cytomegalovirus (CMV), HHV6 and HHV7. The hepatitis family of viruses includes hepatitis A virus (HAV), hepatitis B virus (HBV), hepatitis C virus (HCV), the delta hepatitis virus (HDV), hepatitis E virus (HEV) and hepatitis G virus (HGV). Other viruses or their receptors may be targeted, including, but not limited to, Picornaviridae (*e.g.*, polioviruses, *etc.*); Caliciviridae; Togaviridae (*e.g.*, rubella virus, dengue virus, *etc.*); Flaviviridae; Coronaviridae; Reoviridae; Birnaviridae; Rhabdoviridae (*e.g.*, rabies virus, *etc.*); Filoviridae; Paramyxoviridae (*e.g.*, mumps virus, measles virus, respiratory syncytial virus, *etc.*); Orthomyxoviridae (*e.g.*, influenza virus types A, B and C, *etc.*); Bunyaviridae; Arenaviridae; Retroviridae; lentiviruses (*e.g.*, HTLV-I; HTLV-II; HIV-1 (also known as HTLV-III, LAV, ARV, hTLR, *etc.*) HIV-II); simian immunodeficiency virus (SIV), human papillomavirus (HPV), influenza virus and the tick-borne encephalitis viruses. See, *e.g.* Virology, 3rd Edition (W. K. Joklik ed. 1988); Fundamental Virology, 2nd Edition (B. N. Fields and D. M. Knipe, eds. 1991), for a description of these and other viruses. Receptors for HIV, for example, include CCR-5 and CXCR-4.

[00335] Gene products delivered by the subject AAV variants can be used to alter the level of gene products or gene product activity directly or indirectly linked to muscle diseases and trauma. Skeletal, cardiac or smooth muscle transduced with subject AAV variants can also be used as a biofactory to produce and secrete therapeutic proteins for the treatment of diseases in trans in distant organs. Genes whose gene products are directly or indirectly linked to genetic diseases include, *e.g.*, genes encoding any of the following gene products: dystrophin including mini- and micro -dystrophins (DMD; *e.g.* GenBank Accession Number NP 003997.1); titin (TTN); titin cap (TCAP) cc-sarcoglycan (SGCA), β -sarcoglycan (SGCB), γ -sarcoglycan (SGCG) or δ -sarcoglycan (SGCD); alpha-1 -antitrypsin (AI-AT); myosin heavy chain 6 (MYH6); myosin heavy chain 7 (MYH7); myosin heavy chain 11 (MYH11); myosin light chain 2 (ML2); myosin light chain 3 (ML3); myosin light chain kinase 2 (MYLK2); myosin binding protein C (MYBPC3); desmin (DES); dynamin 2 (DNM2); laminin cc2 (LAMA2); lamin A/C (LMNA); lamin B (LMNB); lamin B receptor (LBR); dysferlin (DYSF);

emerin (EMD); insulin; blood clotting factors, including but not limited to, factor VIII and factor IX; erythropoietin (EPO); lipoprotein lipase (LPL); sarcoplasmic reticulum Ca²⁺⁺-ATPase (SERCA2A), S100 calcium binding protein A1 (S100A1); myotubularin (MTM); DM1 protein kinase (DMPK; *e.g.* GenBank Accession Number NG_009784.1); glycogen phosphorylase L (PYGL); glycogen phosphorylase, muscle associated (PYGM; *e.g.* GenBank Accession Number NP_005600.1); glycogen synthase 1 (GYS1); glycogen synthase 2 (GYS2); cc-galactosidase A (GLA; *e.g.* GenBank Accession Number NP_000160.1; SEQ ID NO:67); a-N-acetylgalactosaminidase (NAGA); acid cc-glucosidase (GAA; *e.g.* GenBank Accession Number NP_000143.2; SEQ ID NO:68), sphingomyelinase phosphodiesterase 1 (SMPD1); lysosomal acid lipase (LIP A); collagen type I a1 chain (COL1A1); collagen type I o2 chain (COL1A2); collagen type III a1 chain (COL3A1); collagen type V a1 chain (COL5A1); collagen type V a2 chain (COL5A2); collagen type VI a1 chain (COL6A1); collagen type VI o2 chain (COL6A2); collagen type VI a3 chain (COL6A3); procollagen-lysine 2-oxoglutarate 5-dioxygenase (PLOD1); lysosomal acid lipase (LIP A); frataxin (FXN; *e.g.* GenBank Accession Number NP_000135.2); myostatin (MSTN); β -N-acetyl hexosaminidase A (HEXA); β -N-acetylhexosaminidase B (HEXB); β -glucocerebrosidase (GBA); adenosine monophosphate deaminase 1 (AMPD1); β -globin (HBB); iduronidase (IDUA); iduronate 2-sulfate (IDS); troponin 1 (TNNT1); troponin T2 (TNNT2); troponin C (TNNT1); tropomyosin 1 (TPM1); tropomyosin 3 (TPM3); N-acetyl-a-glucosaminidase (NAGLU); N-sulfoglucosamine sulfohydrolase (SGSH); heparan-a-glucosaminide N-acetyltransferase (HGSNAT); integrin a 7 (IGTA7); integrin a 9 (IGTA9); glucosamine(N-acetyl)-6-sulfatase (GNS); galactosamine(N-acetyl)-6-sulfatase (GALNS); β -galactosidase (GLB1); β -glucuronidase (GUSB); hyaluronoglucosaminidase 1 (HYAL1); acid ceramidase (ASAH1); galactosylceramidase (GALC); cathepsin A (CTSA); cathepsin D (CTSA); cathepsin K (CTSK); GM2 ganglioside activator (GM2A); arylsulfatase A (ARSA); arylsulfatase B (ARSB); formylglycine- generating enzyme (SUMF1); neuraminidase 1 (NEU1); N-acetylglucosamine-1 -phosphate transferase a (GNPTA); N-acetylglucosamine-1 -phosphate transferase β (GNPTB); N-acetylglucosamine-1 -phosphate transferase γ (GNPTG); mucolipin-1 (MCOLN1); NPC intracellular transporter 1 (NPC1); NPC intracellular transporter 2 (NPC2); ceroid lipofuscinosis 5 (CLN5); ceroid lipofuscinosis 6 (CLN6); ceroid lipofuscinosis 8 (CLN8); palmitoyl protein thioesterase 1 (PPT1); tripeptidyl peptidase 1 (TPP1); battenin (CLN3); DNAJ

heat shock protein family 40 member C5 (DNAJC5); major facilitator superfamily
 domain containing 8 (MFSD8); mannosidase a class 2B member 1 (MAN2B1);
 mannosidase β (MANBA); aspartylglucosaminidase (AGA); cc-L-fucosidase
 (FUCA1); cystinosin, lysosomal cysteine transporter (CTNS); sialin; solute carrier
 5 family 2 member 10 (SLC2A10); solute carrier family 17 member 5 (SLC17A5); solute
 carrier family 6 member 19 (SLC6A19); solute carrier family 22 member 5
 (SLC22A5); solute carrier family 37 member 4 (SLC37A4); lysosomal associated
 membrane protein 2 (LAMP2); sodium voltage-gated channel α subunit 4 (SCN4A);
 sodium voltage-gated channel β subunit 4 (SCN4B); sodium voltage-gated channel α
 10 subunit 5 (SCN5A); sodium voltage-gated channel α subunit 4 (SCN4A); calcium
 voltage-gated channel subunit $\alpha 1C$ (CACNA1C); calcium voltage-gated channel subunit
 $\alpha 1S$ (CACNA1S); phosphoglycerate kinase 1 (PGK1); phosphoglycerate mutase 2
 (PGAM2); amylo- α -1,6-glucosidase, 4-cc-glucanotransferase (AGL); potassium
 voltage-gated channel ISK-related subfamily member 1 (KCNE1); potassium voltage-
 15 gated channel ISK-related subfamily member 2 (KCNE2); potassium voltage-gated
 channel subfamily J member 2 (KCNE2); potassium voltage-gated channel subfamily J
 member 5 (KCNE5); potassium voltage-gated channel subfamily H member 2
 (KCNE2); potassium voltage-gated channel KQT-like subfamily member 1 (KCNE1);
 hyperpolarization-activated cyclic nucleotide-gated potassium channel 4 (HCN4);
 20 chloride voltage-gated channel 1 (CLCN1); carnitine palmitoyltransferase 1 A (CPT1
 A); ryanodine receptor 1 (RYSR1); ryanodine receptor 2 (RYSR2); bridging integrator 1
 (BIN1); LARGE xylosyl- and glucuronyltransferase 1 (LARGE1); docking protein 7
 (DOK7); fukutin (FKTN); fukutin related protein (FKRP); selenoprotein N
 (SELENON); protein O-mannosyltransferase 1 (POMT1); protein O-
 25 mannosyltransferase 2 (POMT2); protein O-linked mannose N-
 acetylglucosaminyltransferase 1 (POMGNT1); protein O-linked mannose N-
 acetylglucosaminyltransferase 2 (POMGNT2); protein-O-mannose kinase (POMK);
 isoprenoid synthase domain containing (ISPD); plectin (PLEC); cholinergic receptor
 nicotinic epsilon subunit (CHRNE); choline O-acetyltransferase (CHAT); choline
 30 kinase β (CHKB); collagen like tail subunit of asymmetric acetylcholinesterase
 (COLQ); receptor associated protein of the synapse (RAPSIN); four and a half LIM
 domains 1 (FHL1); β -1,4-glucuronyltransferase 1 (B4GAT1); β -1-N-
 acetylgalactosaminyltransferase 2 (B3GALNT2); dystroglycan 1 (DAG1);
 transmembrane protein 5 (TMEM5); transmembrane protein 43 (TMEM43); SECIS

binding protein 2 (SECISBP2); glucosamine (UDP-N-acetyl)-2-epimerase/N-acetylmannosamine kinase (GNE); anoctamin 5 (ANO5); structural maintenance of chromosomes flexible hinge domain containing 1 (SMCHD1); lactate dehydrogenase A (LDHA); lactate dehydrogenase B (LHDB); calpain 3 (CAPN3); caveolin 3 (CAV3);

5 tripartite motif containing 32 (TRIM32); CCHC-type zinc finger nucleic acid binding protein (CNBP); nebulin (NEB); actin, ccl, skeletal muscle (ACTA1); actin, ccl, cardiac muscle (ACTC1); actinin cc2 (ACTN2); poly(A)-binding protein nuclear 1 (PABPN1); LEM domain-containing protein 3 (LEMD3); zinc metalloproteinase STE24 (ZMPSTE24); microsomal triglyceride transfer protein (MTTP); a cholinergic receptor

10 nicotinic ccl subunit; a tocopherol transferase protein (TPPA); kinesin family member 21 A (KIF21 A); paired-like homeobox 2a (PHOX2A); heparan sulfate proteoglycan 2 (HSPG2); stromal interaction molecule 1 (STIM1); notch 1 (NOTCH1); notch 3 (NOTCH3); dystrobrevin a (DTNA); protein kinase AMP- activated, noncatalytic j2 (PRKAG2); cysteine- and glycine-rich protein 3 (CSRP3); vinculin (VCL); myozenin

15 2 (MyoZ2); myopalladin (MYPN); junctophilin 2 (JPH2); phospholamban (PLN); calreticulin 3 (CALR3); nexilin F-actin-binding protein (NEXN); LIM domain binding 3 (LDB3); eyes absent 4 (EYA4); huntingtin (HTT); androgen receptor (AR); protein tyrosine phosphate non-receptor type 11 (PTPN1 1); junction plakoglobin (JUP); desmoplakin (DSP); plakophilin 2 (PKP2); desmoglein 2 (DSG2); desmocollin 2

20 (DSC2); catenin cc3 (CTNNA3); NK2 homeobox 5 (NKX2-5); A-kinase anchor protein 9 (AKAP9); A-kinase anchor protein 10 (AKAP10); guanine nucleotide-binding protein a- inhibiting activity polypeptide 2 (GNAI2); ankyrin 2 (ANK2); syntrophin cc-1 (SNTA1); calmodulin 1 (CALM1); calmodulin 2 (CALM2); HTRA serine peptidase 1 (HTRA1); fibrillin 1 (FBN1); fibrillin 2 (FBN2); xylosyltransferase

25 1 (XYLT1); xylosyltransferase 2 (XYLT2); tafazzin (TAZ); homogentisate 1 ,2-dioxygenase (HGD); glucose-6-phosphatase catalytic subunit (G6PC); 1,4-alpha-glucan enzyme 1 (GBE1); phosphofructokinase, muscle (PFKM); phosphorylase kinase regulatory subunit alpha 1 (PHKA1); phosphorylase kinase regulatory subunit alpha 2 (PHKA2); phosphorylase kinase regulatory subunit beta (PHKB); phosphorylase

30 kinase catalytic subunit gamma 2 (PHKG2); phosphoglycerate mutase 2 (PGAM2); cystathionine-beta-synthase (CBS); methylenetetrahydrofolate reductase (MTHFR); 5-methyltetrahydro folate-homocysteine methyltransferase (MTR); 5 -methyl tetrahydrofolate-homocysteine methyltransferase reductase (MTRR); methylmalonic aciduria and homocystinuria, cbld type (MMADHC); mitochondrial DNA, including,

but not limited to mitochondrially encoded NADH:ubiquinone oxidoreductase core subunit 1 (MT-ND1); mitochondrially encoded NADH:ubiquinone oxidoreductase core subunit 5 (MT-ND5); mitochondrially encoded tRNA glutamic acid (MT-TE); mitochondrially encoded tRNA histidine (MT-TH); mitochondrially encoded tRNA leucine 1 (MT-TL1); mitochondrially encoded tRNA lysine (MT-TK); mitochondrially encoded tRNA serine 1 (MT-TS1); mitochondrially encoded tRNA valine (MT-TV); mitogen- activated protein kinase 1 (MAP2K1); B-Raf proto-oncogene, serine/threonine kinase (BRAF); raf-1 proto-oncogene, serine/threonine kinase (RAF1); growth factors, including, but not limited to insulin growth factor 1 (IGF-1); transforming growth factor β 3 (TGF 3); transforming growth factor β receptor, type I (TGF R1); transforming growth factor β receptor, type II (TGF R2), fibroblast growth factor 2 (FGF2), fibroblast growth factor 4 (FGF4), vascular endothelial growth factor A (VEGF-A), vascular endothelial growth factor B (VEGF-B); vascular endothelial growth factor C (VEGF-C), vascular endothelial growth factor D (VEGF-D), vascular endothelial growth factor receptor 1 (VEGFR1), and vascular endothelial growth factor receptor 2 (VEGFR2); interleukins; immunoadhesins; cytokines; and antibodies. In some embodiments, genes that encode products that are immunomodulators are delivered. Exemplary immunomodulatory genes include cytokines, chemokines, and the fusion proteins or antibodies that are specific for them and/or their receptors, *e.g.* the anti-IL-6 fusion protein Rilonacept 1, the Complement Factor H-specific antibody lampalizumab, etc.

[00336] In some embodiments, genes encoding a site-specific endonuclease are delivered. Exemplary endonucleases include naturally occurring restriction enzymes and the like. In some embodiments, the endonucleases delivered include zinc finger nucleases, TALENs, megaTALs, meganucleases, CRISPR/Cas systems including Cas9, CasX, CasY and the like. Such site-specific nucleases can be engineered to cut specific locations within a genome, and non-homologous end joining can then repair the break while inserting or deleting several nucleotides (also referred to as "INDELs"). Such site-specific endonucleases then throw the protein out of frame and effectively knock out the gene.

[00337] In some embodiments of the variant rAAV vector disclosed herein, a nucleotide sequence encoding a gene product of interest is operably linked to a constitutive promoter. Suitable constitutive promoters include *e.g.* cytomegalovirus promoter (CMV) (Stinski *et al.* (1985) *Journal of Virology* 55(2): 431 -441), CMV

early enhancer/chicken β -actin (CBA) promoter/rabbit β -globin intron (CAG) (Miyazaki *et al.* (1989) *Gene* 79(2): 269-277, CBSB (Jacobson *et al.* (2006) *Molecular Therapy* 13(6): 1074-1084), human elongation factor 1 α promoter (EF1 α) (Kim *et al.* (1990) *Gene* 91 (2): 217-223), human phosphoglycerate kinase promoter (PGK) (Singer-Sam *et al.* (1984) *Gene* 32(3): 409-417, mitochondrial heavy-strand promoter (Loderio *et al.* (2012) *Proc Natl Acad Sci USA* 109(17): 6513-6518), ubiquitin promoter (Wulff *et al.* (1990) *FEBS Letters* 261 : 101 -105). In other embodiments, a nucleotide sequence encoding a gene product of interest is operably linked to an inducible promoter. In some instances, a nucleotide sequence encoding a gene product of interest is operably linked to a tissue-specific or cell type- specific regulatory element. For example, in some instances, a nucleotide sequence encoding a gene product of interest is operably linked to a liver-specific regulatory element (*e.g.*, a liver specific promoter), *e.g.*, a regulatory element that confers selective expression of the operably linked gene in a liver cell. Suitable liver-specific regulatory elements include, *e.g.*, the albumin promoter, the α 1-antitrypsin, and the transthyretin promoter (TTR). In some instances, a gene of interest is operably linked to a CNS specific promoter or regulatory element. Suitable CNS specific promoters include, but are not limited to, the GFAP promoter (astrocytes), SYN1 promoter (neurons) and the NSE/RU5' promoter (mature neurons). In some instances, a gene of interest is operably linked to a ligand responsive promoter or molecular switch (for example, the TetR system (Berens and Hillen (2003) *Eur J Biochem* 270: 3109-3121).

[00338] As noted above, the compositions and methods described herein can be used for gene modification, gene correction, and gene disruption.

[00339] The compositions and methods described herein can also be applied to stem cell based therapies, including but not limited to editing that results in: correction of somatic cell mutations; disruption of dominant negative alleles; disruption of genes required for the entry or productive infection of pathogens into cells; enhanced tissue engineering, for example, by editing gene activity to promote the differentiation or formation of functional tissues; and/or disrupting gene activity to promote the differentiation or formation of functional tissues; blocking or inducing differentiation, for example, by editing genes that block differentiation to promote stem cells to differentiate down a specific lineage pathway. Cell types for this procedure include but are not limited to, T-cells, B cells, hematopoietic stem cells, and embryonic stem cells. Additionally, induced pluripotent stem cells (iPSC) may be used which would also be

generated from a patient's own somatic cells. Therefore, these stem cells or their derivatives (differentiated cell types or tissues) could be potentially engrafted into any person regardless of their origin or histocompatibility.

[00340] The compositions and methods can also be used for somatic cell therapy, thereby allowing production of stocks of cells that have been modified to enhance their biological properties. Such cells can be infused into a variety of patients, independent of the donor source of the cells and their histocompatibility to the recipient.

[00341] In addition to therapeutic applications, the DNA-editing complexes described herein can be used for cell line engineering and the construction of disease models.

10 EXAMPLES

Example 1: Library construction

[00342] *Overview:* The methods and compositions disclosed herein are useful in designing and identifying AAV capsids that can be used for a variety of applications including specific delivery to tissues, cells or organelles, and to the discovery of AAV capsids that are capable of evading anti-AAV neutralizing antibodies that may be present in patients to be dosed using AAV. The methods describe insertion of random sequences (libraries) into one of the surface-exposed loops and/or hypervariable regions in the AAV capsid protein to confer new and/or improved attributes to the AAV. The methods also include the insertion of the random sequences into the capsid proteins of many naturally occurring AAV serotypes producing several AAV libraries for screening. The libraries of these AAV variants are then injected into animals or used to infect cell lines. To aid in the identification of AAV variants that are capable of enhanced transduction of desired tissues, cells or organelles, the genome of the AAV variants may comprise a fluorescent reporter protein for tracking the delivery and transgene expression of the AAV. In some embodiments, the reporter protein is linked to a barcode that is bioinformatically associated with the random sequences inserted into the capsid gene. In some embodiments, the AAV libraries are subject to *in vivo* selection wherein nuclei in the desired tissue and/or cells are isolated following exposure to the AAV variant libraries. The inserted sequences can be then identified through sequencing of the associated barcode, or by purification and sequencing of AAV payload nucleic acid from cells expressing the reporter gene. The selected AAV nucleic acid sequence can then be analyzed to determine the parent AAV serotype comprising the inserted sequences as well as determining the inserted amino acids

themselves. The process may be repeated 2, 3 or more rounds where the AAV variants isolated from the first round are pooled or synthesized and used to inject a second set of animals or another set of cells to further bolster confidence in the specificity and performance of the isolated AAV variants.

- 5 [00343] *Construction:* Capsid libraries were constructed by insertion of peptides into the exposed loops of the capsid proteins. Libraries comprising insertions that encoded 7, 10 or 15 amino acid peptides were made in the capsid proteins of AAVs 1, 2, 3B, 5, 6, 8 and 9. The AAV capsid sequences were each manufactured synthetically (ATUM). Prior to insertion of the sequences encoding the peptides, silent mutations were
- 10 introduced into the areas encoding the capsid proteins adjacent to the insertion site. In this way, the same set of primers (*e.g.* DO112_MiCap1_VRVIII_Fwd and DO113_MiCap1_VRVIII_Rev) could be used on all libraries (see Fig. 1). In addition, restriction enzyme sites needed for molecular cloning including HindIII, AgeI, and BsaI were ablated by silent mutagenesis. Table 1 below shows the wildtype sequences for
- 15 each capsid gene in the region that the mutations were introduced. Mutated nucleotides are indicated in bold. The resulting sequences can be amplified with a conserved NGS primer pair.

- [00344] A similar approach was used to design conserved primer binding sites flanking other variable regions or surface exposed loops in the capsid gene. The full
- 20 capsid gene nucleotide sequences that were synthesized are included below:

Table 1: Positions of silent mutations for primer binding sites flanking the VR-VIII insertion region

Capsid	Wildtype Forward Sequence (Nucleotides for mutation in bold)	aa positions	Wildtype Reverse Sequence (Nucleotides for mutation in bold)	aa positions
AAV1	TAACCCTGTGGCCA CCGAA (SEQ ID NO:33)	571	GACGTGTACCTGCAG GGTCCC (SEQ ID NO:34)	612, 617
AAV2	CAATCCCGTGGCTA CGGAG (SEQ ID NO:35)	568, 569, 572, 573, 574	GATGTGTACCTTCAG GGGCCC (SEQ ID NO:36)	610, 611, 613, 615, 616, 617
AAV3B	CAATCCTGTGGCAA CAGAG (SEQ ID NO:37)	569, 570, 571, 573, 574, 575	GACGTGTACCTTCAA GGACCT (SEQ ID NO:38)	612, 614, 615, 616
AAV6	TAACCCCGTGGCCA CCGAA	N/A	GACGTATACCTGCAG GGTCCT	N/A

	(SEQ ID NO:39)		(SEQ ID NO:40)	
AAV8	TAACCTGTGGCTA CAGAG (SEQ ID NO:41)	573, 575, 576, 577	GACGTGTACCTGCAG GGTCCC (SEQ ID NO:42)	614, 619
AAV9	TAACCCGGTAGCAA CGGAG (SEQ ID NO:43)	571, 572, 573, 574, 575	GATGTGTACCTGCAA GGACCC (SEQ ID NO:44)	611, 612, 615, 616, 617

[00345] AAV1 synthesized VP1 capsid gene (SEQ ID No: 45)

5 ATGGCTGCCGATGGTTATCTTCCAGATTGGCTCGAGGACAACCTCTCTGAG
GGCATTCGCGAGTGGTGGGACTTGAAACCTGGAGCCCCGAAGCCCAAAGC
CAACCAGCAAAAGCAGGACGACGGCCGGGTCTGGTGCTTCCTGGCTACA
AGTACCTCGGACCCTTCAACGGACTCGACAAGGGGGAGCCCGTCAACGCG
GCGGACGCAGCGGCCCTCGAGCACGACAAGGCCTACGACCAGCAGCTCA
AAGCGGGTGACAATCCGTACCTGCGGTATAACCACGCCGACGCCGAGTTT
10 CAGGAGCGTCTGCAAGAAGATACGTCTTTTGGGGGCAACCTCGGGCGAGC
AGTCTTCCAGGCCAAGAAGCGGGTTCTCGAACCTCTCGGTCTGGTTGAGG
AAGGCGCTAAGACGGCTCCTGGAAAGAAACGTCCGGTAGAGCAGTCGCC
ACAAGAGCCAGACTCCTCCTCGGGCATCGGCAAGACAGGCCAGCAGCCC
GCTAAAAAGAGACTCAATTTTGGTCAGACTGGCGACTCAGAGTCAGTCCC
15 CGATCCACAACCTCTCGGAGAACCTCCAGCAACCCCCGCTGCTGTGGGAC
CTACTACAATGGCTTCAGGCGGTGGCGCACCAATGGCAGACAATAACGAA
GGCGCCGACGGAGTGGGTAATGCCTCAGGAAATTGGCATTGCGATTCCAC
ATGGCTGGGCGACAGAGTCATCACCACCAGCACCCGCACCTGGGCCTTGC
CCACCTACAATAACCACCTCTACAAGCAAATCTCCAGTGCTTCAACGGGG
20 GCCAGCAACGACAACCACTACTTCGGCTACAGCACCCCCTGGGGGTATTT
TGATTTCAACAGATTCCACTGCCACTTTTACCACGTGACTGGCAGCGACT
CATCAACAACAATTGGGGATTCCGGCCCAAGAGACTCAACTTCAAACCTCT
TCAACATCCAAGTCAAGGAGGTCACGACGAATGATGGCGTCACAACCATC
GCTAATAACCTTACCAGCACGGTTCAGTCTTCTCGGACTCGGAGTACCA
25 GCTTCCGTACGTCCTCGGCTCTGCGCACCAAGGGCTGCCTCCCTCCGTTCCC
GGCGGACGTGTTTCATGATTCCGCAATACGGCTACCTGACGCTCAACAATG
GCAGCCAAGCCGTGGGACGTTTCATCCTTTTACTGCCTGGAATATTTCCCTT
CTCAGATGCTGAGAACGGGCAACAACCTTTACCTTCAGCTACACCTTTGAG
GAAGTGCCTTTCCACAGCAGCTACGCGCACAGCCAGAGCCTGGACCGGCT
30 GATGAATCCTCTCATCGACCAGTACCTGTATTACCTGAACAGAACTCAAA
ATCAGTCCGGAAGTGCCCAAAACAAGGACTTGCTGTTTAGCCGTGGATCT
CCAGCTGGCATGTCTGTTTCAGCCCAAAAACCTGGCTACCTGGACCCCTGTTAC
CGGCAGCAGCGCGTTTCTAAAACAAAAACAGACAACAACAACAGCAATT
TTACCTGGACTGGTGCTTCAAAATATAACCTCAATGGGCGTGAATCCATC
35 ATCAACCCTGGCACTGCTATGGCCTCACACAAAGACGACGAAGACAAGTT
CTTTCCCATGAGCGGTGTCATGATTTTTTGAAAAGAGAGCGCCGGAGCTT
CAAACACTGCATTGGACAATGTCATGATTACAGACGAAGAGGAAATTTAA
GCCACTAACCCCGTGGCCACCGAAAGATTGGGACCGTGGCAGTCAATTT
CCAGAGCAGCAGCACAGACCCTGCGACCGGAGATGTGCATGCTATGGGA
40 GCATTACCTGGCATGGTGTGGCAAGATAGAGACGTATACCTGCAGGGTCC
TATTTGGGCCAAAATTCCTCACACAGATGGACACTTTCACCCGTCTCCTCT
TATGGGCGGCTTTGGACTCAAGAACCCGCCTCCTCAGATCCTCATCAAAA

ACACGCCTGTTCTCCTGCGAATCCTCCGGCGGAGTTTTTCAGCTACAAAGTTTG
CTTCATTCATCACCCAATACTCCACAGGACAAGTGAGCGTGGAGATTGAA
TGGGAGCTGCAGAAAGAAAACAGCAAGCGCTGGAATCCCGAAGTGCAGT
ACACATCCAATTATGCAAAATCTGCCAACGTTGATTTTACTGTGGACAAC
5 AATGGACTTTATACTGAGCCTCGCCCCATTGGCACCCGTTACCTTACCCGT
CCCCTGTAA

[00346] AAV2 synthesized VP1 capsid gene (SEQ ID No: 46)
ATGGCTGCCGATGGTTATCTTCCAGATTGGCTCGAGGACACTCTCTCTGAA
10 GGAATAAGACAGTGGTGGAAGCTCAAACCTGGCCCACCACCACCAAAGC
CCGCAGAGCGGCATAAGGACGACAGCAGGGGTCTTGTGCTTCTGGGTAC
AAGTACCTCGGACCCTTCAACGGACTCGACAAGGGAGAGCCGGTCAACG
AGGCAGACGCCGCGGCCCTCGAGCACGACAAAGCCTACGACCGGCAGCT
CGACAGCGGAGACAACCCGTACCTCAAGTACAACCACGCCGACGCGGAG
15 TTTCAGGAGCGCCTTAAAGAAGATACGTCTTTTGGGGGCAACCTCGGACG
AGCAGTCTTCCAGGCGAAAAAGAGGGTCTTGAACCTCTGGGCCTGGTTG
AGGAACCTGTAAAGACGGCTCCGGGAAAAAAGAGGCCGGTAGAGCACTC
TCCTGTGGAGCCAGACTCCTCCTCGGGAACCGGAAAGGCCGGGCCAGCAGC
CTGCAAGAAAAAGACTCAATTTTGGTCAGACTGGCGACGCAGACTCAGTA
20 CCTGACCCCCAGCCTCTCGGACAGCCACCAGCAGCCCCCTCTGGTCTGGG
AACTAATACGATGGCTACAGGCAGTGGCGCACCAATGGCAGACAATAAC
GAGGGCGCCGACGGAGTGGGTAAATCCTCGGGAAATTGGCATTGCGATTG
CACATGGATGGGCGACAGAGTCATCACCACCAGCACCCGAACCTGGGCCC
TGCCACCTACAACAACCACCTCTACAAACAAATTTCCAGCCAATCAGGA
25 GCCTCGAACGACAATCACTACTTTGGCTACAGCACCCCCCTGGGGGTATTTT
GATTTCAACAGATTCCACTGCCACTTTTACCACGTGACTGGCAAAGACTC
ATCAACAACAACCTGGGGATTCCGACCCAAGAGACTCAACTTCAAGCTCTT
TAACATTCAAGTCAAAGAGGTACGCAGAATGACGGTACGACGACGATTG
CCAATAACCTTACCAGCACGGTTCAGGTGTTTACTGACTCGGAGTACCAG
30 CTCCCGTACGTCTCTCGGCTCGGCGCATCAAGGCTGCCTCCCTCCGTCCCG
GCGGACGTCTTCATGGTGCCACAGTATGGATACCTCACCTGAACAACGG
GAGTCAGGCAGTAGGACGCTCTTCATTTTACTGCCTGGAGTACTTTCTTC
TCAGATGCTGCGTACCGGAAACAACCTTTACCTTCAGCTACACTTTTGAGGA
CGTTCCTTTCCACAGCAGCTACGCTCACAGCCAGAGTCTGGACCGTCTCAT
35 GAATCCTCTCATCGACCAGTACCTGTATTACCTGAGCAGAACAAACACTC
CAAGTGGAACCACCACGCAGTCAAGGCTTCAGTTTTCTCAGGCCGGAGCG
AGTGACATTCGGGACCAGTCTAGGAACTGGCTTCCTGGACCCTGTTACCG
GCAGCAGCGAGTATCAAAGACATCTGCGGATAACAACAACAGTGAATAC
TCGTGGACTGGAGCTACCAAGTACCACCTCAATGGCAGAGACTCTCTGGT
40 GAATCCGGGCCCCGGCCATGGCAAGCCACAAGGACGATGAAGAAAAGTTT
TTTCCTCAGAGCGGGGTCTCATCTTTGGGAAGCAAGGCTCAGAGAAAAC
AAATGTGGACATTGAAAAGGTCATGATTACAGACGAAGAGGAAATCAGG
ACAATAACCCCGTGGCCACCGAACAGTATGGTTCTGTATCTACCAACCT
CCAGAGAGGCAACAGACAAGCAGCTACCGCAGATGTCAACACACAAGGC
45 GTTCTTCCAGGCATGGTCTGGCAGGACAGAGACGTATACCTGCAGGGTCC
TATTTGGGCAAAGATTCCACACACGGACGGACATTTTCACCCCTCTCCCCT
CATGGGTGGATTTCGGACTTAAACACCCTCCTCCACAGATTCTCATCAAGA
ACACCCCGGTACCTGCGAATCCTTCGACCACCTTCAGTGCGGCAAAGTTT
GCTTCCTTCATCACACAGTACTCCACGGGACAGGTCAGCGTGGAGATTGA
50 ATGGGAGCTGCAGAAGGAAAACAGCAAACGCTGGAATCCCGAAATTCAG

TACACTTCCAACACTACAACAAGTCTGTTAATGTGGACTTTACTGTGGACACT
AATGGCGTGTATTTCAGAGCCTCGCCCCATTGGCACCAGATACCTGACTCG
TAATCTGTAA

- 5 [00347] AAV3B synthesized VP1 capsid gene (SEQ ID No: 47)
ATGGCTGCTGACGGTTATCTTCCAGATTGGCTCGAGGACAACCTTTCTGAA
GGCATTTCGTGAGTGGTGGGCTCTGAAACCTGGAGTCCCTCAACCCAAAGC
GAACCAACAACACCAGGACAACCGTCGGGGTCTTGTGCTTCCGGGTACA
AATACCTCGGACCCGTAACGGACTCGACAAAGGAGAGCCGGTCAACGA
10 GGCGGACGCGGCAGCCCTCGAACACGACAAAAGCCTACGACCAGCAGCTC
AAGGCCGGTGACAACCCGTACCTCAAGTACAACCACGCCGACGCCGAGTT
TCAGGAGCGTCTTCAAGAAGATACGTCTTTTGGGGGCAACCTTGGCAGAG
CAGTCTTCCAGGCCAAAAAGAGGATCCTTGAGCCTCTTGGTCTGGTTGAG
GAAGCAGCTAAAACGGCTCCTGGAAAGAAGAGGCCTGTAGATCAGTCTCC
15 TCAGGAACCGGACTCATCATCTGGTGTGGCAAATCGGGCAAACAGCCTG
CCAGAAAAAGACTCAATTTTGGTCAGACTGGCGACTCAGAGTCAGTCCCA
GACCCTCAACCTCTCGGAGAACCACCAGCAGCCCCACAAGTTTGGGATC
TAATACAATGGCTTCAGGCGGTGGCGCACCAATGGCAGACAATAACGAG
GGTGCCGATGGAGTGGGTAAATCCTCAGGAAATTGGCATTGCGATTCCCA
20 ATGGCTGGGCGACAGAGTCATCACCACCAGCACCCGAACCTGGGCCCTGC
CCACTTACAACAACCATCTCTACAAGCAAATCTCCAGCCAATCAGGAGCT
TCAAACGACAACCACTACTTTGGCTACAGCACCCCTGGGGGTATTTTATG
TTCAACAGATTCCACTGCCACTTCTCACCACGTGACTGGCAGCGACTCATT
AACAACAACCTGGGGATTCCGGCCCCAAGAACTCAGCTTCAAGCTCTTCAA
25 CATCCAAGTTAAAGAGGTCACGCAGAACGATGGCACGACGACTATTGCCA
ATAACCTTACCAGCACGGTTCAAGTGTTCACGGACTCGGAGTATCAGCTC
CCGTACGTGCTCGGGTCGGCGCACCAAGGCTGCCTCCCTCCGTTCCCGGC
GGACGTCTTCATGGTCCCTCAGTATGGATACCTCACCTGAACAACGGAA
GTCAAGCGGTGGGACGCTCATCCTTTTACTGCCTGGAGTACTTCCCTTCGC
30 AGATGCTAAGGACTGGAAATAACTTCCAATTACAGCTATACCTTCGAGGAT
GTACCTTTTCACAGCAGCTACGCTCACAGCCAGAGTTTGGATCGCTTGATG
AATCCTCTCATCGACCAGTACCTGTATTACCTGAACAGAACGCAAGGAAC
AACCTCTGGAACAACCAACCAATCACGGCTGCTTTTTAGCCAGGCTGGGC
CTCAGTCTATGTCTTTGCAGGCCAGAAATTGGCTACCTGGACCCTGTTACC
35 GGCAGCAGAGACTTTCAAAGACTGCTAACGACAACAACAACAGTAACTTT
CCTTGGACAGCGGCCAGCAAATATCATCTCAATGGCCGCGACTCGCTGGT
GAATCCAGGACCAGCTATGGCCAGTCACAAGGACGATGAAGAAAAATTTT
TCCCTATGCACGGCAATCTAATATTTGGCAAAGAAGGGACAACGGCAAGT
AACGCAGAAATTAGATAATGTAATGATTACGGATGAAGAAGAGATTCGTAC
40 CACTAACCCCGTGGCCACCGAACAGTATGGAACGTGGCAAATAACTTGC
AGAGCTCAAATACAGCTCCCACGACTAGAACTGTCAATGATCAGGGGGGCC
TTACCTGGCATGGTGTGGCAAGATCGTGACGTATACCTGCAGGGTCTTAT
TGGGCAAAGATTCTCTCACACGGATGGACACTTTCATCCTTCTCCTCTGATG
GGAGGCTTTGGACTGAAACATCCGCCTCTCAAATCATGATCAAAAATAC
45 TCCGGTACCGGCAAATCCTCCGACGACTTTCAGCCCGGCCAAGTTTGCTTC
ATTTATCACTCAGTACTCCACTGGACAGGTCAGCGTGGAGATTGAATGGG
AGCTGCAGAAAGAAAACAGCAAACGTTGGAATCCAGAGATTCAGTACAC
TTCCAACACTACAACAAGTCTGTTAATGTGGACTTTACTGTAGACACTAATGG

TGTTTATAGTGAACCTCGCCCTATTGGAACCCGGTATCTCACACGAAACTT
GTGA

[00348] AAV5 synthesized VP1 capsid gene (SEQ ID No: 48)

5 ATGTCTTTTGGTTGATCACCTCCAGATTGGTTGGAAGAAGTTGGTGAAGGT
CTTCGCGAGTTTTTGGGCCTTGAAGCGGGCCACCGAAACCAAAACCCAA
TCAGCAGCATCAAGATCAAGCCCGTGGTCTTGTGCTGCCTGGTTATAACTA
TCTCGGACCCGGAACGGACTCGATCGAGGAGAGCCTGTCAACAGGGCA
GACGAGGTGCGCGAGAGCACGACATCTCGTACAACGAGCAGCTTGAGG
10 CGGGAGACAACCCCTACCTCAAGTACAACCACGCGGACGCCGAGTTTCAG
GAGAAGCTCGCCGACGACACATCCTTCGGGGGAAACCTCGGAAAGGCAG
TCTTTCAGGCCAAGAAAAGGGTTCTCGAACCTTTTGGCCTGGTTGAAGAG
GGTGCTAAGACGGCCCCCTACCGGAAAGCGGATAGACGACCACTTTCCAAA
AAGAAAGAAGGCTCGGACCGAAGAGGACTCCAAGCCTTCCACCTCGTCA
15 GACGCCGAAGCTGGACCCAGCGGATCCAGCAGCTGCAAATCCCAGCCCA
ACCAGCCTCAAGTTTGGGAGCTGATACAATGTCTGCGGGAGGTGGCGGCC
CATTGGGCGACAATAACCAAGGTGCCGATGGAGTGGGCAATGCCTCGGG
AGATTGGCATTGCGATTCCACGTGGATGGGGGACAGAGTCGTCACCAAGT
CCACCCGAACCTGGGTGCTGCCCAGCTACAACAACCACCAGTACCGAGAG
20 ATCAAAAGCGGCTCCGTGACGGAAGCAACGCCAACGCCTACTTTGGATA
CAGCACCCCTGGGGGTACTTTGACTTTAACCGCTTCCACAGCCACTGGA
GCCCCCGAGACTGGCAAAGACTCATCAACAATACTGGGGCTTCAGACCC
CGGTCCCTCAGAGTCAAAATCTTCAACATTCAAGTCAAAGAGGTCACGGT
GCAGGACTCCACCACCACCATCGCCAACAACCTCACCTCCACCGTCCAAG
25 TGTTTACGGACGACGACTACCAGCTGCCCTACGTCGTCGGCAACGGGACC
GAGGGATGCCTGCCGGCCTTCCCTCCGCAGGTCTTTACGCTGCCGCAGTAC
GGTTACGCGACGCTGAACCGCGACAACACAGAAAATCCCACCGAGAGGA
GCAGCTTCTTCTGCCTAGAGTACTTTCCAGCAAGATGCTGAGAACGGGC
AACAACTTTGAGTTTACCTACAACCTTTGAGGAGGTGCCCTTCCACTCCAGC
30 TTCGCTCCCAGTCAGAACCTGTTCAAGCTGGCCAACCCGCTGGTGGACCA
GTACTTGTACCGCTTCGTGAGCACAAATAAATACTGGCGGAGTCCAGTTCA
ACAAGAACCTGGCCGGGAGATACGCCAACACCTACAAAACTGGTTCCCG
GGGCCCATGGGGCCGAACCCAGGGCTGGAACCTGGGCTCCGGGGTCAACC
GCGCCAGTGTGACGCGCTTCGCCACGACCAATAGGATGGAGCTCGAGGGC
35 GCGAGTTACAGGTGCCCCCGCAGCCGAACGGCATGACCAACAACCTCCA
GGGCAGCAACACCTATGCCCTGGAGAACACTATGATCTTCAACAGCCAGC
CGGCGAACCCGGGCACCACCGCCACGTACCTCGAGGGCAACATGCTCATC
ACCAGCGAGAGCGAGACGACGCGCGGTGAACCGCGTGGCGTACAACGTCG
GCGGGCAGATGGCCACCAACAACAGAGCTCCACCACTGCCCCCGCGACC
40 GGCACGTACAACCTCCAGGAAATCGTGCCCGGCAGCGTGTGGATGGAGA
GGGACGTGTACCTCCAAGGACCCATCTGGGCCAAGATCCCAGAGACGGG
GGCGCACTTTCACCCCTCTCCGGCCATGGGCGGATTCGGACTCAAACACC
CACCGCCCATGATGCTCATCAAGAACACGCCTGTGCCCGGAAATATCACC
AGCTTCTCGGACGTGCCCGTCAGCAGCTTCATCACCCAGTACAGCACCGG
45 GCAGGTACCGTGGAGATGGAGTGGGAGCTCAAGAAGGAAAACCTCCAAG
AGGTGGAACCCAGAGATCCAGTACACAACAATACTACAACGACCCCCAGTT

TGTGGACTTTGCCCCGGACAGCACCGGGGAATACAGAACCACCAGACCTA
TCGGAACCCGATACCTTACCCGACCCCTTTAA

[00349] AAV6 synthesized VP1 capsid gene (SEQ ID No: 49)

5 ATGGCTGCCGATGGTTATCTTCCAGATTGGCTCGAGGACAACCTCTCTGAG
GGCATTTCGCGAGTGGTGGGACTTGAAACCTGGAGCCCCGAAACCCAAAGC
CAACCAGCAAAAGCAGGACGACGGCCGGGTCTGGTGCTTCCTGGCTACA
AGTACCTCGGACCCTTCAACGGACTCGACAAGGGGGAGCCCGTCAACGCG
GCGGATGCAGCGGCCCTCGAGCACGACAAGGCCTACGACCAGCAGCTCA
10 AAGCGGGTGACAATCCGTACCTGCGGTATAACCACGCCGACGCCGAGTTT
CAGGAGCGTCTGCAAGAAGATACGTCTTTTGGGGGCAACCTCGGGCGAGC
AGTCTTCCAGGCCAAGAAGAGGGTTCTCGAACCTTTTGGTCTGGTTGAGG
AAGGTGCTAAGACGGCTCCTGGAAGAAACGTCCGGTAGAGCAGTCGCC
ACAAGAGCCAGACTCCTCCTCGGGCATTGGCAAGACAGGCCAGCAGCCCG
15 CTAAGAGAGACTCAATTTTGGTCAAGTGGCGACTCAGAGTCAGTCCCC
GACCCACAACCTCTCGGAGAACCTCCAGCAACCCCGCTGCTGTGGGACC
TACTACAATGGCTTCAGGCGGTGGCGCACCAATGGCAGACAATAACGAAG
GCGCCGACGGAGTGGGTAATGCCTCAGGAAATTGGCATTGCGATTCCACA
TGGCTGGGCGACAGAGTCATCACCACCAGCACCCGAACATGGGCCTTGCC
20 CACCTATAACAACCACCTCTACAAGCAAATCTCCAGTGCTTCAACGGGGG
CCAGCAACGACAACCCTACTTCGGCTACAGCACCCCTGGGGGTATTTT
GATTTCAACAGATTCCACTGCCATTTCTCACCACGTGACTGGCAGCGACTC
ATCAACAACAATTGGGGATTCCGGCCCAAGAGACTCAACTTCAAGCTCTT
CAACATCCAAGTCAAGGAGGTCACGACGAATGATGGCGTCACGACCATCG
25 CTAATAACCTTACCAGCACGGTTCAAGTCTTCTCGGACTCGGAGTACCAGT
TGCCGTACGTCTCGGCTCTGCGCACCAAGGGCTGCCCTCCCTCCGTTCCCGG
CGGACGTGTTTCATGATTCCGCAGTACGGCTACCTAACGCTCAACAATGGC
AGCCAGGCAGTGGGACGGTCATCCTTTTACTGCCTGGAATATTTCCCATCG
CAGATGCTGAGAACGGGCAATAACTTTACCTTCAGCTACACCTTCGAGGA
30 CGTGCTTTCCACAGCAGCTACGCGCACAGCCAGAGCCTGGACCGGCTGA
TGAATCCTCTCATCGACCAGTACCTGTATTACCTGAACAGAACTCAGAATC
AGTCCGGAAGTGCCCAAAACAAGGACTTGCTGTTTAGCCGGGGCTCTCCA
GCTGGCATGTCTGTTTCAGCCCAAAAACCTGGCTACCTGGACCCTGTTACCG
GCAGCAGCGCTTTCTAAAAACAAAACAGACAACAACAACAGCAACTTT
35 ACCTGGACTGGTGTCTTCAAAATATAACCTTAATGGGCGTGAATCTATAAT
CAACCTGGCACTGCTATGGCCTCACACAAAGACGACAAAGACAAGTTCT
TTCCCATGAGCGGTGTCATGATTTTTGGAAAGGAGAGCGCCGGAGCTTCA
AACACTGCATTGGACAATGTCATGATCACAGACGAAGAGGAAATCAAAG
CCACTAACCCCGTGGCCACCGAAAGATTTGGGACTGTGGCAGTCAATCTC
40 CAGAGCAGCAGCACAGACCCTGCGACCGGAGATGTGCATGTTATGGGAG
CCTTACCTGGAATGGTGTGGCAAGACAGAGACGTATACCTGCAGGGTCCT
ATTTGGGCCAAAATTCCTCACACGGATGGACACTTTCACCCGTCTCCTCTC
ATGGGCGGCTTTGGACTTAAGCACCCGCTCCTCAGATCCTCATCAAAAA
CACGCTGTTCCTGCGAATCCTCCGGCAGAGTTTTCGGCTACAAAGTTTGC
45 TTCATTATCACCCAGTATTCCACAGGACAAGTGAGCGTGGAGATTGAAT
GGGAGCTGCAGAAAGAAAACAGCAAACGCTGGAATCCCGAAGTGCAGTA
TACATCTAACTATGCAAAATCTGCCAACGTTGATTTCACTGTGGACAACA

ATGGACTTTATACTGAGCCTCGCCCCATTGGCACCCGTTACCTCACCCGTC
CCCTGTAA

[00350] AAV8 synthesized VP1 capsid gene (SEQ ID No: 50)

5 ATGGCTGCCGATGGTTATCTTCCAGATTGGCTCGAGGACAACCTCTCTGAG
GGCATTTCGCGAGTGGTGGGCGCTGAAACCTGGAGCCCCGAAGCCCAAAG
CCAACCAGCAAAAGCAGGACGACGGCCGGGTCTGGTGCTTCCTGGCTAC
AAGTACCTCGGACCCTTCAACGGACTCGACAAGGGGGAGCCCGTCAACGC
GGCGGACGCAGCGGCCCTCGAGCAGACAAGGCCTACGACCAGCAGCTG
10 CAGGCGGGTGACAATCCGTACCTGCGGTATAACCACGCCGACGCCGAGTT
TCAGGAGCGTCTGCAAGAAGATACGTCTTTTGGGGGCAACCTCGGGCGAG
CAGTCTTCCAGGCCAAGAAGCGGGTTCTCGAACCTCTCGGTCTGGTTGAG
GAAGGCGCTAAGACGGCTCCTGGAAAGAAGAGGCCGGTAGAGCCATCAC
CCCAGCGTTCTCCAGACTCCTCTACGGGCATCGGCAAGAAAGGCCAACAG
15 CCCGCCAGAAAAAGACTCAATTTTGGTCAGACTGGCGACTCAGAGTCAGT
TCCAGACCCTCAACCTCTCGGAGAACCTCCAGCAGCGCCCTCTGGTGTGG
GACCTAATACAATGGCTGCAGGCGGTGGCGCACCAATGGCAGACAATAA
CGAAGGCGCCGACGGAGTGGGTAGTTCCTCGGGAAATTGGCATTGCGATT
CCACATGGCTGGGCGACAGAGTCATCACCACCAGCACCCGAACCTGGGCC
20 CTGCCCACCTACAACAACCACCTCTACAAGCAAATCTCCAACGGGACATC
GGGAGGAGCCACCAACGACAACACCTACTTCGGCTACAGCACCCCTGGG
GGTATTTTGATTTCAACAGATTCCACTGCCACTTTTCACCACGTGACTGGC
AGCGACTCATCAACAACAACCTGGGGATTCCGGCCCAAGAGACTCAGCTTC
AAGCTCTTCAACATCCAGGTCAAGGAGGTCACGCAGAATGAAGGCACCA
25 AGACCATCGCCAATAACCTCACCAGCACCATCCAGGTGTTTACGGACTCG
GAGTACCAGCTGCCGTACGTTCTCGGCTCTGCCACCAGGGCTGCCTCCCT
CCGTTCCCGGCGGACGTGTTTCATGATTCCCCAGTACGGCTACCTAACACTC
AACAACGGTAGTCAGGCCGTGGGACGCTCCTCCTTCTACTGCCTGGAATA
CTTTCCTTCGCAGATGCTGAGAACCGGCAACAACCTCCAGTTTACTTACAC
30 CTTTCGAGGACGTGCCTTTCCACAGCAGCTACGCCACAGCCAGAGCTTGG
ACCGGCTGATGAATCCTCTCATCGACCAGTACCTGTATTACCTGTCTCGGA
CTCAAAACAACAGGAGGCACGGCAAATACGCAGACTCTGGGCTTCAGCCA
AGGTGGGCCTAATACAATGGCCAATCAGGCAAAGAACTGGCTGCCTGGAC
CCTGTTACCGGCAGCAGCGCGTCTCAACGACAACCGGGCAAAACAACAT
35 AGCAACTTTGCCTGGACTGCTGGGACCAAATACCATCTGAATGGAAGAAA
TTCATTGGCTAATCCTGGCATCGCTATGGCAACACACAAAGACGACGAGG
AGCGTTTTTTTCCAGTAACGGGATCCTGATTTTTTGGCAAACAAAATGCTG
CCAGAGACAATGCGGATTACAGCGATGTCATGCTCACCAGCGAGGAAGA
AATCAAAACCACTAACCCCGTGGCCACCGAAGAATACGGTATCGTGGCAG
40 ATAACTTGCAGCAGCAAAACACGGCTCCTCAAATTGGAAGTGTCAACAGC
CAGGGGGCCTTACCCGGTATGGTCTGGCAGAACCGGGACGTATACCTGCA
GGGTCTTATTTGGGCCAAGATTCTCTCACACGGACGGCAACTTCCACCCGT
CTCCGCTGATGGGCGGCTTTGGCCTGAAACATCCTCCGCCTCAGATCCTGA
TCAAGAACACGCCTGTACCTGCGGATCCTCCGACCACCTTCAACCAGTCA
45 AAGCTGAAGTCTTTTCATCACGCAATACAGCACCGGACAGGTCAGCGTGGA
GATTGAATGGGAGCTGCAGAAGGAAAACAGCAAGCGCTGGAACCCCGAG
ATCCAGTACACCTCCAACCTACTACAAATCTACAAGTGTGGACTTTGCTGTT

AATACAGAAGGCGTGTACTCTGAACCCCGCCCCATTGGCACCCGTTACCT
CACCCGTAATCTGTAA

[00351] AAV9 synthesized VP1 capsid gene (SEQ ID No: 51)

5 ATGGCTGCCGATGGTTATCTTCCAGATTGGCTCGAGGACAACCTTAGTGA
AGGAATTCGCGAGTGGTGGGCTTTGAAACCTGGAGCCCCTCAACCCAAGG
CAAATCAACAACATCAAGACAACGCTCGAGGTCTTGTGCTTCCGGGTAC
AAATACCTTGGACCCGGCAACGGACTCGACAAGGGGGAGCCGGTCAACG
CAGCAGACGCGGCGGCCCTCGAGCACGACAAGGCCTACGACCAGCAGCT
10 CAAGGCCGGAGACAACCCGTACCTCAAGTACAACCACGCCGACGCCGAG
TTCCAGGAGCGGCTCAAAGAAGATACGTCTTTTGGGGGCAACCTCGGGCG
AGCAGTCTTCCAGGCCAAAAAGAGGCTTCTTGAACCTCTTGGTCTGGTTG
AGGAAGCGGCTAAGACGGCTCCTGGAAAGAAGAGGCCTGTAGAGCAGTC
TCCTCAGGAACCGGACTCCTCCGCGGGTATTGGCAAATCGGGTGCACAGC
15 CCGCTAAAAAGAGACTCAATTTTGGTTCAGACTGGCGACACAGAGTCAGTC
CCAGACCCTCAACCAATCGGAGAACCTCCCGCAGCCCCCTCAGGTGTGGG
ATCTCTTACAATGGCTTCAGGTGGTGGCGCACCAGTGGCAGACAATAACG
AAGGTGCCGATGGAGTGGGTAGTTCCTCGGGAAATTGGCATTGCGATTCC
CAATGGCTGGGCGACAGAGTCATCACCACCAGCACCCGAACCTGGGCCCT
20 GCCCACCTACAACAATCACCTCTACAAGCAAATCTCCAACAGCACATCTG
GAGGATCTTCAAATGACAACGCCTACTTCGGCTACAGCACCCCTGGGGG
TATTTTGATTTCAACAGATTCCACTGCCATTTCTCACCACGTGACTGGCAG
CGACTCATCAACAACAACCTGGGGATTCCGGCCTAAGCGACTCAACTTCAA
GCTCTTCAACATTCAGGTCAAAGAGGTTACGGACAACAATGGAGTCAAGA
25 CCATCGCCAATAACCTTACCAGCACGGTCCAGGTCTTCACGGACTCAGAC
TATCAGCTCCCGTACGTGCTCGGGTCGGCTCACGAGGGCTGCCTCCCTCCG
TTCCCGGCGGACGTTTTTCATGATTCTCAGTACGGGTATCTGACGCTTAAT
GATGGAAGCCAGGCCGTGGGTGCTTCGTCCTTTTACTGCCTGGAATATTTT
CCGTCGCAAATGCTAAGAACGGGTAACAACCTTCCAGTTCAGTACGAGTT
30 TGAGAACGTACCTTTCCATAGCAGCTACGCTCACAGCCAAAGCCTGGACC
GACTAATGAATCCACTCATCGACCAGTACCTGTATTACCTGTCAAAGACT
ATTAACGGTTCTGGACAGAATCAACAACGCTAAAATTCAGTGTGGCCGG
ACCCAGCAACATGGCTGTCCAGGGAAGAACTACATACTGGACCCTGTT
ACCGGCAGCAGCGTGTCTCAACCACTGTGACTCAAAACAACAACAGCGAA
35 TTTGCTTGGCCTGGAGCTTCTTCTTGGGCTCTCAATGGACGTAATAGCTTG
ATGAATCCTGGACCTGCTATGGCCAGCCACAAAGAAGGAGAGGACCGTTT
CTTTCCTTTGTCTGGATCTTTAATTTTGGCAAACAAGGAACCTGGAAGAGA
CAACGTGGATGCGGACAAAGTCATGATAACCAACGAAGAAGAAATTAAA
ACTACTAACCCCGTGGCCACCGAATCCTATGGACAAGTGGCCACAAACCA
40 CCAGAGTGCCCAAGCACAGGCGCAGACCGGCTGGGTTCAAAACCAAGGA
ATACTTCCGGGTATGGTTTGGCAGGACAGAGACGTATACCTGCAGGGTCC
TATTTGGGCCAAAATTCCTCACACGGACGGCAACTTTCACCCTTCTCCGCT
GATGGGAGGGTTTGGAAATGAAGCACCCGCCTCCTCAGATCCTCATAAAA
ACACACCTGTACCTGCGGATCCTCCAACGGCCTTCAACAAGGACAAGCTG
45 AACTCTTTCATCACCCAGTATTCTACTGGCCAAGTCAGCGTGGAGATTGAA
TGGGAGCTGCAGAAGGAAAACAGCAAGCGCTGGAACCCGGAGATCCAGT
AACTTCCAACCTATTACAAGTCTAATAATGTTGAATTTGCTGTTAATACTG

AAGGTGTATATAGTGAACCCCGCCCCATTGGCACCAGATACCTGACTCGT
AATCTGTAA

- [00352] AAV1 VP1 capsid protein (SEQ ID No: 206)
- 5 MAADGYLPDWLEDNLSEGIREWWDLKPGAPKPKANQQKQDDGRG
LVLPGYKYLGPFGNLDKGEPVNAADAAALEHDKAYDQQLKAGDNPYLRYNHADAE
FQERLQEDTSFGGNLGRAVFQAKKRVLPLGLVEEGAKTAPGKKRPVEQSPQEPDSS
SGIGKTGQQPAKKRLNFGQTGDSESVDPQPLGEPPATPAAVGPTTMASGGGAPMAD
NNEG DG VGNASGNWHCDSTWLGDRVITTSTRTWALPTYNNHLYKQISSASTGASND
10 NHYFGYSTPWGYFDFNRFHCHFSRDPWQRLINNNWGFRPKRLNFKLFNIQVKEVTT
NDGVTTIANNLTSTVQVFSDEYQLPYVLGSAHQGCLPPFPADVFMIPQYGYLTLNN
GSQAVGRSSFYCLEYFPSQMLRTGNNFTFSYTFEEVPFHSSY AHSQSLDRLMNPLIDQ
YLYYLNRTQNQSGSAQNKDLLFSRGSAPGMSVQPKNWLPGPCYRQQRVSKTKTDN
NNSNFTWTGASKYNLNGRESIINPGTAMASHKDDEDKFFPMSGVMIFGKESAGASNT
15 ALDNVMITDEEEIKATNPVATERFGTVAVNFQSSSTDPATGDVHAMGALPGMVWQD
RDVYLQGPIWAKIPHTDGHFHPSPLMGGFGLKNPPPQILIKNTVPANPPAEFSATKFA
SFITQYSTGQVSVEIEWELQKENS KRWNPEVQYTSNYAKSANVDFTVDNNGLYTEPR
PIGTRYLTRPL
- 20 [00353] AAV2 VP1 capsid protein (SEQ ID No: 207)
- MAADGYLPDWLEDTLSEGIRQWWKLKPGPPPKPAERHKDDSRG
LVLPGYKYLGPFGNLDKGEPVNEADAAALEHDKAYDRQLDSGDNPYLKYNHADAE
FQERLKEDTSFGGNLGRAVFQAKKRVLPLGLVEEPVKTAPGKKRPVEHSPVEPDSS
SGTGKAGQQPARKRLNFGQTGDADSVDPQPLGQPPAAPSGLTNTMATGSGAPMA
25 DNNEGADGVGNSSGNWHCDSTWMGDRVITTSTRTWALPTYNNHLYKQISSQSGAS
NDNHYFGYSTPWGYFDFNRFHCHFSRDPWQRLINNNWGFRPKRLNFKLFNIQVKEV
TQNDGTTTIANNLTSTVQVFTDSEYQLPYVLGSAHQGCLPPFPADVFMVPQYGYLTL
NNGSQA VGRSSFYCLEYFPSQMLRTGNNFTFSYTFEDVPFHSSY AHSQSLDRLMNPLI
DQYLYYLSRTNTPSGTTTQSRLQFSQAGASDIRDQSRNWLPGPCYRQQRVSKTSADN
30 NNSEYSWTGATKYHLNGRDSLVPNGPAMASHKDDEEKFFPQSGVLIFGKQGSEKTN
VDIEKVMITDEEEIRTTNPVATEQYGSVSTNLQRGNRQAATADVNTQGVLPGMVWQ
DRDVYLQGPIWAKIPHTDGHFHPSPLMGGFGLKHPPPQILIKNTVPANPSTTFSAAKF
ASFITQYSTGQVSVEIEWELQKENS KRWNPEIQYTSNYNKS VNVDFTVDNNGVYSEP
RPIGTRYLTRNL
- 35 [00354] AAV3B VP1 capsid protein (SEQ ID No: 208)
- MAADGYLPDWLEDNLSEGIREWWALKPGVPQPKANQQHQDNRRG
LVLPGYKYLGPFGNLDKGEPVNEADAAALEHDKAYDQQLKAGDNPYLKYNHADA
40 EFQERLQEDTSFGGNLGRAVFQAKKRILEPLGLVEEAAKTAPGKKRPVDQSPQEPDSS
SGVGKSGKQPARKRLNFGQTGDSESVDPQPLGEPPAAPSTLSGNTMASGGGAPMA
DNNEGADGVGNSSGNWHCDSQWLGDRTVITTSTRTWALPTYNNHLYKQISSQSGASN
DNHYFGYSTPWGYFDFNRFHCHFSRDPWQRLINNNWGFRPKKLSFKLFNIQVKEVT
QNDGTTTIANNLTSTVQVFTDSEYQLPYVLGSAHQGCLPPFPADVFMVPQYGYLTLN
45 NGSQA VGRSSFYCLEYFPSQMLRTGNNFQFSYTFEDVPFHSSY AHSQSLDRLMNPLID
QYLYYLNRTQGTSTGTTNQSRLLSQAGPQMSLQARNWLPGPCYRQQRLSKTAND
NNNSNFPWTAASKYHLNGRDSLVPNGPAMASHKDDEEKFFPMHGNLIFGKEGTTAS
NAELDNVMITDEEEIRTTNPVATEQYGTVANLQSSNTAPTTRTVNDQGALPGMVW
QDRDVYLQGPIWAKIPHTDGHFHPSPLMGGFGLKHPPPQIMIKNTVPANPPTTFSPA

KFASFITQYSTGQVSVEIEWELQKENS KRWNPEIQYTSN YNKS VNVDFTVDTNGVYS
EPRPIGTRYLTRNL

5 [00355] AAV5 VP1 capsid protein (SEQ ID No: 209)

MSFVDHPPDWLEEVGEGLEFLGLEAGPPKPKPNQQHQDQARGLVLPGYNYLGPNG
GLDRGEPVNRADDEVAREHDISYNEQLEAGDNPYLKYNHADA E FQ EKLADDTSF GGN
LGKAVFQAKKRVLEPFGLVEEGAKTAPTGKRIDDHFPKRKKARTEEDSKPSTSSDAE
10 AGPSGSQQLQIPAPASSLGADTMSAGGGGPLGDNNQGADGVGNASGDWHCDSTW
MGDRVVTKSTRTWVLPSSYNNHQYREIKSGSV DGSNANAYFGYSTPWGYFDFNR FHS
HWSPRDWQRLINNYWGFPRSLRVKIFNIQVKEVTVQDSTTTIANNLTSTVQVFTDD
DYQLPYVVGNGTEGCLPAFPQVFTLPQYGYATLNRDNTENPTERS SFFCLEYFPSK
MLRTGNNFEFTYNFEEVPHSSFAPSQNLFKLANPLVDQYLYRFVSTNNTGGVQFN
15 KNLAGRYANTYKNWFP GPMGRTQGWNLGS GVN RASVS AFATTNRMELEGASYQV
PPQPNGMTNNLQGSNTYALENTMIFNSQPANPGTTATYLEGNMLITSESETQPVNRV
AYNVGGQMATNNQSSTTAPATGTYNLQEIVPGSVWMERDVYLQGPWAKIPETGAH
FHPSPAMGGFGLKHPPPMMLIKNTVPVGNITSFSDVPVSSFITQYSTGQVTVEMEWEL
KKENSKRWNPEIQYTNNYNDPQFVDFAPDSTGEYRTTRPIGTRYLTRPL
20

[00356] AAV6 VP1 capsid protein (SEQ ID No: 210)

MAADGYLPDWLEDNLSEGIREWWDLKPGAPKPKANQQKQDDGRGLVLPGY
25 KYLGPFNGLDKGEPVNAADAAALEHDKAYDQQLKAGDNPYLRYNHADA E F
QERLQEDTSFGGNLGRAVFQAKKRVLEPFGLVEEGAKTAPGKKRPVEQSPQE
PDSSSGIGKTGQQPAKKRLNFGQTGDSESVDPQPLGEPPATPAAVGPTTMA S
GGGAPMADNNEGADGVGNASGNWHCDSTWLGDRVITTSTRTWALPTYNNH
LYKQISSASTGASNDNHYFGYSTPWGYFDFNR FHC HFS PRDWQRLINNNWGF
30 RPKRLNFKLFNIQVKEVTTNDGVTTIANNLTSTVQVFS DSEYQLPYVLGSAHQ
GCLPPFPADVFMIPQYGYLTLNNGSQAVGRSSFYCLEYFPSQMLRTGNNFTFS
YTFEDVPFHSSY AHSQSLDRLMNPLIDQYLYLNRTQNQSGSAQNKDLLFSR
GSPAGMSVQPKNWLPGPCYRQQRVSKTKTDNNNSNFTWTGASKYNLNGRE
SIINPGTAMASHKDDKDKFFPMSGVMIFGKESAGASNTALDNVMITDEEEIKA
35 TNPVATERFGTVAVNLQSSSTD PATGDVHVMGALPGMVWQDRDVYLQGP I
WAKIPH TDGHFHPSPLMGGFGLKHPPPQILIKNTVPV ANPPAEFSATKFASFIT
QYSTGQVSVEIEWELQKENS KRWNPEVQYTSNYAKSANVDFTVDNNGLYTE
PRPIGTRYLTRPL

40 [00357] AAV8 VP1 capsid protein (SEQ ID No: 211)

MAADGYLPDWLEDNLSEGIREWWALKPGAPKPKANQQKQDDGRGLVLPGY
KYLGPFNGLDKGEPVNAADAAALEHDKAYDQQLQAGDNPYLRYNHADA E F
QERLQEDTSFGGNLGRAVFQAKKRVLEPLGLVEEGAKTAPGKKRPVEPSPQR
45 SPDSSTGIGKKGQQPARKRLNFGQTGDSESVDPQPLGEPPAAPSGVGPNTMA
AGGGAPMADNNEGADGVGSSSGNWHCDSTWLGDRVITTSTRTWALPTYNN
HLKQISNGTSGGATNDNTYFGYSTPWGYFDFNR FHC HFS PRDWQRLINNN
WGFPRKRLSFKLFNIQVKEVTQNEGKTIANNLTSTIQVFTDSEYQLPYVLGS
AHQGCLPPFPADVFMIPQYGYLTLNNGSQAVGRSSFYCLEYFPSQMLRTGNN
50 FQFTYTFEDVPFHSSY AHSQSLDRLMNPLIDQYLYLSRTQTTGGTANTQTLG
FSQGGPNTMANQAKNWLPGPCYRQQRVSTTTGQNNNSNFAWTAGTKYHLN
GRNSLANPGIAMATHKDDEERFFPSNGILIFGKQNAARDNADYSDVMLTSEE

EIKTTNPVATEEYGIVADNLQQQNTAPQIGTVNSQGALPGMVWQNRDVYLQ
 GPIWAKIPHTDGNFHPSPMLGGFGLKHPPPQILIKNTPVPADPPTTFNQSKLNS
 FITQYSTGQVSVEIEWELQKENS KRWNPEIQYTSNYYKSTSVDFAVNTEGVYS
 EPRPIGTRYLTRNL

5

[00358] AAV9 VP1 capsid protein (SEQ ID No: 212)

MAADGYLPDWLEDNLSEGIREWWALKPGAPQPKANQQHQDNARGLVLPGY
 KYLGPGNGLDKGEPVNAADAAALEHDKAYDQQLKAGDNPYLKYNHADAEF
 10 QERLKEDTSFGGNLGRAVFQAKKRLLEPLGLVEEAAKTAPGKKRPVEQSPQE
 PDSSAGIGKSGAQPAKKRLNFGQTGDTESVPDPQPIGEPPAAPSGVGS LTMAS
 GGGAPVADNNEGADGVGSSSGNWHCDSQWLGDRVITTSTRTWALPTYNNH
 LYKQISNSTSGGSSNDNAYFGYSTPWGYFDNRFHCHFSPRDWQRLINNNWG
 FRPKRLNFKLFNIQVKEVTDNNGVKTIANNLTSTVQVFTDSYQLPYVLGSA
 15 HEGCLPPFPADVFMIPQYGYLTLDGSAVGRSSFYCLEYFPSQMLRTGNF
 QFSYEFENVPFHSSYAHSQLDRLMNPLIDQYLYLSKTINGSGQNQQLKFS
 VAGPSNMAVQGRNYIPGPSYRQQRVSTVTQNNNSEFAWPGASSWALNGRN
 SLMNPGPAMASHKEGEDRFFPLSGSLIFGKQGTGRDNVDADKVMITNEEEIK
 TTNPVATESYGQVATNHQSAQAQAQTGWVQNQGILPGMVWQDRDVYLQGP
 20 IWAKIPHTDGNFHPSPMLGGFGMKHPPPQILIKNTPVPADPPTAFNKDKLNSFI
 TQYSTGQVSVEIEWELQKENS KRWNPEIQYTSNYYKSNNVEFAVNTEGVYSE
 PRPIGTRYLTRNL

25 [00359] An exemplary selection of the NGS primers are depicted in the table below,
 wherein the variable region is indicated in the primer name.

Table 2: Primers used for next-generation sequencing analysis

Primer name	Primer nucleotide sequence (5'-3')	SEQ ID NO:
DO106_MiCap1_VRI_Fwd	ACACGACGCTCTTCCGATCT NNNNAGAGTCATCACCACCA GCACC	52
DO107_MiCap1_VRI_Rev	GACGTGTGCTCTTCCGATCTN NNNGAAATCAAAATACCCCC AGGG	53
DO108_MiCap1_VRIV_Fwd	ACACGACGCTCTTCCGATCT NNNNATCGACCAGTACCTGT ATTACCTG	54
DO109_MiCap1_VRIV_Rev	GACGTGTGCTCTTCCGATCTN NNNTGCCGGTAACAGGGTCC AG	55
DO112_MiCap1_VRVIII_Fwd	ACACGACGCTCTTCCGATCT NNNNTAACCCCGTGGCCACC GAA	56

DO113_MiCap1_VRVIII_Rev	GACGTGTGCTCTTCCGATCTN NNNAGGACCCTGCAGGTATA CGTCT	57
DO319_AAV5_MiCap1_VRVII I_Fwd	ACACGACGCTCTTCCGATCT NNNNGTGAACCGCGTGGCGT ACAAC	58
DO320_AAV5_MiCap1_VRVII I_Rev	GACGTGTGCTCTTCCGATCTN NNNGGGTCCTTGGAGGTACA CGTCC	59

[00360] Gibson assembly was used to generate the capsid libraries where the introduced peptides were encoded by the primers used to amplify the right fragment (see Fig. 2). Two PCR products from the capsid gene sequence (“Cap”) were amplified (left and right fragments) that had an overlap region to facilitate assembly using the Gibson assembly procedure into a plasmid backbone (see *e.g.* Gibson *et al* (2009) *Nat Meth* 6(5):343-345). Specifically, the primer for the right fragment (“RF Fwd”) comprises random nucleotide sequences encoding the inserted peptide built into the primer. This primer also comprises sequences encoding the overlap region so this right fragment amplified product will overlap with the amplified left fragment. Finally, the RF Fwd primer comprises a homology region which has homology to the right fragment of the sequence encoding the capsid.

[00361] The insertion position for the peptides differed for each AAV serotype (numbering begins at VP1 start codon). Table 2 below shows the amino acid position within the capsid protein where the peptide insertion occurred. Note that two libraries in the AAV6 capsid were constructed where the fragments were inserted into either position 454 or 590. Also note that three libraries based on the AAV9 capsid were constructed where the fragments were inserted into either position 266, 455, or 589.

Table 3: Insertion sites of peptides

Serotype	Insertion site (aa position)
AAV1	590
AAV2	588
AAV3B	589
AAV5	578

AAV6	454
AAV6	590
AAV8	591
AAV9	266
AAV9	455
AAV9	589

[00362] The Gibson assembly reactions were transformed into electrocompetent *E. coli* and the resulting plasmid library purified. The plasmid DNA library was transfected into HEK293 cells at low multiplicity of transfection to preserve the linkage
5 between capsid genotype and phenotype.

[00363] The libraries were then manufactured to generate a library of viral capsids for testing. Wild type AAV comprises gene sequences that encode the “Rep” proteins Rep78, Rep68, Rep52, and Rep40 necessary for replication of the viral nucleic acid and for packing it into a viral particle in the presence of adenovirus helper functions. The
10 AAV libraries described herein do not contain “Rep” in *cis* with viral ITRs and “Cap”, therefore, to achieve efficient packaging of the libraries into viral capsids, the replication gene (“rep”) and the adenovirus helper functions (for example E2A, E4, VA, E1A and E1B) are supplied in *trans* during viral manufacturing. For example, a helper plasmid that supplies Rep in *trans* during viral manufacturing was constructed. The
15 Rep gene (NC_001401, nucleotides 191-2252) was amplified from a standard AAV helper plasmid using the following primers:

Table 4: Primers for amplifying a Rep gene

Primer name	Primer nucleotide sequence (5'-3')	SEQ ID NO:
DO7_Rep_Fwd	GTACTCTAGAGTCCTGTATTAGA GGTCACGTGA	60
DO8_Rep_Rev	TGCTGCATGCTGTACCGAATTAA CATGTTTATTGGTACGATCAGAG AGAGTGTCTCGAGC	61

[00364] These primers add XbaI and SphI sites respectively and amplify the entire Rep
20 gene. The amplified Rep fragment was then cloned by restriction digest and ligation into the XbaI and SphI sites in the multiple cloning site of pUC19 to generate

pRepInTrans. An additional modification was introduced by site-directed mutagenesis using the following primers to convert the VP1 ACG start codon to ATG generating pRepInTrans-ATG.

Table 5: Primers for modification of Rep gene

Primer name	Primer nucleotide sequence (5'-3')	SEQ ID NO:
DO444_QCRep78_Fwd	ACCCCGCCATGGTGGCTGCGCGTT	62
DO445_QCRep78_Rev	AACGCGCAGCCACCATGGCGGGGT	63

5

[00365] The ACG to ATG modification was introduced in order to increase replication of the capsid construct through greater Rep78/68 expression and thereby improve AAV library manufacturing yield. Removal of Rep renders AAV replication-deficient, an important feature for selections in non-human primates that frequently harbor AAV helper viruses including herpes simplex virus (see Morton *et al* (2008) *ILAR J* 49(2):137-44). In addition, removal of Rep is superior to a simple genetic knockout that still invites the possibility of recombination with a Rep plasmid supplied in trans that could reconstitute replication competent AAV.

[00366] The AAV libraries are then packaged in an HEK293 production system by transient transfection and purified using cesium chloride density gradient ultracentrifugation (for an exemplary process, see Xiao and Samulski (1998) *J Virol* 40:241-247).

[00367] The goal of this technique is to develop methods that can be used in all species, tissues, cell types and tissue processing conditions. Thus, AAVs are designed to carry the capsid libraries described above and some type of identifying marker that links the sequence of the variant capsid gene in a single AAV to a unique barcode identifier also carried by the AAV such that subsequent independent sequencing of the barcode will identify the linked capsid mutations. Further, the single AAV will also carry a reporter gene of some type such that the successful delivery of the AAV particle to its intended target (for example an organ (*e.g.* liver or CNS), and or specific cell types within an organ (*e.g.* hepatocytes or neurons)) can be monitored and selected for.

[00368] In addition, in this example, the reporter gene included a localization signal to cause the reporter to be localized to the cell nucleus once the cell had been transduced by the variant AAV capsid. Initially, an SV40 large T-antigen (PKKKRKV, SEQ ID NO:64) was introduced at the N-terminus of EGFP or mCherry. A second method used

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a KASH domain fused to the C-terminus of the EGFP or mCherry. KASH domains localize proteins to the nuclear envelope, in effect tethering the reporter to the nucleus and preventing diffusion out of the nuclear pore complex. A third method fused a histone H2B gene to the C-terminus of the EGFP, mClover3 or mRuby3 reporter (see 5 Fig. 3A and B). The hSyn1 (synapsin) promoter used to drive expression of the fluorescent reporter was selected to be specific for expression in neurons. Other promoters may be used for other targeted tissues or cells including the liver-specific transthyretin promoter. The underlying concept is to have the sequence comprising the variant AAV capsid linked physically to the reporter in the target tissue, cell or 10 organelle. In this way, the target tissue, cell or organelle could be isolated using the fluorescent protein once successfully transduced with the AAV particle such that the user could then determine what capsid variant allowed transduction of the AAV particle into the target tissue, cell or organelle.

[00369] In some examples, a barcode is inserted into each AAV genome comprising 15 a variant capsid protein to allow the user to identify the mutation in the capsid protein by independent sequencing analysis of the barcode once the library had been through *in vivo* selection (see below). The underlying concept is to have the sequence comprising the variant AAV capsid linked physically to the reporter in the target tissue, cell or organelle. In this way, the target tissue, cell or organelle could be isolated using 20 the fluorescent protein once successfully transduced with the AAV particle such that the user could then determine what capsid variant allowed transduction of the AAV particle into the target tissue, cell or organelle. In some examples, each peptide coding sequence is synthesized with multiple different nucleic acid sequences, all encoding the same peptide. Each nucleic acid sequence is linked to a unique bar code such that 25 performance (*e.g.* enrichment) of a peptide variant can be verified when two or more variants are identified with the same peptide sequence, but the variants comprise different nucleic acid sequences encoding that peptide.

[00370] For libraries generated by DNA synthesis and subsequent molecular cloning steps, all barcode and peptide encoding sequences were designed computationally. 30 Importantly, sequences comprising restriction enzyme recognition sites that would be used for later cloning were omitted. The sequences were designed to have 40-60% GC content, no homopolymers greater than 3 in length, and minimal similarity (edit distance) between sequences.

[00371] To bioinformatically link each barcode with each mutated capsid sequence, two approaches were performed.

[00372] Method 1 employed ILLUMINA® sequencing. First, a barcode was inserted into the expression constructs as outlined in Figs. 4A and B. To insert the barcode sequences, the 5' Gibson assembly region #1 was synthesized as a DNA fragment linked to the variable region in the capsid gene linked in turn to the 3' Gibson assembly region #2 (see Fig. 4A, step 1). Thus, the synthetic sequence comprises a variable barcode region and a variable capsid sequence. It also comprises two restriction nuclease sites between the barcode sequence and the variable sequence. Type IIs restriction sites BsaI were used to facilitate scarless assembly of the final construct. A separate PCR procedure was performed where the 3' sequence of the capsid gene was amplified (step 2). Next, an intermediate AAV construct was generated by Gibson assembly where the construct comprised in a 5' to 3' order the 5' ITR, the SV40 poly A signal, the barcode, the two restriction endonuclease sites, the variant capsid sequences, the 3' region of the capsid protein, the polyA sequence for the capsid expression construct and the 3' ITR (step 3). In an alternate approach (Fig. 4C) steps 1-3 are modified. In step 1, two DNA fragments are synthesized. Fragment A comprises Gibson assembly region #1, a BsaI site, the variable capsid region, and a region homologous to the capsid gene that is used as a PCR primer. Fragment B comprises Gibson assembly region #2, a random barcode, a BsaI site, and Gibson assembly region #1. Next, a PCR procedure is performed where the 3' sequence of capsid gene is amplified using fragment A synthesized in step 1 as a PCR primer. Next, an intermediate AAV construct is generated by Gibson assembly where the construct comprises in a 5' to 3' order the 5' ITR, the SV40 poly A signal, the barcode, the two restriction endonuclease sites, the variant capsid sequences, the 3' region of the capsid protein, the polyA sequence for the capsid expression construct and the 3' ITR (step 3). For both approaches described in Figs. 4A/B and 4C/D steps 4-7 are equivalent. Paired-end ILLUMINA® sequencing is performed to span the barcode and variant capsid sequences in both directions (step 4). The sequences generated thus link specific barcode sequences to specific variant sequences in the capsid gene. ILLUMINA® sequencing at Step 4 indicated a 99.6% correct match between the barcode and variant sequence specified during synthesis. Step 5 comprised digestion with the BsaI restriction enzyme. Step 6 was a PCR amplification step where the H2B, EGFP, cell-

type specific promoter (e.g. hSyn1), p40 promoter, and the 5' end of the capsid gene were prepared. Alternatively, the H2B, EGFP, cell-type specific promoter (e.g. hSyn1), p40 promoter, and the 5' end of the capsid gene can be prepared in a separate donor plasmid, digested with BsaI, and gel purified. Step 7 was the scarless golden gate cloning step to assemble the final construct. Sanger sequencing of a sample of the final library demonstrated that 88/88 individual clones showed the correct specified linkage between the barcode and the variant capsid sequences.

[00373] Method 2 employed both ILLUMINA® and OXFORD NANOPORE® sequencing. First, the AAV capsid libraries were assembled through the method shown in Fig. 2 where the variable sequences were added into the capsid gene using primers. Next, the capsid gene libraries were cloned into a vector comprising the reporter gene and random barcode sequences (see Fig. 5). To link each random barcode sequence with each variant capsid sequence, two types of sequencing analyses were performed. Standard ILLUMINA® sequencing is highly accurate for short stretches of nucleic acid (approximately 300 bp), while OXFORD NANOPORE® sequencing can give much longer sequence reads. However, OXFORD NANOPORE® sequencing has an approximate 12% error rate and can generate indels in the reading sequence, so is not suitable for this purpose on its own. Thus, two sets of ILLUMINA® sequencing reactions were initially performed: one set that sequenced the barcode region and one set that sequenced the variable capsid sequence. Following that, an OXFORD NANOPORE® sequencing reaction was completed to provide long read lengths that spanned the entire AAV viral genome. Although less accurate than the ILLUMINA® sequencing, the Nanopore sequencing provides long-read length data that permits matching of known barcode sequences with known variant capsid sequences.

[00374] The result of both of these methods was that a 'lookup' table was created matching each barcode to each variant capsid sequence. Once an AAV was isolated from a target cell, tissue or organelle, only sequencing of nucleic acid barcode was necessary because through use of the lookup table, one could then know the sequence of the variant capsid.

[00375] The libraries were tested in primary mouse cortical neurons (Gibco) *in vitro*. The libraries were a mixture of all the AAV variants in each of the serotypes. Cells were treated with the AAV variants over a dose range of 3×10^3 , 1×10^4 , 3×10^4 , 1×10^5 , and 3×10^5 vector genomes per cell and EGFP positive nuclei were isolated as described

below. Separately, total RNA was isolated from the infected neurons and used for reverse transcription to cDNA following standard protocols and a primer specific to the AAV mRNA transcripts, DO441_AAVSpecific_RT: 5' GGTTACAAATAAAGCAATAGCATCAC (SEQ ID NO:65). The resulting cDNA barcodes were then sequenced by ILLUMINA® sequencing with NGS primers DO439_RNABarcode_Fwd: 5' ACACGACGCTCTTCCGATCTNNNNGCATCACAAATTCACAAATAAAGC (SEQ ID NO:66) and DO440_RNABarcode_Rev: 5' GACGTGTGCTCTTCCGATCTNNNNGCCGTGTCCGAGGGTACTAAG (SEQ ID NO: 67) to quantify variant performance. The results of a sample of the AAV variants recovered are shown in Fig. 6, where the log2 fold change represents the enrichment of the variant isolated from transduced cells as compared to its frequency in the administered library. The X axis of Fig. 6 represents the relative variability of variant performance across sample replicates. As can be seen, variant performance often clusters based on parent serotype, with variants comprising peptide insertions into AAV1 being the most enriched and least variable. Fig. 7A shows the AAV1 serotype variants plotted alone, and also indicates the performance of the wildtype AAV1 serotype (no inserted amino acids in the capsid sequence). As can be seen, there were a great deal of variants that showed an increased enrichment as compared to the wildtype AAV1 serotype. Similarly, Fig. 7B shows the variants based on peptide insertions into AAV2 plotted alone and indicates the relative performance of wildtype AAV2. The methods produced AAV2 variants that showed an enrichment in transgene expression in comparison with the wildtype sequence. A comparison was also done to see if the different methods of identifying the enriched AAV variants produced similar results. Fig. 8 shows that variant performance evaluated based on RNA isolation, cDNA synthesis, and barcode quantification was similar to performance evaluated by isolation of EGFP positive nuclei and sequencing of the variable capsid region. Additionally, library performance was evaluated in Neuro2A cells (ATCC CCL-131) and iCell neurons derived from human induced pluripotent stem cells (NCR-100-010-001, Cellular Dynamics International). Individual variant performance differed across cell lines that present different selective pressures. The methods described herein to evaluate variant performance were consistently applicable and successful. The variants were as follows:

Table 6. AAV variants evaluated.

AAV variant	SEQ ID NO
KSPHPSV (AAV1)	SEQ ID NO: 199
IKSNLTY (AAV1)	SEQ ID NO: 200
STSPHAPSKE (AAV2)	SEQ ID NO: 201
HATPQFDPSQ (AAV6)	SEQ ID NO: 202
SALGLQAKAY (AAV9)	SEQ ID NO: 203

Example 2: *In vivo* selection of variant AAV libraries in mice

[00376] The goal of the construction of these AAV libraries was to identify AAV capsid variants that would allow delivery of AAV to any tissue, cell or organelle in any species.

[00377] *CNS delivery.* One potential use of this technology is the delivery of genome editing, transgenes and regulators of gene expression to specific cell types. Thus, it was important for this particular application to identify AAV variants that would not only target particular cells within particular tissues, but would also travel to the nucleus within the cell and mediate transgene expression. In addition, isolation of nuclei from tissues is straight forward as compared to isolation of specific whole cell bodies from tissue. Nuclei have uniform morphology across tissues and are easily stained for DNA content to facilitate FACS analysis (*e.g.* DAPI or Hoescht dyes). For example, neurons have very extended cell bodies and are difficult to isolate intact from brain tissue. Also, some components within the brain such as lipofuscin and myelin basic protein can autofluorescence, confounding analyses that are dependent on the fluorescence signal of reporter genes (*see* for example Hainsworth *et al* (2017) *Neuropathol Appl Neurobiol* 44(4): 417-426). Thus, as shown in Figs. 3A and 3B different approaches were taken to localize the reporter genes in the AAV genomes to the nucleus including fusing them to nuclear localization sequences (SV40 NLS), nuclear envelope binding protein domains (KASH) and histone binding domains for incorporation into nuclear chromatin (H2B).

[00378] Constructs were made to test delivery into HEK293 cells. Constructs comprising just the reporter alone with no nuclear localization sequence (EGFP and mCherry) were compared to those in which the reporters had been fused to an SV40 NLS, or to a KASH domain (*see* Fig. 9). All constructs showed fluorescence in the cells, while the NLS tagged constructs showed localization within the nucleus and the

KASH linked constructs showed the reporter was bound to the nuclear envelope. However, upon isolation of the nuclei from the HEK293 transduced cells, only the KASH linked constructs showed retention of the signal. Signal loss after nuclei isolation is likely due to the small size of the reporter proteins (27 kDa) relative to the nuclear pore cutoff (60 kDa) in the non-tethered constructs. In the absence of a living cell the active transport mechanisms for nuclear import of the reporter are lost and the reporter can diffuse out of the nucleus. Further testing was done with fusion of the reporter to the H2B domain and robust retention of the signal in isolated nuclei was also observed. All H2B constructs drove highly efficient incorporation of the reporter into the nuclear chromatin that was stable after both nuclei isolation and freeze/thaw treatment of cells and tissue

[00379] Nuclei were isolated from cultured cells and tissue essentially as described in the protocol by Krishnaswami *et al.* (described in Kelder *et al* (2016) *Nat Protoc* 11(3):499). In brief, 2-3 mm³ sections of tissue were excised with a sterile razor blade. If cultured cells were being used, the cells were collected and resuspended at approximately 1x10⁶ cells per mL in cold PBS. The tissue or cells were homogenized using a dounce homogenizer in a Tris buffer comprising sucrose, MgCl₂, KCL, and NuPAGE sample reducing agent (Thermo). Also included was 0.1% Triton and Hoescht 33352 (Molecular Probes). The homogenate was then filtered using a 40 or 70 micron Flowmi cell strainer (Flowmi) to remove remaining tissue fragments or high order aggregates of nuclei.

[00380] The AAV capsid library constructs comprising the EGFP-H2B, mClover3-H2B, mRuby3-H2B, and EGFP-KASH under the control of the neuron specific hSynapsin1 promoter were evaluated in C57BL/6J mice. AAV capsid libraries were manufactured by standard techniques and administered by tail vein intravenous injection at a dose of 2x10¹¹ vector genomes per mouse (n=3 per group). Two weeks after administration of the test article, mice were sacrificed, and the left hemisphere of the brain was preserved in 4% paraformaldehyde for immunohistochemistry studies targeting the expressed reporter to confirm nuclear localization by techniques know in the art. The right hemisphere was flash frozen for FACS sorting of transduced neuronal nuclei. Images from the immunohistochemistry studies verified nuclear localization for each of the constructs in the tissue (see Figs. 10A and 10B) although for the mRuby3 constructs, direct visualization of the nuclear localized mRuby3 native fluorescence was used.

[00381] Nuclei were isolated from the frozen central nervous system mouse tissues as described above, stained with Hoescht dye during nuclei isolation, and sorted for EGFP, mClover3, mRuby3, or EGFP-KASH signal by using a Sony SH800 cell sorter according to manufacturer's instructions. For FACS sorting, the 70 micron chip was used, at sample pressure 5, in semi-purity mode. The FACS plots were gated on singlets to prevent sorting of doublets, triplets, or higher order groupings of attached nuclei. Samples were sorted into Tris buffer, pH 7.5, comprising sucrose and MgCl₂.

[00382] DNA was isolated from the sorted cells using a Roche High Pure Viral nucleic acid kit according to manufacturer's protocols.

[00383] The FACS plots (Fig. 11) demonstrate that EGFP positive nuclei could be isolated from central nervous tissues in the mice injected with the libraries comprising the EGFP-H2B construct. Further, signal could be detected in the thalamus of mice treated with the mClover3 construct and in the cortex of mice treated with the EGFP-KASH libraries (Figs. 12 and 13). Importantly, reporter signal above background could not be detected in either liver or cardiac tissue when mice were injected with the EGFP-H2B libraries (where EGFP-H2B was driven by the neuron specific hSynapsin promoter), see Fig. 14.

Example 3: *In vivo* selection in non-human primates

[00384] *Liver delivery*: The methods and compositions described herein also were used to identify liver targeting AAV variants from the libraries. In these experiments, the liver-specific promoter transthyretin (TTR) was used to express the reporter genes. The library constructs were thus modified to comprise the TTR promoter in place of the hSynapsin promoter. The libraries were first tested in cells *in vitro*, where a dose response was seen. HepG2 cells (ATCC HB-8065) were transduced with the AAV libraries across a range of multiplicity of infections (MOI) and then nuclei were sorted as above to measure fluorescence from the reporter gene. The results (see Figs 15A-C) demonstrated a dose response, which is summarized in Table 7 below:

Table 7: Dose response in HepG2 cells

MOI	% EGFP positive
Mock	0.2
3e3	0.5
1e4	2.5
3e4	8.6
1e5	36.9
3e5	53.3
1e6	64.3

[00385] Dose response experiments were also done in nonhuman primate hepatocytes (BioIVT) where a dose response was also observed (see Table 8 below).

Table 8: Dose response in NHP hepatocytes

MOI	% EGFP Positive
Mock	0.6
3e3	1.3
3e4	3.8
3e5	12.4

[00386] In a similar manner, the dose response was measured in primary human hepatocytes (Corning), and the data is shown below in Table 9.

Table 9: Dose response in primary human hepatocytes

MOI	% EGFP Positive
Mock	0.4
5e4	6.7
1e5	20.0
2e5	35.4
4e5	47.3
8e5	50.2

[00387] Library variant performance was also evaluated in C57BL/6J mice using the libraries where the reporter gene was driven by the TTR promoter. AAV capsid libraries were manufactured by standard techniques and administered by tail vein intravenous injection at a dose of 2E11 vector genomes per mouse (n=3 males and n=3 females). Two weeks after administration of the test article, mice were sacrificed and the liver removed to evaluate targeting of the expressed EGFP transgene.

[00388] The selections were also performed in non-human primates (cynomolgus macaques) to isolate AAV variants that would have the most relevance for transduction of human liver.

[00389] In selection round 1, a library pool comprising AAV variants from all the different serotypes was injected at a dose of 5E12 vector genomes per kilogram. In this first round, millions of unique variants were injected into one male and one female NHP. After 15 days the NHPs were sacrificed and the liver analyzed. A pool of successful AAV variants recovered from the NHP livers was generated and sequenced. The AAV variants were then used to make a single library comprising approximately 500,000 unique variants. These were then injected into a new NHP pair intravenously at a dose of 1.6E13 vector genomes per kilogram. After 28 days, the NHP were sacrificed and their livers analyzed. Endpoints analyzed were enrichment of the

individual AAV variants in the liver tissue as compared with the administered library formulation, the enrichment in hepatocyte nuclei expressing EGFP encoded by the AAV variants, and sequencing of the mRNA barcodes to determine enrichment of AAV capsid variants compared to the administered library formulation.

- 5 [00390] Nuclei were isolated from the livers as described above and EGFP positive hepatocyte nuclei were sorted by FACS. The results (Fig. 16, Panel A) showed that the EGFP signal was readily detectable above background. The numbers of EGFP positive nuclei isolated from three samples of each individual liver lobe for each NHP are shown below in Table 10. In addition, immunohistochemistry detection of EGFP was
10 performed (Fig. 16, Panel B) to demonstrate nuclear localization of the reporter gene.

Table 10: Number of AAV variants isolated from male and female NHP liver tissue.

Tissue Region	NHP 1001 (Male)		NHP 1501 (Female)	
	GFP+ Nuclei (%)	Sorted Count	GFP+ Nuclei (%)	Sorted Count
Left lateral lobe 1	6.0	133,043	1.5	28,746
Left lateral lobe 2	4.4	44,044	1.2	24,641
Left lateral lobe 3	4.1	71,123	1.2	18,762
Right lateral lobe 1	2.4	31,872	1.9	31,814
Right lateral lobe 2	4.5	76,013	1.6	34,736
Right lateral lobe 3	4.6	54,185	1.5	24,675
Left medial lobe 1	3.2	66,751	1.7	18,433
Left medial lobe 2	3.6	45,289	1.6	17,613
Left medial lobe 3	2.9	40,757	1.7	17,961
Right medial lobe 1	3.8	51,326	1.2	21,438
Right medial lobe 2	3.7	58,040	0.9	12,986
Right medial lobe 3	3.2	52,832	1.5	16,695
Quadrangle lobe 1	4.0	57,774	0.8	10,325
Quadrangle lobe 2	2.7	44,248	1.1	13,333
Quadrangle lobe 3	3.5	58,053	1.3	15,150

- [00391] Interestingly, a comparison of the top 2500 AAV variants isolated after
15 application of distinct selective pressures indicates striking differences in the parent

serotypes of AAV variants that were most heavily enriched (Figs. 17A and B). HepG2 and primary human hepatocytes were evaluated *in vitro* while mice and NHP were evaluated *in vivo*. These significant species-specific differences support AAV selections in animal models that are closer to human, for example NHP.

- 5 [00392] Approximately 100 AAV variants were selected for in-depth analysis based on their consistent fold enrichment in NHP mRNA, NHP EGFP positive hepatic nuclei, and NHP liver total genomic DNA. Variants excluded included those with low yield in HEK293 AAV manufacturing and a low confidence of the mapping of the barcode by Nanopore sequencing. Clustering analysis was also performed to select AAV
- 10 variants that comprise unique physicochemical properties (for example, recurrent amino acid motifs or strong hydrophobicity) in response to the selective pressure.
- [00393] The top 32 sequences from this initial analysis are shown in Fig. 18 and Table 11. The analysis shows the parent serotype as well as the fold enrichment in liver observed after selection in non-human primate. Also shown is the sequence of the
- 15 peptide inserted into the capsid loop. Importantly, the ability to produce each AAV variant in a HEK293 AAV production system was tracked to insure any AAV identified by the methods described herein could be produced efficiently. Thus, in some embodiments, the inserted peptide sequence and AAV parent serotype may be any one of those set forth in Table 11.

20 **Table 11**

Inserted Peptide Sequence	AAV parent serotype	SEQ ID NO	Inserted Peptide Sequence	AAV parent serotype	SEQ ID NO
KSPQSKV	AAV1	1	VSRSYPA	AAV9	17
SDLRSKV	AAV1	2	QRARPDT	AAV9	18
TTTVRKV	AAV1	3	SQLTPHS	AAV6	19
GRSDMAG	AAV2	4	LGSHLPS	AAV6	20
LLSSERS	AAV2	5	YTLSSGQ	AAV6	21
EQRPNV	AAV2	6	SSRIPPD	AAV6	22
TRQISSD	AAV2	7	WTETIPR	AAV6	23
QGALAQV	AAV3B	8	HGLQGVA	AAV6	24
YPSSNTP	AAV3B	9	TMRVSDQ	AAV6	25
MLNP RTE	AAV3B	10	GSSKVVM	AAV6	26
QMRTRDE	AAV3B	11	SALDRGV	AAV6	27
MPGRAPI	AAV9	12	KELGTQR	AAV5	28
LGRLTAN	AAV9	13	RSSDVQR	AAV5	29
SYSTSR	AAV9	14	PSAPKTF	AAV5	30
TRPSSTN	AAV9	15	HTKRSEY	AAV5	31
VPQSSSR	AAV9	16	IKGSNLP	AAV5	32

[00394] *CNS delivery*: Additional experiments were conducted to identify AAV variants with improved transduction of the CNS using the methods described herein. For these experiments the hSynapsin promoter (hSyn1) was used to express the reporter gene and mRNA barcode. The selections were performed in non-human primates
5 (cynomolgus macaques) to isolate AAV variants that would have the most relevance for transduction of the human CNS.

[00395] In non-human primate selection round 1 a library pool comprising AAV variants based on serotypes AAV1, AAV2, AAV3B, AAV6, AAV8, and AAV9 was injected by lumbar intrathecal puncture at a total dose of 1×10^{13} vector genomes. In this
10 first round, millions of unique variants were injected into one male and one female NHP. After 15 days the NHPs were sacrificed and the CNS tissues were analyzed to assess AAV variant performance.

[00396] A subset of the AAV variants with high fold enrichment in the round 1 CNS non-human primate selection were synthesized using Method 1 described above to
15 generate the library for round 2 selection. The total size of the round 2 library was 10,818 variants. Each AAV variant was synthesized using three different nucleotide sequences that code for the same peptide. Each nucleotide sequence was linked to a unique mRNA barcode driven by the hSyn1 promoter in order to rank transgene expression in neurons. The inclusion of three replicate sequences enables increased
20 confidence in assessing variant performance since each of the three sequences can be treated independently during bioinformatic analysis.

[00397] The library prepared for round 2 selection to target the CNS was first evaluated *in vitro* in Neuro2A cells (ATCC CCL-131) (Fig. 19), primary mouse cortical neurons (Gibco) (Fig. 20), and iCell human neurons derived from human induced
25 pluripotent stem cells (NCR-100-010-001, Cellular Dynamics International) (Fig. 21) as described in Example 1.

[00398] The round 2 library was next evaluated in C57BL/6J mice by unilateral intracerebroventricular injection at a dose of 1.59×10^{11} vector genomes per mouse in a volume of 10 microliters ($n=3$ males and $n=3$ females). 28 days after administration of
30 the test article, mice were sacrificed, and CNS tissues removed to evaluate library performance (Fig. 22). Analysis was completed on brain regions contralateral to the injected hemisphere to avoid confounding transduction associated with the injection tract.

- [00399] Finally, the round 2 library was administered intrathecally into two male and one female cynomolgus macaques at a dose of 4.37×10^{13} vg per animal. After 28 days, the NHPs were sacrificed and CNS tissues were analyzed. The brain was sliced at a 3 mm coronal slice thickness. Each slice was hemisected along the mid-sagittal plane.
- 5 Punch samples (3 mm) were obtained from the brain slices from the left hemisphere for analysis of vector genome DNA. The right hemisphere was placed in RNAlater and refrigerated for approximately 24 hours to preserve RNA integrity. After storage, 3 mm punches were collected sampling various brain regions. The spinal cord was divided into cervical, thoracic, and lumbar segments for analysis.
- 10 [00400] Library AAV variant performance was assessed by analysis of vector genome DNA frequency (Figs. 23-25) as well as by quantification of cDNA reverse-transcribed from library mRNA transcript expressed specifically in neurons (Figs. 26-28). These two data sets are referred to as DNA analysis and RNA analysis respectively. Next-generation sequencing analysis of non-human primate CNS tissues identified high
- 15 performing AAV variants exhibiting transduction superior to parental wild type serotypes. A subset of these top performing variants was selected for further evaluation based on their performance across different metrics, including enrichment in both DNA and RNA analyses. A summary of the variant performance for this subset is shown in Figs. 29A-29D. The analysis shows the parent serotype as well as the fold enrichment
- 20 in tissue observed after selection in non-human primate. Also shown is the peptide sequence of the peptide inserted into the capsid loop. The variants are numbered 1-43 (SEQ ID Nos.: 68-110, see Table 12) and this numbering is used to annotate their performance relative to the rest of the library in the bubble plots in Figs. 19 through 28. In some embodiments, the inserted peptide and AAV parent serotype may be any one
- 25 of those set forth in Table 12.

Table 12

No.	Inserted Peptide Sequence	AAV parent serotype	SEQ ID NO	No	Inserted Peptide Sequence	AAV parent serotype	SEQ ID NO
1	AALRDIR	AAV1	68	23	MTLTRQE	AAV2	90
2	PAIKTYS	AAV1	69	24	TSNSRTE	AAV2	91
3	TGDRISRTL	AAV1	70	25	EVRRGPS	AAV2	92
4	SVVVSSDSSK RPRNL	AAV1	71	26	VISDRSS	AAV2	93
5	VGARLSA	AAV1	72	27	PRDTFNG	AAV2	94
6	IEKPNTSTKK	AAV1	73	28	RPLTAND	AAV2	95
7	DTVRSKN	AAV1	74	29	PLRMVNE	AAV2	96

8	KELNKAR	AAV1	75	30	DVGIRPS	AAV2	97
9	PYASITG	AAV3B	76	31	KDSTAFG	AAV2	98
10	TGAFSST	AAV3B	77	32	YPGRNPD	AAV2	99
11	EQFRNLA	AAV3B	78	33	ISDTRIS	AAV2	100
12	FNSPVIQ	AAV3B	79	34	ENFSKVA	AAV2	101
13	TDFRSPQ	AAV3B	80	35	RDALSGLRP E	AAV2	102
14	MYSLMKD	AAV3B	81	36	LGNGKMTV QP	AAV2	103
15	LYLSSAS	AAV3B	82	37	VSNPLNQ	AAV2	104
16	YGSRSDV	AAV3B	83	38	LNERGLG	AAV2	105
17	LYSHQVS	AAV3B	84	39	GRNTVGLSS A	AAV2	106
18	ISTHSPP	AAV3B	85	40	VGHAGNP	AAV2	107
19	RQPTTIP	AAV9	86	41	SRAGTVP	AAV2	108
20	RSTSSLL	AAV9	87	42	GLVAKLP	AAV2	109
21	FRLSSPQ	AAV9	88	43	AESLRTP	AAV2	110
22	NIPKAYG	AAV9	89				

Example 4: Evaluation of top performing AAV variants identified in library screens

[00401] After two rounds of selection in non-human primate a subset of highly enriched variants was identified in liver and CNS tissues (Figs. 18 and 29 respectively).

5 Rather than proceeding directly to individual evaluation of just one or two variants, we instead generated a barcoded expression cassette to enable head-to-head comparison of dozens of the top performing variants in liver and CNS. In this approach the barcodes linked to each AAV are known with certainty because each AAV variant is manufactured and titered separately prior to pooling. Each AAV is manufactured with

10 a vector genome (Fig. 30) containing a cell-type specific RNA polymerase II promoter (e.g. transthyretin or hSynapsin1) driving expression of the EGFP-H2B transgene and a unique barcode nucleotide sequence. A second RNA polymerase III promoter (e.g. hU6) was also included to provide an independent assessment of vector performance. The hU6 promoter is ubiquitously expressed in all cell types and therefore enables

15 assessment of expression in all cell and tissue types. Moreover, the hU6 transcript is restricted to the nucleus, an advantage for single nuclei sequencing approaches. All barcodes listed in Table 13 were designed computationally to minimize the potential for transcriptional bias.

Table 13: Unique barcodes used for pooled AAV variant evaluation

Cassette No.	RNA polymerase II barcode	SEQ ID NO:	RNA polymerase III barcode	SEQ ID NO:
1	AAATCACCTGAC	111	CTTGTCGATAAG	155
2	TGATTCTTCTAC	112	GTGGTAAGCACG	156
3	GGCCACTGGTTG	113	AACTGGCTCCCA	157
4	AATCTATCGCCT	114	TGCGATCGTACA	158
5	AGACGATCAAGG	115	CAGAGGATAGCT	159
6	GTGTAGTGATCG	116	GAGGAGTCTCAT	160
7	TGGTAGTTTCCA	117	AGTTCCACGGA	161
8	GATCAGTTGCGG	118	CCCTTCAGCAGT	162
9	CTTGGGACACAC	119	CGTACTCCGCGA	163
10	GATGCGGCCTCG	120	TCACCGACGTGG	164
11	CGCATCCTCGTT	121	CAACGGTCTTCC	165
12	ACGATGTCTACG	122	GTAACAGTCCGG	166
13	GTGTTCCACCTG	123	GTCGAGGATACC	167
14	GGAGGGAGCTGG	124	TGCGATGTGATG	168
15	CATAACTCTTGC	125	TAACCCGCCGAA	169
16	TGACAGTCTCGC	126	CGACCAACGACA	170
17	CTACCAGGATTC	127	CTGCTGCCATCA	171
18	ACACATGATGGC	128	CTAGTACACGCG	172
19	GGTGCTCGCAAT	129	TAGGTGCTAGTG	173
20	GATTGCACCGCA	130	TCCTCCCAGGAT	174
21	AACGGAGGCTGC	131	TAGGCGGCATTA	175
22	GGGAGAGTTCCG	132	CTTAGGCTAGCT	176
23	CGGGTAGCCGAA	133	CGACGTGCGATA	177
24	TGACCTAATTGG	134	ACCATTCCATCG	178
25	GGGTGAAGGATT	135	TGGAAAGGCCTA	179
26	CTGTGAGAGAAG	136	GGGAACATTGGA	180
27	ACTTGGTTCGCG	137	AAGTGAACGCGC	181
28	GTTGGCTGTACC	138	AGCAACGTTGTA	182
29	TGTAAGCTGTAG	139	AAGTGACGGACC	183
30	AGCTACCCTGGA	140	AGTAACGCCCGT	184
31	CCAAACAAGCGT	141	TGGGCTATGACA	185
32	GCTTGCCCATCC	142	CTGCAGTGAAGT	186
33	CATTCCGGGTTA	143	ATTCTGTTTCGCA	187
34	CTTTGCCGGTAC	144	CTTCCTCACCTC	188
35	CATCAACTGTGC	145	GAGAGTCGAAAC	189
36	GCACAGCCGAAT	146	AGTCGTGAATCG	190
37	ATGCATCGGTCA	147	GGTGACAACAAT	191
38	GAACCAGAATGC	148	GCCTAGTAGCAT	192
39	CGGACGGTATGG	149	ACAGAAGCGCCT	193
40	TCCTATGAACAA	150	CTAGTTGAGTTC	194
41	TGGGAGTAGAGG	151	AAGTTCAGGATA	195
42	GCTCAACGATCG	152	TTGCCTCTATTC	196
43	GGACTAGGATAT	153	TGAACGTCTAAG	197
44	CCATTGTGGGAA	154	CGCTATCACGCA	198

[00402] An example of the application of this expression cassette to evaluate a subset of high performing CNS-tropic AAV variants (listed in Fig. 29A-D) identified from library screening is shown in Fig. 31. In addition to the engineered serotypes developed in this work several control serotypes were included: AAV9, PHP.B, and AAV2_HSPGKO. AAV9 has been evaluated extensively in the field for its CNS transduction properties including in human clinical trials (Lowes *et al.* *Pediatr Neurol.* 2019; 98:39-45), accordingly it is the primary benchmark for performance. PHP.B is an engineered AAV9 serotype that was previously shown to exhibit high potency in C57BL/6J mice (Deverman *et al.* *Nat Biotechnol.* 2016; 34(2):204-9), these properties do not extend to non-human primates (Hordeaux *et al.* *Mol Ther.* 2018 Mar; 26(3):664-668). AAV2_HSPGKO is a variant of AAV2 with two mutations (R585A and R588A) that abolish binding to heparan sulfate proteoglycan (HSPG) (Opie *et al.* *Virol.* 2003 Jun; 77(12):6995-7006). This serotype has also been previously evaluated in non-human primates (Naidoo *et al.* *Mol Ther.* 2018 Oct 3; 26(10):2418-2430). In this experiment, barcoded AAV variants were evaluated *in vitro* in Neuro2A cells, primary mouse cortical neurons, and iCell human neurons derived from human induced pluripotent stem cells. Virus was produced in HEK293T cells, purified using a CsCl density-gradient, and titered by real time qPCR according to methods known in the art. Each individually manufactured and barcoded virus was then mixed together to form a single pool for downstream evaluation and the frequency of each variant in this pool was assessed by next-generation sequencing (NGS). The vector genome cassette described in Fig. 30 was employed for the pooled evaluation to enable distinct barcoded transcript quantifications from the hSyn1 pol II promoter and the hU6 pol III promoter. The barcoded virus pool was used to infect cells at 3×10^5 , 1×10^5 , 3×10^4 , 1×10^4 , 3×10^3 , and 1×10^3 vector genome copies per cell. After either 72 hours (Neuro2A), 48 hours (primary mouse cortical neurons), or 96 hours (hiPSC derived human neurons) total RNA was extracted and AAV transcripts were reverse transcribed using gene specific primers targeting the hSyn1 and hU6 transcripts respectively. Next-generation sequencing was then applied to quantify the percentage of NGS reads derived from each AAV variant. These percentages were normalized by the frequency of each AAV variant in the pool that was used for infection. The results show a distribution of performance with several AAV variants based on AAV1 and AAV2 exhibiting high performance across all three cell types. Generally, the performance of AAV variants

based on AAV3B was lower. The observed trends in variant performance were successfully predicted by the round 2 library data obtained in the same cell types (Figs. 19, 20, 21). In addition, these data show the successful application of the dual pol II hSyn1 and pol III hU6 barcode measurement approach. In homogeneous cell lines like Neuro2A, the agreement between the hSyn1 and hU6 measurements is high. In primary mouse cortical neurons and hiPSC derived neurons there is a greater heterogeneity of neuronal subtypes, leading to a greater divergence in the two measurements. However, generally the two measurements are still correlated.

Example 5: *In vitro* evaluation of CNS-tropic variants for transduction of non-neuronal cells

[00403] The same subset of CNS-tropic AAV variants and controls were evaluated for transduction of non-neuronal cell types *in vitro* (Fig. 32). In this experiment, barcoded AAV variants were evaluated for transduction of iCell human astrocytes derived from human induced pluripotent stem cells and iCell human endothelial cells derived from human induced pluripotent stem cells. The identical AAV barcoded pool test article and methodology described above in Example 4 was used with the following specifications. For evaluation in hiPSC-derived astrocytes 3×10^5 , 1×10^5 , 3×10^4 , 1×10^4 , 3×10^3 , and 1×10^3 vector genome copies per cell were used for infection. For evaluation in hiPSC-derived endothelial cells 3×10^5 , 1×10^5 , and 3×10^4 vector genome copies per cell were used for infection. Both the astrocytes and endothelial cells were harvested 72 hours post-infection. Total RNA was extracted and AAV transcripts were reverse transcribed using gene specific primers targeting the hU6 transcript, the hSyn1 transcript was not probed because the hSyn1 promoter has minimal activity in non-neuronal cell types. Next-generation sequencing was then applied to quantify the percentage of NGS reads derived from each AAV variant. These percentages were normalized by the frequency of each AAV variant in the pool that was used for infection. In hiPSC-derived astrocytes the results show a distribution of performance with several AAV variants based on AAV2 exhibiting high performance. Generally, the performance of AAV variants based on AAV1 and AAV9 was lower. In hiPSC-derived endothelial cells the results show a distribution of performance with several AAV variants based on AAV1 and AAV2 exhibiting high performance. Generally, the performance of AAV variants based on AAV3B and AAV9 was lower.

Example 6: *In vivo* evaluation of CNS-tropic AAV variants in mice and rats

- [00404] The same subset of CNS-tropic AAV variants was further evaluated for transduction of the central nervous system in C57BL/6J mice and Sprague-Dawley rats *in vivo* (Figs 33 and 34). Transduction in rodents was assessed in order to complete a thorough evaluation of AAV performance across species that are commonly used for the development of therapeutics. For evaluation in C57BL/6J mice 1E11 vector genomes in a volume of 10 microliters was administered by unilateral intracerebroventricular injection into the left lateral ventricle (n=3 males and n=3 females). For evaluation in Sprague-Dawley rats 2E11 vector genomes in a volume of 20 microliters was administered by unilateral intracerebroventricular injection into the left lateral ventricle (n=3 males and n=3 females). Animals were sacrificed 32 days after administration of the test article and CNS tissues were dissected. Analysis was completed on brain regions contralateral to the injected hemisphere to avoid confounding from transduction associated with the injection tract. Total RNA was extracted from CNS tissues and AAV transcripts were reverse transcribed using gene specific primers targeting the hSyn1 and hU6 transcripts respectively. Next-generation sequencing was then applied to quantify the percentage of NGS reads derived from each AAV variant. These percentages were normalized by the frequency of each AAV variant in the pool that was administered.
- [00405] In C57BL/6J mice the hSyn1 barcode measurements of transcripts expressed in neuronal cells show a distribution of performance with many AAV variants based on peptide insertions into AAV1 and AAV2 disclosed herein exhibiting high performance relative to the AAV9 benchmark. As expected, the PHP.B control serotype is high performing in C57BL/6J mice. Generally, the performance of AAV variants based on AAV9 and AAV3B was lower. In C57BL/6J mice, the hU6 barcode measurements of transcripts expressed in all cell types show a distribution of performance with many AAV variants based on peptide insertions into AAV2 and especially AAV1 disclosed herein exhibiting high performance relative to the AAV9 benchmark. Generally, the performance of AAV variants based on AAV9 and AAV3B was lower. Fig. 33.
- [00406] In Sprague-Dawley rats the hSyn1 barcode measurements of transcripts expressed in neuronal cells show a distribution of performance with many AAV variants based on peptide insertions into AAV1 and AAV2 disclosed herein exhibiting high performance relative to the AAV9 benchmark. As expected, the PHP.B control serotype performs worse in Sprague-Dawley rats than it does in C57BL/6J mice.

Generally, the performance of AAV variants based on AAV9 and AAV3B was lower. In Sprague-Dawley rats the hU6 barcode measurements of transcripts expressed in all cell types shows a distribution of performance with many AAV variants based on peptide insertions into AAV1 and AAV2 disclosed herein exhibiting high performance relative to the AAV9 benchmark. Generally, the performance of AAV variants based on AAV9 and AAV3B was lower. Fig. 34.

Example 7: *In vivo* evaluation of CNS-tropic AAV variants in non-human primates

[00407] We next further evaluated the same subset of CNS-tropic AAV variants for transduction of the central nervous system in non-human primates (cynomolgus macaques) *in vivo*. Among the various evaluations described above, assessment of transduction in cynomolgus macaques is of particular importance for clinical translation to humans since non-human primates best exemplify the genetics and physiology of the human CNS. The pool of AAV variants was administered intrathecally into one male and one female cynomolgus macaque at a dose of 5.2×10^{13} vector genomes (vg) per animal. For intrathecal administration a threaded catheter was employed to deposit the test article closer to the brain at the cervical and thoracic levels. Animals were sacrificed 57 days after administration of the test article. The brain was sliced at a 3 mm coronal slice thickness. Each slice was hemisected along the mid-sagittal plane. Punch samples (3 mm) were obtained from the brain slices from the left hemisphere for analysis of AAV genomic DNA. The right hemisphere was placed in RNAlater and refrigerated for approximately 24 hours to preserve RNA integrity. After storage, 3 mm punches were collected sampling various brain regions. The spinal cord was divided into cervical, thoracic, and lumbar segments for analysis. Genomic DNA and total RNA were extracted separately from the CNS tissues and subsequent analyses are referred to as DNA analysis and RNA analysis respectively. For DNA analysis, each of the unique barcodes, hSyn1 and hU6, was amplified separately by PCR. Next-generation sequencing was applied to quantify the percentage of NGS reads derived from each AAV variant. Note that for DNA analysis there is no cellular restriction provided by the promoters, therefore, the hSyn1 and hU6 barcodes are expected to amplify with equal likelihood. For RNA analysis, AAV transcripts were reverse transcribed using gene specific primers targeting the hSyn1 (neuronal) and hU6 (all cell types) transcripts respectively. Next-generation sequencing was then applied to quantify the percentage of NGS reads derived from each AAV variant. For both DNA and RNA analyses, these

percentages were normalized by the frequency of each AAV variant in the pool that was administered.

[00408] In cynomolgus macaques, the RNA analysis results (Fig. 35), based on hSyn1 barcode measurements of transcripts expressed in neuronal cells, show a distribution of performance with many AAV variants based on peptide insertions into AAV3B, AAV2, and AAV1 disclosed herein exhibiting high performance relative to the AAV9 benchmark. Generally, the performance of AAV variants based on AAV9 was lower. In cynomolgus macaques, the hU6 barcode measurements of transcripts expressed in all cell types show a distribution of performance with many AAV variants based on peptide insertions into AAV3B, AAV2, and AAV1 disclosed herein exhibiting high performance relative to the AAV9 benchmark. Generally, the performance of AAV variants based on AAV9 was lower. Fold improvement of the serotypes disclosed herein compared to the AAV9 benchmark are plotted in Figs 37 and 38.

[00409] In cynomolgus macaques, the DNA analysis results (Fig. 36) based on hSyn1 and hU6 barcode measurements of AAV vector genomes in CNS tissues show a distribution of performance with many AAV variants across all serotypes including engineered variants based on AAV9 exhibiting very high performance relative to the wild-type AAV9 benchmark. Fold improvement of the serotypes disclosed herein compared to the AAV9 benchmark are plotted in Figs 39 and 40.

[00410] Although the RNA analysis indicates which AAV variants provided highest levels of productive transgene expression in neurons and all CNS cells, it is notable that the DNA analysis suggests there are additional AAVs that are very highly enriched in brain tissue.

[00411] An overview of serotype performance across all cell culture and *in vivo* evaluations is plotted in Figs 41 and 42. The results show differences in transduction across species and highlight the value of performing serotype screening and evaluations in non-human primates.

[00412] All patents, patent applications and publications mentioned herein are hereby incorporated by reference in their entirety.

[00413] Although disclosure has been provided in some detail by way of illustration and example for the purposes of clarity of understanding, it will be apparent to those skilled in the art that various changes and modifications can be practiced without departing from the spirit or scope of the disclosure. Accordingly, the foregoing descriptions and examples should not be construed as limiting.

[00414] Particular embodiments of the disclosure are set forth in the following numbered paragraphs:

[00415] 1. A method of identifying an AAV capsid variant with a desired characteristic compared to a natural AAV serotype, comprising:

- 5 (i) contacting a cell, cell line, or tissue with a library of AAV variants, wherein each member of the library comprises:
 - a) a nucleic acid encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein; and one or more of:
 - 10 b) one or more silent mutations in the nucleic acid sequence flanking the peptide insertion site in the AAV variant capsid protein of a);
 - c) a nucleic acid encoding a localization signal;
 - d) a nucleic acid comprising a barcode; and
 - e) a nucleic acid encoding a reporter protein;
- 15 (ii) allowing the AAV variants in said library to transduce the cell, cell line, or tissue;
- (iii) recovering from the cell, cell line, or tissue the AAV variant; and
- (iv) identifying the AAV capsid variant with the desired characteristic.

[00416] 2. A method of identifying an AAV capsid variant with a desired characteristic compared to a natural AAV serotype, comprising:

- 20 (i) contacting a cell, cell line, or tissue with a library of AAV variants, wherein each member of the library comprises:
 - a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein; and one or more of:
 - b) one or more silent mutations in the nucleic acid encoding the AAV variant capsid protein of a) in the nucleic acid sequence flanking the peptide insertion site;
 - 25 c) a nucleic acid encoding a localization signal;
 - d) a nucleic acid comprising a barcode; and
 - e) a nucleic acid encoding a reporter protein;
- (ii) allowing the AAV variants in said library to transduce the cell, cell line, or tissue;
- 30 (iii) recovering from the cell, cell line, or tissue the AAV variant; and
- (iv) identifying the AAV capsid variant with the desired characteristic.

- [00417] 3. The method of embodiment 1, wherein each member of the library comprises one or more silent mutations in the nucleic acid sequence flanking the peptide insertion site in the AAV variant capsid protein of a).
- [00418] 4. The method of embodiment 2, wherein each member of the library
5 comprises one or more silent mutations in the nucleic acid encoding the AAV variant capsid protein of a) in the nucleic acid sequence flanking the peptide insertion site.
- [00419] 5. The method of any one of embodiments 1-4, wherein each member of the library comprises a nucleic acid encoding a localization signal.
- [00420] 6. The method of any one of embodiments 1-5, wherein each member of the
10 library comprises a nucleic acid comprising a barcode.
- [00421] 7. The method of any one of embodiments 1-6, wherein each member of the library comprises a nucleic acid encoding a reporter protein.
- [00422] 8. The method of any one of embodiments 1-7, wherein the nucleic acid encoding an AAV variant capsid protein, and the nucleic acid encoding a localization
15 signal, the nucleic acid comprising a barcode, and/or the nucleic acid encoding a reporter protein, are located in separate nucleic acid molecules.
- [00423] 9. The method of any one of embodiments 1-7, wherein the nucleic acid encoding an AAV variant capsid protein, the nucleic acid encoding a localization
20 signal, the nucleic acid comprising a barcode, and/or the nucleic acid encoding a reporter protein, are located in one nucleic acid molecule.
- [00424] 10. The method of embodiment 9, wherein the nucleic acid encoding an AAV variant capsid protein, and the nucleic acid encoding a localization signal, the nucleic acid comprising a barcode, and/or the nucleic acid encoding a reporter protein, are linked to each other in any order.
- [00425] 11. The method of embodiment 10, wherein each member of the library
25 comprises: a 5'ITR sequence, the nucleic acid comprising a barcode, the nucleic acid encoding a reporter protein, the nucleic acid encoding an AAV variant capsid protein, and a 3'ITR sequence, in that order.
- [00426] 12. The method of any one of embodiments 1-11, wherein the library of AAV
30 variants comprises AAV variant capsid proteins derived from two or more AAV serotypes.
- [00427] 13. The method of any one of embodiments 1-12, wherein the AAV serotype of the library of AAV variants is selected from one or more of: AAV1, AAV2, AAV3B,

AAV5, AAV6, AAV8, AAV9, AAV3, AAV4, AAV7, AAV11, AAVrh10, AAVrh39, and AAVrh74.

[00428] 14. The method of any one of embodiments 1-13, wherein the nucleic acid encoding the reporter protein and the nucleic acid encoding an AAV variant capsid are each independently operatively linked to a promoter.

[00429] 15. The method of any one of embodiments 1-14, wherein the desired characteristic is enhanced cell or tissue tropism.

[00430] 16. A method of identifying an AAV capsid variant with a desired characteristic compared to a natural AAV serotype, comprising:

- 10 (i) inserting a plurality of nucleic acids encoding peptides, into a population of nucleic acids encoding a hypervariable and/or surface-exposed loop of an AAV capsid protein to create a library of nucleic acids encoding AAV variant capsid proteins;
- (ii) linking each nucleic acid encoding an AAV variant capsid protein in said library to one or more of:
 - 15 (a) a nucleic acid comprising a barcode,
 - (b) a nucleic acid encoding a reporter protein, and
 - (c) a nucleic acid encoding a localization signal;
- (iii) manufacturing a library of AAV variants in producer cells by providing adenovirus helper and AAV rep functions *in trans*;
- 20 (iv) purifying the library of AAV variants;
- (v) contacting a cell, cell line, or tissue with the library of AAV variants;
- (vi) recovering the AAV variants from the target cell, cell line, or tissue; and
- (vii) identifying the AAV capsid variant with the desired characteristic.

[00431] 17. The method of embodiment 16, wherein each nucleic acid encoding an AAV variant capsid protein in said library is linked to a nucleic acid comprising a barcode.

[00432] 18. The method of any one of embodiments 1-17, wherein each member of the library comprises a first nucleic acid comprising a first barcode and a second nucleic acid comprising a second barcode.

30 [00433] 19. The method of embodiment 18, wherein the first nucleic acid comprising the first barcode and the second nucleic acid comprising the second barcode are different.

- [00434] 20. The method of embodiment 18 or 19, wherein the first nucleic acid comprising the first barcode comprises a sequence selected from any one of sequences SEQ ID NO: 111-154.
- [00435] 21. The method of embodiment 18 or 19, wherein the first nucleic acid comprising the first barcode is selected from any one of sequences SEQ ID NO: 111-154.
- [00436] 22. The method of embodiment 18 or 19, wherein the second nucleic acid comprising the second barcode comprises a sequence selected from any one of sequences SEQ ID NO: 155-198.
- [00437] 23. The method of embodiment 18 or 19, wherein the second nucleic acid comprising the second barcode is selected from any one of sequences SEQ ID NO: 155-198.
- [00438] 24. The method of any one of embodiments 18-23, wherein each of the first nucleic acid comprising the first barcode and the second nucleic acid comprising the second barcode is independently operatively linked to a promoter.
- [00439] 25. The method of embodiment 24, wherein the promoter operatively linked to the first nucleic acid comprising the first barcode and the promoter operatively linked to the second nucleic acid comprising the second barcode is each independently an RNA Pol II promoter.
- [00440] 26. The method of embodiment 24, wherein the promoter operatively linked to the first nucleic acid comprising the first barcode and the promoter operatively linked to the nucleic acid comprising the second barcode is each independently an RNA Pol III promoter.
- [00441] 27. The method of embodiment 24, wherein the promoter operatively linked to the first nucleic acid comprising the first barcode is an RNA Pol II promoter and the promoter operatively linked to the second nucleic acid comprising the second barcode is an RNA Pol III promoter.
- [00442] 28. The method of any one of embodiments 25-27, wherein each RNA Pol II promoter is independently selected from the group consisting of: human synapsin promoter (hSyn1), transthyretin promoter (TTR), cytokeratin 18, cytokeratin 19, unc-45 myosin chaperon B (unc45b) promoter, cardiac troponin T (cTnT) promoter, glial fibrillary acidic protein (GFAP) promoter, myelin basic protein (MBP) promoter, and methyl CpG-binding protein 2 (Mecp2) promoter.

- [00443] 29. The method of any one of embodiments 26-27, wherein each RNA Pol III promoter is independently selected from the group consisting of U6 promoter, H1 promoter and 7SK promoter.
- [00444] 30. The method of any one of embodiments 16-29, wherein each nucleic acid encoding an AAV variant capsid protein in said library is linked to a nucleic acid encoding a reporter protein.
- [00445] 31. The method of any one of embodiments 16-30, wherein each nucleic acid encoding an AAV variant capsid protein in said library is linked to a nucleic acid encoding a localization signal.
- [00446] 32. The method of any one of embodiments 16-31, wherein each nucleic acid encoding an AAV variant capsid protein further comprises one or more silent mutations in the nucleic acid sequence flanking the peptide insertion site.
- [00447] 33. The method of any one of embodiments 16-32, wherein step (iv) further comprises combining libraries of variant AAVs based on two or more AAV serotypes to generate a single pool.
- [00448] 34. The method of any one of embodiments 16-33, wherein the population of nucleic acid sequences encoding a hypervariable and/or surface-exposed loop of an AAV capsid protein comprises sequences derived from two or more AAV serotypes.
- [00449] 35. The method of any one of embodiments 16-34, wherein the AAV serotype is selected from one or more of: AAV1, AAV2, AAV3B, AAV5, AAV6, AAV8, AAV9, AAV3, AAV4, AAV7, AAV11, AAVrh10, AAVrh39, and AAVrh74.
- [00450] 36. The method of any one of embodiments 16-35, wherein the helper functions comprise one or more of E2A, E4, VA, E1A, and E1B.
- [00451] 37. The method of any one of embodiments 16-36, wherein the AAV rep function comprises rep78, rep 68, rep 52 and rep40 genes.
- [00452] 38. The method of embodiment 37, wherein the start codon of the rep78 and/or rep68 gene is modified from ACG to ATG.
- [00453] 39. The method of any one of embodiments 16-38, wherein the producer cells are HEK293 cells.
- [00454] 40. The method of any one of embodiments 16-39, wherein the nucleic acid encoding an AAV variant capsid protein, the nucleic acid comprising a barcode, the nucleic acid encoding a reporter protein, and/or a nucleic acid encoding a localization signal are linked to each other in any order.

- [00455] 41. The method of any one of embodiments 16-40, wherein each member of the library comprises: a 5'ITR sequence, the nucleic acid comprising a barcode, the nucleic acid encoding a reporter protein, the nucleic acid encoding an AAV variant capsid protein, and a 3'ITR sequence, in that order.
- 5 [00456] 42. The method of any one of embodiments 16-41, wherein the nucleic acid encoding a reporter protein and the nucleic acid encoding an AAV variant capsid are each independently operatively linked to a promoter.
- [00457] 43. The method of any one of embodiments 16-42, wherein the desired characteristic is enhanced cell or tissue tropism.
- 10 [00458] 44. The method of any one of embodiments 1-43, wherein the peptide has a length of 4-15 amino acids.
- [00459] 45. The method of any one of embodiments 1-44, wherein the peptide has a length of 6-15 amino acids.
- [00460] 46. The method of embodiment 45, wherein the peptide has a length of 7, 10, 15 or 15 amino acids.
- [00461] 47. The method of embodiment 46, wherein the peptide has a length of 7 amino acids.
- [00462] 48. The method of any one of embodiments 1-47, wherein the peptide is inserted into a region selected from the group consisting of VR-I, VR-II, VR-III, VR-IV, VR-V, VR-VI, VR-VII, VR-VIII and VR-IX region of the capsid protein.
- 20 [00463] 49. The method of embodiment 48, wherein the peptide is inserted into the VR-I of the capsid protein.
- [00464] 50. The method of embodiment 48, wherein the peptide is inserted into the VR-IV of the capsid protein.
- 25 [00465] 51. The method of embodiment 48, wherein the peptide is inserted into the VR-VIII of the capsid protein.
- [00466] 52. The method of any one of embodiments 1-49, wherein the peptide is inserted into the capsid protein VP1, VP2, or VP3.
- [00467] 53. The method of any one of embodiments 1-50, wherein the peptide is 30 inserted at a location between amino acid residues 450 and 600 of the capsid protein.
- [00468] 54. The method of any one of embodiments 1-51, wherein
- (i) the AAV serotype is AAV1 and the peptide is inserted at amino acid position 590 of the capsid protein,

- (ii) the AAV serotype is AAV6 and the peptide is inserted at amino acid position 454 or 590 of the capsid protein,
- (iii) the AAV serotype is AAV2 and the peptide is inserted at amino acid position 588 of the capsid protein,
- 5 (iv) the AAV serotype is AAV3B and the peptide is inserted at amino acid position 589 of the capsid protein,
- (v) the AAV serotype is AAV5 and the peptide is inserted at amino acid position 578 of the capsid protein,
- (vi) the AAV serotype is AAV8 and the peptide is inserted at amino acid position 591
- 10 of the capsid protein, or
- (vii) the AAV serotype is AAV9 and the peptide is inserted at amino acid position 266, 455, or 589 of the capsid protein,
- wherein the positions correspond to the numbering of VP1 in the AAV serotype.
- [00469] 55. The method of any one of embodiments 1-54, wherein the reporter protein
- 15 is a fluorescent protein.
- [00470] 56. The method of embodiment 55, wherein the reporter protein is selected from the group consisting of: EGFP, mCherry, mClover3, mRuby3, mApple, iRFP, tdTomato, mVenus, YFP, RFP, firefly luciferase, and nanoluciferase.
- [00471] 57. The method of any one of embodiments 1-56, wherein the nucleic acid
- 20 encoding an AAV variant capsid protein is operatively linked to a p40 promoter.
- [00472] 58. The method of any one of embodiments 1-57, wherein the nucleic acid encoding a reporter protein is operatively linked to a cell type and/or tissue specific promoter.
- [00473] 59. The method of embodiment 58, wherein the cell type and/or tissue specific
- 25 promoter is selected from the group consisting of: human synapsin promoter (hSyn1), transthyretin promoter (TTR), cytokeratin 18, cytokeratin 19, unc-45 myosin chaperon B (unc45b) promoter, cardiac troponin T (cTnT) promoter, glial fibrillary acidic protein (GFAP) promoter, myelin basic protein (MBP) promoter, and methyl CpG-binding protein 2 (Mecp2) promoter.
- [00474] 60. The method of embodiment 59, wherein the cell type and/or tissue specific
- 30 promoter is the hSyn1 promoter.
- [00475] 61. The method of embodiment 60, wherein the cell type and/or tissue specific promoter is the TTR promoter.

- [00476] 62. The method of any one of embodiments 1-61, wherein the reporter protein is fused to the localization signal.
- [00477] 63. The method of embodiment 62, wherein the localization signal is fused N-terminally, C-terminally or both N-terminally and C-terminally to the reporter protein.
- 5 [00478] 64. The method of any one of embodiments 1-63, wherein the localization signal is a nuclear localization signal (NLS), a nuclear envelope binding domain or a histone binding domain.
- [00479] 65. The method of embodiment 64, wherein the NLS is the SV40 NLS.
- [00480] 66. The method of embodiment 64, wherein the nuclear envelope binding
10 domain is a KASH domain.
- [00481] 67. The method of embodiment 64, wherein the histone binding domain is H2B.
- [00482] 68. The method of any one of embodiments 1-67, wherein the nucleic acid comprising the barcode is 5-18 nucleotides long.
- 15 [00483] 69. The method of any one of embodiments 1-68, wherein the nucleic acid comprising the barcode comprises a sequence selected from any one of sequences SEQ ID NO: 111-154.
- [00484] 70. The method of any one of embodiments 1-68, wherein the nucleic acid comprising the barcode comprises a sequence selected from any one of sequences SEQ
20 ID NO: 155-198.
- [00485] 71. The method of any one of embodiments 1-68, wherein the nucleic acid comprising the barcode is selected from any one of sequences SEQ ID NO: 111-154.
- [00486] 72. The method of any one of embodiments 1-68, wherein the nucleic acid comprising the barcode is selected from any one of sequences SEQ ID NO: 155-198.
- 25 [00487] 73. The method of any one of embodiments 1-72, wherein the AAV capsid variant with the desired characteristic is identified through sequencing of the associated one or more barcodes.
- [00488] 74. The method of any one of embodiments 1-73, wherein the AAV capsid variant with the desired characteristic is identified by purification and sequencing of
30 the AAV genome.
- [00489] 75. The method of any one of embodiments 1-74, wherein the cell, cell line or tissue is selected from the group consisting of CNS, heart, lung, trachea, esophagus, muscle, bone, cartilage, stomach, pancreas, intestine, liver, bladder, kidney, ureter,

urethra, uterus, fallopian tube, ovary, testes, prostate, eye, blood, lymph, and oral mucosa.

[00490] 76. The method of any one of embodiments 1-74, wherein the cell is selected from: neurons, glial cells, astrocytes, oligodendroglia, microglia, Schwann cells, ependymal cells, hepatocytes, stellate fat storing cells, Kupffer cells, liver endothelial cells, epithelial cells, cardiomyocytes, smooth muscle cells, T-cells, B cells, hematopoietic stem cells, and embryonic stem cells.

[00491] 77. A library of AAV variants, wherein each member of said library comprises:

- 10 a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein; and
one or more of:
- b) one or more silent mutations in the nucleic acid sequence flanking the peptide
- 15 insertion site in the AAV variant capsid protein of a);
- c) a nucleic acid encoding a localization signal;
- d) a nucleic acid comprising a barcode; and
- e) a nucleic acid encoding a reporter protein.

[00492] 78. A library of AAV variants, wherein each member of said library

20 comprises:

- a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein; and
one or more of:
- b) one or more silent mutations in the nucleic acid encoding the AAV variant capsid
- 25 protein of a) in the nucleic acid sequence flanking the peptide insertion site;
- c) a nucleic acid encoding a localization signal;
- d) a nucleic acid comprising a barcode; and
- e) a nucleic acid encoding a reporter protein.

[00493] 79. The library of embodiment 77, wherein each member of the library

30 comprises one or more silent mutations in the nucleic acid sequence flanking the peptide insertion site in the AAV variant capsid protein of a).

[00494] 80. The library of embodiment 78, wherein each member of the library comprises one or more silent mutations in the nucleic acid encoding the AAV variant capsid protein of a) in the nucleic acid sequence flanking the peptide insertion site.

- [00495] 81. The library of any one of embodiments 77-80, wherein each member of the library comprises a nucleic acid encoding a localization signal.
- [00496] 82. The library of any one of embodiments 77-81, wherein each member of the library comprises a nucleic acid comprising a barcode.
- 5 [00497] 83. The library of any one of embodiments 77-82, wherein each member of the library comprises a first nucleic acid comprising a first barcode and a second nucleic acid comprising a second barcode.
- [00498] 84. The library of embodiment 83, wherein the first nucleic acid comprising the first barcode and the second nucleic acid comprising the second barcode are
10 different.
- [00499] 85. The library of embodiment 84, wherein the first nucleic acid comprising the first barcode sequence comprises a sequence selected from any one of sequences SEQ ID NO: 111-154.
- [00500] 86. The library of embodiment 84, wherein the first nucleic acid comprising
15 the first barcode sequence is selected from any one of sequences SEQ ID NO: 111-154.
- [00501] 87. The library of embodiment 84, wherein the second nucleic acid comprising the second barcode sequence comprises a sequence selected from any one of sequences SEQ ID NO: 155-198.
- [00502] 88. The library of embodiment 84, wherein the second nucleic acid
20 comprising the second barcode sequence is selected from any one of sequences SEQ ID NO: 155-198.
- [00503] 89. The library of any one of embodiments 83-88, wherein each of the first nucleic acid comprising the first barcode and the second nucleic acid comprising the second barcode is independently operatively linked to a promoter.
- 25 [00504] 90. The library of embodiment 89, wherein the promoter operatively linked to the first nucleic acid comprising the first barcode and the promoter operatively linked to the second nucleic acid comprising the second barcode is each independently an RNA Pol II promoter.
- [00505] 91. The library of embodiment 89, wherein the promoter operatively linked to
30 the first nucleic acid comprising the first barcode and the promoter operatively linked to the second nucleic acid comprising the second barcode is each independently an RNA Pol III promoter.
- [00506] 92. The library of embodiment 89, wherein the promoter operatively linked to the first nucleic acid comprising the first barcode is operatively linked to an RNA Pol

II promoter and the promoter operatively linked to the second nucleic acid comprising the second barcode is an RNA Pol III promoter.

[00507] 93. The library of any one of embodiments 90-91, wherein the RNA Pol II promoter is selected from the group consisting of: human synapsin promoter (hSyn1),
5 transthyretin promoter (TTR), cytokeratin 18, cytokeratin 19, unc-45 myosin chaperon B (unc45b) promoter, cardiac troponin T (cTnT) promoter, glial fibrillary acidic protein (GFAP) promoter, myelin basic protein (MBP) promoter, and methyl CpG-binding protein 2 (Mecp2) promoter.

[00508] 94. The library of any one of embodiments 91-93, wherein the RNA Pol III
10 promoter is selected from the group consisting of U6 promoter, H1 promoter and 7SK promoter.

[00509] 95. The library of any one of embodiments 77-94, wherein each member of the library comprises a nucleic acid encoding a reporter protein.

[00510] 96. The library of any one of embodiments 77-95, wherein the nucleic acid
15 encoding an AAV variant capsid protein, and the nucleic acid encoding a localization signal, the nucleic acid comprising a barcode, and/or the nucleic acid encoding a reporter protein, are located in separate nucleic acid molecules.

[00511] 97. The library of any one of embodiments 77-95, wherein the nucleic acid
20 encoding an AAV variant capsid protein, the nucleic acid encoding a localization signal, the nucleic acid comprising a barcode, and/or the nucleic acid encoding a reporter protein, are located in one nucleic acid molecule.

[00512] 98. The library of embodiment 97, wherein the nucleic acid encoding an AAV
25 variant capsid protein, and the nucleic acid encoding a localization signal, the nucleic acid comprising a barcode, and/or the nucleic acid encoding a reporter protein, are linked to each other in any order.

[00513] 99. The library of embodiment 97, wherein each member of the library
comprises: a 5'ITR sequence, the nucleic acid comprising a barcode, the nucleic acid encoding a reporter protein, the nucleic acid encoding an AAV variant capsid protein, and a 3'ITR sequence, in that order.

[00514] 100. The library of any one of embodiments 77-99, wherein the AAV variants
30 are derived from one or more of: AAV1, AAV2, AAV3B, AAV5, AAV6, AAV8, AAV9, AAV3, AAV4, AAV7, AAV11, AAVrh10, AAVrh39, and AAVrh74.

[00515] 101. The library of embodiment 100, wherein the library of AAV variants
comprises AAV variant capsid proteins derived from two or more AAV serotypes.

- [00516] 102. The library of any one of embodiments 77-101, wherein the peptide has a length of 4-15 amino acids.
- [00517] 103. The library of embodiment 102, wherein the peptide has a length of 6-15 amino acids.
- 5 [00518] 104. The library of embodiment 103, wherein the peptide has a length of 7, 10, or 15 amino acids.
- [00519] 105. The library of embodiment 104, wherein the peptide has a length of 7 amino acids.
- [00520] 106. The library of any one of embodiments 77-105, wherein the peptide
10 comprises at least 4 contiguous amino acids of an amino acid sequence set forth in any one of SEQ ID NO: 1-32.
- [00521] 107. The library of embodiment 106, wherein the peptide comprises an amino acid sequence set forth in any one of SEQ ID NO: 1-32.
- [00522] 108. The library of any one of embodiments 77-106, wherein the peptide
15 comprises at least 4 contiguous amino acids of an amino acid sequence set forth in any one of SEQ ID NO: 68-110.
- [00523] 109. The library of embodiment 108, wherein the peptide comprises an amino acid sequence set forth in any one of SEQ ID NO: 68-110.
- [00524] 110. The library of any one of embodiments 77-109, wherein the peptide is
20 inserted into a region selected from the group consisting of VR-I, VR-II, VR-III, VR-IV, VR-V, VR-VI, VR-VII, VR-VIII and VR-IX region of the capsid protein.
- [00525] 111. The library of embodiment 110, wherein the peptide is inserted into the VR-I of the capsid protein.
- [00526] 112. The library of embodiment 110, wherein the peptide is inserted into the
25 VR-IV of the capsid protein.
- [00527] 113. The library of embodiment 110, wherein the peptide is inserted into the VR-VIII of the capsid protein.
- [00528] 114. The library of any one of embodiments 77-113, wherein the peptide is inserted into the capsid protein VP1, VP2, or VP3.
- 30 [00529] 115. The library of any one of embodiments 77-114, wherein the peptide is inserted at a location between amino acid residues 450 and 600 of the capsid protein.
- [00530] 116. The library of any one of embodiments 77-115, wherein
(i) the AAV serotype is AAV1 and the peptide is inserted at amino acid position 590 of the capsid protein,

- (ii) the AAV serotype is AAV6 and the peptide is inserted at amino acid position 454 or 590 of the capsid protein,
- (iii) the AAV serotype is AAV2 and the peptide is inserted at amino acid position 588 of the capsid protein,
- 5 (iv) the AAV serotype is AAV3B and the peptide is inserted at amino acid position 589 of the capsid protein,
- (v) the AAV serotype is AAV5 and the peptide is inserted at amino acid position 578 of the capsid protein,
- (vi) the AAV serotype is AAV8 and the peptide is inserted at amino acid position 591
- 10 of the capsid protein, or
- (vii) the AAV serotype is AAV9 and the peptide is inserted at amino acid position 266, 455, or 589 of the capsid protein,
- wherein the positions correspond to the numbering of VP1 in the AAV serotype.
- [00531] 117. The library of any one of embodiments 77-116, wherein the reporter
- 15 protein is a fluorescent protein.
- [00532] 118. The library of embodiment 117, wherein the reporter protein is selected from the group consisting of: EGFP, mCherry, mClover3, mRuby3, mApple, iRFP, tdTomato, mVenus, YFP, RFP, firefly luciferase, and nanoluciferase.
- [00533] 119. The library of any one of embodiments 77-118, wherein the nucleic acid
- 20 encoding an AAV variant capsid protein is operatively linked to a p40 promoter.
- [00534] 120. The library of any one of embodiments 77-119, wherein the nucleic acid encoding a reporter protein is operatively linked to a cell type and/or tissue specific promoter.
- [00535] 121. The library of embodiment 120, wherein the cell type and/or tissue
- 25 specific promoter is selected from the group consisting of: human synapsin promoter (hSyn1), transthyretin promoter (TTR), cytokeratin 18, cytokeratin 19, unc-45 myosin chaperon B (unc45b) promoter, cardiac troponin T (cTnT) promoter, glial fibrillary acidic protein (GFAP) promoter, myelin basic protein (MBP) promoter, and methyl CpG-binding protein 2 (Mecp2) promoter.
- [00536] 122. The library of embodiment 121, wherein the cell type and/or tissue
- 30 specific promoter is the hSyn1 promoter.
- [00537] 123. The library of embodiment 121, wherein the cell type and/or tissue specific promoter is the TTR promoter.

- [00538] 124. The library of any one of embodiments 77-123, wherein the reporter protein is fused to the localization signal.
- [00539] 125. The library of embodiment 124, wherein the localization signal is fused N-terminally, C-terminally or both N-terminally and C-terminally to the reporter protein.
- [00540] 126. The library of any one of embodiments 77-125, wherein the localization signal is a nuclear localization signal (NLS), a nuclear envelope binding domain or a histone binding domain.
- [00541] 127. The library of embodiment 126, wherein the NLS is the SV40 NLS.
- [00542] 128. The library of embodiment 126, wherein the nuclear envelope binding domain is a KASH domain.
- [00543] 129. The library of embodiment 126, wherein the histone binding domain is H2B.
- [00544] 130. The library of any one of embodiments 77-129, wherein the nucleic acid comprising the barcode is 5-18 nucleotides long.
- [00545] 131. The library of any one of embodiments 77-130, wherein the nucleic acid comprising the barcode comprises a sequence selected from any one of sequences SEQ ID NO: 111-154.
- [00546] 132. The library of any one of embodiments 77-130, wherein the nucleic acid comprising the barcode comprises a sequence selected from any one of sequences SEQ ID NO: 155-198.
- [00547] 133. The library of any one of embodiments 77-132, wherein the nucleic acid comprising the barcode is selected from any one of sequences SEQ ID NO: 111-154.
- [00548] 134. The library of any one of embodiments 77-132, wherein the nucleic acid comprising the barcode is selected from any one of sequences SEQ ID NO: 155-198.
- [00549] 135. An AAV variant comprising:
- a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein; and
 - one or more of:
 - b) one or more silent mutations in the nucleic acid sequence flanking the peptide insertion site in the AAV variant capsid protein of a);
 - c) a nucleic acid encoding a localization signal;
 - d) a nucleic acid comprising a barcode; and

e) a nucleic acid encoding a reporter protein.

[00550] 136. An AAV variant comprising:

a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein; and

5 one or more of:

b) one or more silent mutations in the nucleic acid encoding the AAV variant capsid protein of a) in the nucleic acid sequence flanking the peptide insertion site;

c) a nucleic acid encoding a localization signal;

d) a nucleic acid comprising a barcode; and

10 e) a nucleic acid encoding a reporter protein.

[00551] 137. The variant of embodiment 135, wherein the variant comprises one or more silent mutations in the nucleic acid sequence flanking the peptide insertion site in the AAV variant capsid protein of a).

15 [00552] 138. The variant of embodiment 136, wherein the variant comprises one or more silent mutations in the nucleic acid encoding the AAV variant capsid protein of a) in the nucleic acid sequence flanking the peptide insertion site.

[00553] 139. The variant of any one of embodiments 135-136, wherein the variant comprises a nucleic acid encoding a localization signal.

20 [00554] 140. The variant of any one of embodiment 135-139, wherein the variant comprises a nucleic acid comprising a barcode.

[00555] 141. The variant of any one of embodiments 138-139, wherein the variant comprises a first nucleic acid comprising a first barcode and a second nucleic acid comprising a second barcode.

25 [00556] 142. The variant of embodiment 141, wherein the first nucleic acid comprising the first barcode and the second nucleic acid comprising the second barcode are different.

[00557] 143. The variant of embodiment 142, wherein the first nucleic acid comprising the first barcode sequence comprises a sequence selected from any one of sequences SEQ ID NO: 111-154.

30 [00558] 144. The variant of embodiment 142, wherein the first nucleic acid comprising the first barcode sequence is selected from any one of sequences SEQ ID NO: 111-154.

[00559] 145. The variant of embodiment 142, wherein the second nucleic acid comprising the second barcode sequence comprises a sequence selected from any one of sequences SEQ ID NO: 155-198.

- [00560] 146. The variant of embodiment 142, wherein the second nucleic acid comprising the second barcode sequence is selected from any one of sequences SEQ ID NO: 155-198.
- 5 [00561] 147. The variant of any one of embodiments 142-146, wherein each of the first nucleic acid comprising the first barcode and the second nucleic acid comprising the second barcode is independently operatively linked to a promoter.
- [00562] 148. The variant of embodiment 147, wherein the promoter operatively linked to the first nucleic acid comprising the first barcode and the promoter operatively linked to the second nucleic acid comprising the second barcode is each independently an
- 10 RNA Pol II promoter.
- [00563] 149. The variant of embodiment 147, wherein the promoter operatively linked to the first nucleic acid comprising the first barcode and the promoter operatively linked to the second nucleic acid comprising the second barcode is each independently an RNA Pol III promoter.
- 15 [00564] 150. The variant of embodiment 147, wherein the promoter operatively linked to the first nucleic acid comprising the first barcode is operatively linked to an RNA Pol II promoter and the promoter operatively linked to the second nucleic acid comprising the second barcode is an RNA Pol III promoter.
- [00565] 151. The variant of any one of embodiments 148-150, wherein the RNA Pol
- 20 II promoter is selected from the group consisting of: human synapsin promoter (hSyn1), transthyretin promoter (TTR), cytokeratin 18, cytokeratin 19, unc-45 myosin chaperon B (unc45b) promoter, cardiac troponin T (cTnT) promoter, glial fibrillary acidic protein (GFAP) promoter, myelin basic protein (MBP) promoter, and methyl CpG-binding protein 2 (Mecp2) promoter.
- 25 [00566] 152. The variant of any one of embodiments 149-151, wherein the RNA Pol III promoter is selected from the group consisting of U6 promoter, H1 promoter and 7SK promoter.
- [00567] 153. The variant of any one of embodiment 135-152, wherein the variant comprises a nucleic acid encoding a reporter protein.
- 30 [00568] 154. The variant of any one of embodiments 135-153, wherein the nucleic acid encoding an AAV variant capsid protein, and the nucleic acid encoding a localization signal, the nucleic acid comprising a barcode, and/or the nucleic acid encoding a reporter protein, are located in separate nucleic acid molecules.

[00569] 155. The variant of any one of embodiments 135-154, wherein the nucleic acid encoding an AAV variant capsid protein, the nucleic acid encoding a localization signal, the nucleic acid comprising a barcode, and/or the nucleic acid encoding a reporter protein, are located in one nucleic acid molecule.

5 [00570] 156. The variant of embodiment 155, wherein the nucleic acid encoding an AAV variant capsid protein, and the nucleic acid encoding a localization signal, the nucleic acid comprising a barcode, and/or the nucleic acid encoding a reporter protein, are linked to each other in any order.

[00571] 157. The variant of embodiment 156, wherein the variant comprises: a 5' ITR sequence, the nucleic acid comprising a barcode, the nucleic acid encoding a reporter protein, the nucleic acid encoding an AAV variant capsid protein, and a 3' ITR sequence, in that order.

[00572] 158. The variant of any one of embodiments 135-157, wherein the AAV variant is derived from the group consisting of: AAV1, AAV2, AAV3B, AAV5, AAV6, 15 AAV8, AAV9, AAV3, AAV4, AAV7, AAV11, AAVrh10, AAVrh39, and AAVrh74.

[00573] 159. The variant of any one of embodiments 135-158, wherein the peptide has a length of 4-15 amino acids.

[00574] 160. The variant of embodiment 159, wherein the peptide has a length of 6-15 amino acids.

20 [00575] 161. The variant of embodiment 160, wherein the peptide has a length of 7, 10, or 15 amino acids.

[00576] 162. The variant of embodiment 161, wherein the peptide has a length of 7 amino acids.

[00577] 163. The variant of any one of embodiments 135-162, wherein the inserted peptide comprises at least 4 contiguous amino acids of an amino acid sequence set forth in any one of SEQ ID NO: 1-32.

[00578] 164. The variant of embodiment 163, wherein the peptide comprises an amino acid sequence set forth in any one of SEQ ID NO: 1-32.

[00579] 165. The variant of any one of embodiments 135-162, wherein the inserted peptide comprises at least 4 contiguous amino acids of an amino acid sequence set forth in any one of SEQ ID NO: 68-110.

[00580] 166. The variant of embodiment 165, wherein the peptide comprises an amino acid sequence set forth in any one of SEQ ID NO: 68-110.

- [00581] 167. The variant of any one of embodiments 135-166, wherein the peptide is inserted into a region selected from the group consisting of VR-I, VR-II, VR-III, VR-IV, VR-V, VR-VI, VR-VII, VR-VIII and VR-IX region of the capsid protein.
- [00582] 168. The variant of embodiment 167, wherein the peptide is inserted into the VR-I of the capsid protein.
- [00583] 169. The variant of embodiment 167, wherein the peptide is inserted into the VR-IV of the capsid protein.
- [00584] 170. The variant of embodiment 168, wherein the peptide is inserted into VR-VIII of the capsid protein.
- [00585] 171. The variant of any one of embodiments 135-170, wherein the peptide is inserted into the capsid protein VP1, VP2, or VP3.
- [00586] 172. The variant of any one of embodiments 135-171, wherein the peptide is inserted at a location between amino acid residues 450 and 600 of the capsid protein.
- [00587] 173. The variant of any one of embodiments 135-172, wherein
- (i) the AAV serotype is AAV1 and the peptide is inserted at amino acid position 590 of the capsid protein,
- (ii) the AAV serotype is AAV6 and the peptide is inserted at amino acid position 454 or 590 of the capsid protein,
- (iii) the AAV serotype is AAV2 and the peptide is inserted at amino acid position 588 of the capsid protein,
- (iv) the AAV serotype is AAV3B and the peptide is inserted at amino acid position 589 of the capsid protein,
- (v) the AAV serotype is AAV5 and the peptide is inserted at amino acid position 578 of the capsid protein,
- (vi) the AAV serotype is AAV8 and the peptide is inserted at amino acid position 591 of the capsid protein, or
- (vii) the AAV serotype is AAV9 and the peptide is inserted at amino acid position 266, 455, or 589 of the capsid protein,
- wherein the positions correspond to the numbering of VP1 in the AAV serotype.
- [00588] 174. The variant of any one of embodiments 135-173, wherein the reporter protein is a fluorescent protein.
- [00589] 175. The variant of embodiment 174, wherein the reporter protein is selected from the group consisting of: EGFP, mCherry, mClover3, mRuby3, mApple, iRFP, tdTomato, mVenus, YFP, RFP, firefly luciferase, and nanoluciferase.

- [00590] 176. The variant of any one of embodiments 135-175, wherein the nucleic acid encoding an AAV variant capsid protein is operatively linked to a p40 promoter.
- [00591] 177. The variant of any one of embodiments 138-176, wherein the nucleic acid encoding a reporter protein is operatively linked to a cell type and/or tissue specific promoter.
- 5 [00592] 178. The variant of embodiment 177, wherein the cell type and/or tissue specific promoter is selected from the group consisting of: human synapsin promoter (hSyn1), transthyretin promoter (TTR), cytokeratin 18, cytokeratin 19, unc-45 myosin chaperon B (unc45b) promoter, cardiac troponin T (cTnT) promoter, glial fibrillary acidic protein (GFAP) promoter, myelin basic protein (MBP) promoter, and methyl CpG-binding protein 2 (Mecp2) promoter.
- 10 [00593] 179. The variant of embodiment 178, wherein the cell type and/or tissue specific promoter is the hSyn1 promoter.
- [00594] 180. The variant of embodiment 178, wherein the cell type and/or tissue specific promoter is the TTR promoter.
- 15 [00595] 181. The variant of any one of embodiments 135-180, wherein the reporter protein is fused to the localization signal.
- [00596] 182. The variant of embodiment 181, wherein the localization signal is fused N-terminally, C-terminally or both N-terminally and C-terminally to the reporter protein.
- 20 [00597] 183. The variant of any one of embodiments 135-182, wherein the localization signal is a nuclear localization signal (NLS), a nuclear envelope binding domain or a histone binding domain.
- [00598] 184. The variant of embodiment 183, wherein the NLS is the SV40 NLS.
- 25 [00599] 185. The variant of embodiment 183, wherein the nuclear envelope binding domain is a KASH domain.
- [00600] 186. The variant of embodiment 183, wherein the histone binding domain is H2B.
- [00601] 187. The variant of any one of embodiments 135-186, wherein the nucleic acid comprising the barcode is 5-18 nucleotides long.
- 30 [00602] 188. The variant of any one of embodiments 135-187, wherein the nucleic acid comprising the barcode comprises a sequence selected from any one of sequences SEQ ID NO: 111-154.

- [00603] 189. The variant of embodiment 188, wherein the nucleic acid comprising the barcode is selected from any one of sequences SEQ ID NO: 111-154.
- [00604] 190. The variant of any one of embodiments 135-187, wherein the nucleic acid comprising the barcode comprises a sequence selected from any one of sequences
- 5 SEQ ID NO: 155-198.
- [00605] 191. The variant of embodiment 190, wherein the nucleic acid comprising the barcode is selected from any one of sequences SEQ ID NO: 155-198.
- [00606] 192. The variant of any one of embodiments 135-191, wherein the AAV variant is derived from AAV1.
- 10 [00607] 193 The variant of embodiment 192, wherein the variant comprises a peptide comprising an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 68 to SEQ ID NO: 75.
- [00608] 194. The variant of embodiment 192, wherein the variant comprises a peptide comprising an amino acid sequence selected from the group consisting of SEQ ID NO:
- 15 1, SEQ ID NO: 2 and SEQ ID NO: 3.
- [00609] 195. The variant of embodiment 192, wherein the variant comprises a peptide comprising the amino acid sequence SEQ ID NO: 71.
- [00610] 196. The variant of any one of embodiments 135-191, wherein the AAV variant is derived from AAV2.
- 20 [00611] 197. The variant of embodiment 196, wherein the variant comprises a peptide comprising an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 90 to SEQ ID NO: 110.
- [00612] 198. The variant of embodiment 196, wherein the variant comprises a peptide comprising any one of the sequences selected from the group consisting of SEQ ID NO:
- 25 95, SEQ ID NO: 94, SEQ ID NO: 96, SEQ ID NO: 101, SEQ ID NO: 103, SEQ ID NO: 106, SEQ ID NO: 91 and SEQ ID NO: 102.
- [00613] 199. The variant of embodiment 196, wherein the variant comprises a peptide comprising an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 4-7.
- 30 [00614] 200. The variant of any one of embodiments 135-191, wherein the AAV variant is derived from AAV3B.
- [00615] 201. The variant of embodiment 200, wherein the variant comprises a peptide comprising any one of the sequences selected from the group consisting of SEQ ID NO:

78, SEQ ID NO: 80, SEQ ID NO: 77, SEQ ID NO: 79, SEQ ID NO: 76 and SEQ ID NO: 83.

[00616] 202. The variant of embodiment 200, wherein the variant comprises a peptide comprising an amino acid sequence selected from the group consisting of any one of
5 SEQ ID NO: 8 to SEQ ID NO: 11.

[00617] 203. The variant of any one of embodiments 135-191, wherein the AAV variant is derived from AAV5.

[00618] 204. The variant of embodiment 203, wherein the variant comprises a peptide comprising an amino acid sequence selected from the group consisting of any one of
10 SEQ ID NO: 28 to SEQ ID NO: 32.

[00619] 205. The variant of any one of embodiments 135-191, wherein the AAV variant is derived from AAV6.

[00620] 206. The variant of embodiment 205, wherein the variant comprises a peptide comprising an amino acid sequence selected from the group consisting of consisting of
15 any one of SEQ ID NO: 19 to SEQ ID NO: 27.

[00621] 207. The variant of any one of embodiments 135-191, wherein the AAV variant is derived from AAV9.

[00622] 208. The variant of embodiment 207, wherein the variant comprises a peptide comprising an amino acid sequence selected from the group consisting of any one of
20 SEQ ID NO: 12 to SEQ ID NO: 18.

[00623] 209. The variant of embodiment 207, wherein the variant comprises a peptide comprising an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 86 to SEQ ID NO: 89.

[00624] 210. The variant of embodiment 207, wherein the variant comprises a peptide comprising the sequence SEQ ID NO: 89.
25

[00625] 211. A nucleic acid molecule comprising:

- a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein; and
30 one or more of:
- b) a nucleic acid sequence encoding a variant capsid protein comprising one or more silent mutations in the nucleotide sequence flanking the peptide insertion site in the hypervariable and/or surface-exposed loop of the variant capsid protein;
- c) a nucleic acid sequence encoding a localization signal;

d) a nucleic acid sequence comprising a barcode; and

e) a nucleic acid sequence encoding a reporter protein.

[00626] 212. The nucleic acid molecule of embodiment 211, wherein the nucleic acid sequence encoding an AAV variant capsid protein comprises one or more silent mutations in the nucleic acid sequence flanking the peptide insertion site in the AAV variant capsid protein of a).

[00627] 213. The nucleic acid molecule of embodiment 212, wherein the nucleic acid molecule comprises a nucleic acid encoding a localization signal.

[00628] 214. The nucleic acid molecule of embodiment 212, wherein the nucleic acid molecule comprises a nucleic acid comprising a barcode.

[00629] 215. The nucleic acid molecule of embodiments 211-214, wherein the nucleic acid molecule comprises a first nucleic acid comprising a first barcode and a second nucleic acid comprising a second barcode.

[00630] 216. The nucleic acid molecule of embodiment 215, wherein the first nucleic acid comprising the first barcode and the second nucleic acid comprising the second barcode are different.

[00631] 217. The nucleic acid molecule of embodiment 216, wherein the first nucleic acid comprising the first barcode sequence comprises a sequence selected from any one of sequences SEQ ID NO: 111-154.

[00632] 218. The nucleic acid molecule of embodiment 217, wherein the first nucleic acid comprising the first barcode sequence is selected from any one of sequences SEQ ID NO: 111-154.

[00633] 219. The nucleic acid molecule of embodiment 216, wherein the second nucleic acid comprising the second barcode sequence comprises a sequence selected from any one of sequences SEQ ID NO: 155-198.

[00634] 220. The nucleic acid molecule of embodiment 217, wherein the second nucleic acid comprising the second barcode sequence is selected from any one of sequences SEQ ID NO: 155-198.

[00635] 221. The nucleic acid molecule of any one of embodiments 215-220, wherein each of the first nucleic acid comprising the first barcode and the second nucleic acid comprising the second barcode is independently operatively linked to a promoter.

[00636] 222. The nucleic acid molecule of embodiment 221, wherein the promoter operatively linked to the first nucleic acid comprising the first barcode and the promoter

operatively linked to the second nucleic acid comprising the second barcode is each independently an RNA Pol II promoter.

[00637] 223. The nucleic acid molecule of embodiment 221, wherein the promoter operatively linked to the first nucleic acid comprising the first barcode and the promoter
5 operatively linked to the second nucleic acid comprising the second barcode is each independently an RNA Pol III promoter.

[00638] 224. The nucleic acid molecule of embodiment 221, wherein the promoter operatively linked to the first nucleic acid comprising the first barcode is operatively linked to an RNA Pol II promoter and the promoter operatively linked to the second
10 nucleic acid comprising the second barcode is an RNA Pol III promoter.

[00639] 225. The nucleic acid molecule of any one of embodiments 222-224, wherein the RNA Pol II promoter is selected from the group consisting of: human synapsin promoter (hSyn1), transthyretin promoter (TTR), cytokeratin 18, cytokeratin 19, unc-45 myosin chaperon B (unc45b) promoter, cardiac troponin T (cTnT) promoter, glial
15 fibrillary acidic protein (GFAP) promoter, myelin basic protein (MBP) promoter, and methyl CpG-binding protein 2 (Mecp2) promoter.

[00640] 226. The nucleic acid molecule of any one of embodiments 223-224, wherein the RNA Pol III promoter is selected from the group consisting of U6 promoter, H1 promoter and 7SK promoter.

20 [00641] 227. The nucleic acid molecule of any one of embodiments 211-226, where the nucleic acid molecule comprises a nucleic acid encoding a reporter protein.

[00642] 228. The nucleic acid molecule of any one of embodiments 211-227, wherein the AAV variants are derived from one or more of: AAV1, AAV2, AAV3B, AAV5, AAV6, AAV8, AAV9, AAV3, AAV4, AAV7, AAV11, AAVrh10, AAVrh39, and
25 AAVrh74.

[00643] 229. The nucleic acid molecule of any one of embodiments 211-228, wherein the inserted peptide has a length of 4-15 amino acids.

[00644] 230. The nucleic acid molecule of embodiment 229, wherein the inserted peptide comprises at least 4 contiguous amino acids of an amino acid sequence set forth
30 in any one of SEQ ID NO: 1-32.

[00645] 231. The nucleic acid molecule of embodiment 229, wherein the inserted peptide comprises at least 4 contiguous amino acids of an amino acid sequence set forth in any one of SEQ ID NO: 68-110.

- [00646] 232. The nucleic acid molecule of any one of embodiments 211-231, wherein the nucleic acid encoding a reporter protein is operatively linked to a cell type and/or tissue specific promoter.
- [00647] 233. The nucleic acid molecule of embodiment 232, wherein the cell type and/or tissue specific promoter is the hSyn1 promoter.
- [00648] 234. The nucleic acid molecule of any one of embodiments 211-233, wherein the nucleic acid comprising the barcode comprises a sequence selected from any one of sequences SEQ ID NO: 111-154.
- [00649] 235. The nucleic acid molecule of any one of embodiments 211-233, wherein the nucleic acid comprising the barcode comprises a sequence selected from any one of sequences SEQ ID NO: 155-198.
- [00650] 236. Use of an AAV variant according to any one of embodiments 135-210 to deliver a transgene to a target cell or tissue.
- [00651] 237. An AAV vector comprising a nucleic acid molecule encoding a peptide that comprises at least 4 contiguous amino acids of an amino acid sequence set forth in any one of SEQ ID NO: 1-32.
- [00652] 238. The AAV vector of embodiment 237, wherein the nucleic acid encodes a peptide that comprises an amino acid sequence set forth in any one of SEQ ID NO: 1-32.
- [00653] 239. The AAV vector of embodiment 237 or 238, wherein the nucleic acid encodes a peptide having a sequence of any of one of SEQ ID NO: 1-32.
- [00654] 240. An AAV vector comprising a nucleic acid molecule encoding a peptide that comprises at least 4 contiguous amino acids of an amino acid sequence set forth in any one of SEQ ID NO: 68-110.
- [00655] 241. The AAV vector of embodiment 240, wherein the nucleic acid encodes a peptide that comprises an amino acid sequence set forth in any one of SEQ ID NO: 68-110.
- [00656] 242. The AAV vector of embodiment 240 or 241, wherein the nucleic acid encodes a peptide having the sequence of any of one of SEQ ID NO: 68-110.
- [00657] 243. The AAV vector of embodiment 240, wherein the nucleic acid encodes a peptide that comprises an amino acid sequence set forth in any one of SEQ ID NO: 71, 76-80, 83, 89, 91, 94-96, 101-103 and 106.
- [00658] 244. The AAV vector of any one of embodiments 237-243, wherein the peptide is a part of a capsid protein.

- [00659] 245. The AAV vector of embodiment 244, wherein the capsid protein is VP1, VP2, or VP3.
- [00660] 246. The AAV vector of any one of embodiments 237-245, wherein the peptide is inserted at a location between amino acid residues 450 and 600 of the capsid protein.
- [00661] 247. The AAV vector of embodiment 246, wherein the peptide is inserted at
- (i) amino acid position 590 of an AAV1 capsid protein,
 - (ii) amino acid position 454 or 590 of an AAV6 capsid protein,
 - (iii) amino acid position 588 of an AAV2 capsid protein,
 - (iv) amino acid position 589 of an AAV3B capsid protein,
 - (v) amino acid position 578 of an AAV5 capsid protein,
 - (vi) amino acid position 591 of the an AAV8 capsid protein, or
 - (vi) amino acid position 266, 455, or 589 of an AAV9 capsid protein,
- wherein the positions correspond to the numbering of VP1 in the AAV serotype.
- [00662] 248. A pharmaceutical composition comprising the AAV vector of any one of embodiments 237-247 and a pharmaceutically acceptable carrier.
- [00663] 249. A peptide comprising an amino acid sequence set forth in any one of SEQ ID NO: 1-32.
- [00664] 250. A peptide comprising an amino acid sequence set forth in any one of SEQ ID NO: 68-110.
- [00665] 251. A peptide comprising an amino acid sequence set forth in any one of SEQ ID NO: 71, 76-80, 83, 89, 91, 94-96, 101-103 and 106.
- [00666] 252. A peptide comprising an amino acid sequence set forth in any one of SEQ ID NO: 71, 76-80, 83 and 94-96.
- [00667] 253. A peptide comprising an amino acid sequence set forth in any one of SEQ ID NO: 89, 91, 101-103 and 106.
- [00668] 254. A peptide comprising an amino acid sequence set forth in any one of SEQ ID NO: 68 to SEQ ID NO: 75.
- [00669] 255. A peptide comprising an amino acid sequence set forth in any one of SEQ ID NO: 1, SEQ ID NO: 2 and SEQ ID NO: 3.
- [00670] 256. A peptide comprising an amino acid sequence set forth in SEQ ID NO: 71.
- [00671] 257. A peptide comprising an amino acid sequence set forth in any one of SEQ ID NO: 90 to SEQ ID NO: 110.

- [00672] 258. A peptide comprising an amino acid sequence set forth in any one of SEQ ID NO: 95, SEQ ID NO: 94, SEQ ID NO: 96, SEQ ID NO: 101, SEQ ID NO: 103, SEQ ID NO: 106, SEQ ID NO: 91 and SEQ ID NO: 102.
- [00673] 259. A peptide comprising an amino acid sequence set forth in any one of
5 SEQ ID NO: 4-7.
- [00674] 260. A peptide comprising an amino acid sequence set forth in any one of SEQ ID NO: 78, SEQ ID NO: 80, SEQ ID NO: 77, SEQ ID NO: 79, SEQ ID NO: 76 and SEQ ID NO: 83.
- [00675] 261. A peptide comprising an amino acid sequence set forth in any one of
10 SEQ ID NO: 8 to SEQ ID NO: 11.
- [00676] 262. A peptide comprising an amino acid sequence set forth in any one of SEQ ID NO: 28 to SEQ ID NO: 32.
- [00677] 263. A peptide comprising an amino acid sequence set forth in any one of SEQ ID NO: 19 to SEQ ID NO: 27.
- [00678] 264. A peptide comprising an amino acid sequence set forth in any one of
15 SEQ ID NO: 12 to SEQ ID NO: 18.
- [00679] 265. A peptide comprising an amino acid sequence set forth in any one of SEQ ID NO: 86 to SEQ ID NO: 89.
- [00680] 266. A peptide comprising an amino acid sequence set forth in SEQ ID NO:
20 89.
- [00681] 267. The peptide of any one of embodiments 249-266, wherein the peptide is part of an AAV vector.
- [00682] 268. The peptide of embodiment 267, wherein the peptide is part of a capsid protein of the AAV vector.
- [00683] 269. A nucleic acid molecule encoding the peptide of any one of embodiments
25 249-268.
- [00684] 270. A capsid protein comprising a peptide comprising at least 4 contiguous amino acids of an amino acid sequence set forth in any one of SEQ ID NO: 1-32.
- [00685] 271. A capsid protein comprising a peptide comprising at least 4 contiguous
30 amino acids of an amino acid sequence set forth in any one of SEQ ID NO: 68-110.
- [00686] 272. The capsid protein of embodiment 270, wherein the peptide comprises the amino acid sequence set forth in any one of SEQ ID NO: 1-32.
- [00687] 273. The capsid protein of embodiment 271, wherein the peptide comprises the amino acid sequence set forth in any one of SEQ ID NO: 68-110.

- [00688] 274. The capsid protein of embodiment 270, comprising the amino acid sequence set forth in any one of SEQ ID NO: 1-32.
- [00689] 275. The capsid protein of embodiment 271, comprising the amino acid sequence set forth in any one of SEQ ID NO: 68-110.
- 5 [00690] 276. The capsid protein of embodiment 271, wherein the peptide comprises an amino acid sequence set forth in any one of SEQ ID NO: 71, 76-80, 83, 89, 91, 94-96, 101-103 and 106.
- [00691] 277. The capsid protein of embodiment 271, wherein the peptide comprises an amino acid sequence set forth in any one of SEQ ID NO: 71, 76-80, 83 and 94-96.
- 10 [00692] 278. The capsid protein of embodiment 271, wherein the peptide comprises an amino acid sequence set forth in any one of SEQ ID NO: 89, 91, 101-103 and 106.
- [00693] 279. The capsid protein of embodiment 271, wherein the peptide comprises an amino acid sequence set forth in any one of SEQ ID NO: 68 to SEQ ID NO: 75.
- [00694] 280. The capsid protein of embodiment 270, wherein the peptide comprises
15 an amino acid sequence set forth in any one of SEQ ID NO: 1, SEQ ID NO: 2 and SEQ ID NO: 3.
- [00695] 281. The capsid protein of embodiment 271, wherein the peptide comprises an amino acid sequence set forth in SEQ ID NO: 71.
- [00696] 282. The capsid protein of embodiment 271, wherein the peptide comprises
20 an amino acid sequence set forth in any one of SEQ ID NO: 90 to SEQ ID NO: 110.
- [00697] 283. The capsid protein of embodiment 271, wherein the peptide comprises an amino acid sequence set forth in any one of SEQ ID NO: 95, SEQ ID NO: 94, SEQ ID NO: 96, SEQ ID NO: 101, SEQ ID NO: 103, SEQ ID NO: 106, SEQ ID NO: 91 and SEQ ID NO: 102.
- 25 [00698] 284. The capsid protein of embodiment 270, wherein the peptide comprises an amino acid sequence set forth in any one of SEQ ID NO: 4-7.
- [00699] 285. The capsid protein of embodiment 271, wherein the peptide comprises an amino acid sequence set forth in any one of SEQ ID NO: 78, SEQ ID NO: 80, SEQ ID NO: 77, SEQ ID NO: 79, SEQ ID NO: 76 and SEQ ID NO: 83.
- 30 [00700] 286. The capsid protein of embodiment 270, wherein the peptide comprises an amino acid sequence set forth in any one of SEQ ID NO: 8 to SEQ ID NO: 11.
- [00701] 287. The capsid protein of embodiment 270, wherein the peptide comprises an amino acid sequence set forth in any one of SEQ ID NO: 28 to SEQ ID NO: 32.

- [00702] 288. The capsid protein of embodiment 270, wherein the peptide comprises an amino acid sequence set forth in any one of SEQ ID NO: 19 to SEQ ID NO: 27.
- [00703] 289. The capsid protein of embodiment 270, wherein the peptide comprises an amino acid sequence set forth in any one of SEQ ID NO: 12 to SEQ ID NO: 18.
- 5 [00704] 290. The capsid protein of embodiment 271, wherein the peptide comprises an amino acid sequence set forth in any one of SEQ ID NO: 86 to SEQ ID NO: 89.
- [00705] 291. The capsid protein of embodiment 271, wherein the peptide comprises an amino acid sequence set forth in SEQ ID NO: 89.
- [00706] 292. A nucleic acid molecule encoding the capsid protein of any one of
10 embodiments 269-291.
- [00707] 293. A method of delivering a nucleic acid to a target cell or tissue of a subject, comprising: administering a composition comprising an AAV vector according to any one of embodiments 237-247.
- [00708] 294. The method of embodiment 293, wherein the capsid protein comprises
15 an amino acid sequence set forth in any one of SEQ ID NO: 1-32.
- [00709] 295. The method of embodiment 293, wherein the capsid protein comprises an amino acid sequence set forth in any one of SEQ ID NO: 68-110.
- [00710] 296. The method of any one of embodiments 293-295, wherein the target cell,
20 cell line or tissue is selected from the group consisting of CNS, heart, lung, trachea, esophagus, muscle, bone, cartilage, stomach, pancreas, intestine, liver, bladder, kidney, ureter, urethra, uterus, fallopian tube, ovary, testes, prostate, eye, blood, lymph, and oral mucosa.
- [00711] 297. The method of any one of embodiments 293-295, wherein the target cell
25 is selected from the group consisting of neurons, glial cells, astrocytes, oligodendroglia, microglia, Schwann cells, ependymal cells, hepatocytes, stellate fat storing cells, Kupffer cells, liver endothelial cells, epithelial cells, cardiomyocytes, smooth muscle cells, T-cells, B cells, hematopoietic stem cells, and embryonic stem cells.
- [00712] 298. The method of embodiment 296, wherein the target cell or tissue is from liver.
- 30 [00713] 299. The method of embodiment 296, wherein the target cell or tissue is from CNS.
- [00714] 300. A pharmaceutical composition comprising the variant of any one of embodiments 135-211 and a pharmaceutically acceptable carrier.

[00715] 301. The library of embodiment 116, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 590 of the capsid protein of an AAV1 serotype.

5 [00716] 302. The library of embodiment 116, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 590 of the capsid protein of an AAV1 serotype.

[00717] 303. The library of embodiment 302, wherein the peptide comprises an amino acid sequence of any one of SEQ ID NO: 68-75.

10 [00718] 304. The library of embodiment 302, wherein the peptide comprises the amino acid sequence SEQ ID NO: 71.

[00719] 305. The library of embodiment 301, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 1, SEQ ID NO: 2 and SEQ ID NO: 3.

15 [00720] 306. The library of embodiment 116, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 454 of the capsid protein of an AAV6 serotype.

[00721] 307. The library of embodiment 116, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 454 of the capsid protein of an AAV6 serotype.

20 [00722] 308. The library of embodiment 116, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 590 of the capsid protein of an AAV6 serotype.

25 [00723] 309. The library of embodiment 116, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 590 of the capsid protein of an AAV6 serotype.

[00724] 310. The library of any one of embodiments 306 and 308, wherein the peptide comprises an amino acid sequence of any one of SEQ ID NO: 19 to SEQ ID NO: 27.

30 [00725] 311. The library of embodiment 116, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 588 of the capsid protein of an AAV2 serotype.

[00726] 312. The library of embodiment 116, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 588 of the capsid protein of an AAV2 serotype.

[00727] 313. The library of embodiment 312, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 90 to SEQ ID NO: 110.

5 [00728] 314. The library of embodiments 312, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 95, SEQ ID NO: 94, SEQ ID NO: 96, SEQ ID NO: 101, SEQ ID NO: 103, SEQ ID NO: 106, SEQ ID NO: 91 and SEQ ID NO: 102.

10 [00729] 315. The library of embodiments 311, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 4-7.

[00730] 316. The library of embodiment 116, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 589 of the capsid protein of an AAV3B serotype.

15 [00731] 317. The library of embodiment 116, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 589 of the capsid protein of an AAV3B serotype.

[00732] 318. The library of embodiment 317, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 76- 85.

20 [00733] 319. The library of embodiment 317, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 78, SEQ ID NO: 80, SEQ ID NO: 77, SEQ ID NO: 79, SEQ ID NO: 76 and SEQ ID NO: 83.

[00734] 320. The library of embodiment 316, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 8 to SEQ ID NO: 11.

25 [00735] 321. The library of embodiment 116, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 578 of the capsid protein of an AAV5 serotype.

30 [00736] 322. The library of embodiment 116, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 578 of the capsid protein of an AAV5 serotype.

[00737] 323. The library of embodiment 321, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one SEQ ID NO: 28 to SEQ ID NO: 32.

5 [00738] 324. The library of embodiment 116, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 591 of the capsid protein of an AAV8 serotype.

[00739] 325. The library of embodiment 116, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 591 of the capsid protein of an AAV8 serotype.

10 [00740] 326. The library of embodiment 116, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 266 of the capsid protein of an AAV9 serotype.

[00741] 327. The library of embodiment 116, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 266
15 of the capsid protein of an AAV9 serotype.

[00742] 328. The library of embodiment 116, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 455 of the capsid protein of an AAV9 serotype.

[00743] 329. The library of embodiment 116, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 455
20 of the capsid protein of an AAV9 serotype.

[00744] 330. The library of embodiment 116, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 589 of the capsid protein of an AAV9 serotype.

25 [00745] 331. The library of embodiment 116, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 589 of the capsid protein of an AAV9 serotype.

[00746] 332. The library of any one of embodiments 326, 328, and 330, wherein the peptide comprises an amino acid sequence selected from the group consisting of any
30 one of SEQ ID NO: 12 to SEQ ID NO: 18.

[00747] 333. The library of any one of embodiments 327, 329, and 331, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 86 to SEQ ID NO: 89.

5 [00748] 334. The library of any one of embodiments 327, 329, and 331, wherein the peptide comprises the sequence of SEQ ID NO: 89.

[00749] 335. The AAV variant of embodiment 173, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 590 of the capsid protein of an AAV1 serotype.

10 [00750] 336. The AAV variant of embodiment 173, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 590 of the capsid protein of an AAV1 serotype.

[00751] 337. The AAV variant of embodiment 336, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 68 to SEQ ID NO: 75.

15 [00752] 338. The AAV variant of embodiment 336, wherein the peptide comprises the amino acid sequence SEQ ID NO: 71.

[00753] 339. The AAV variant of embodiment 335, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 1, SEQ ID NO: 2 and SEQ ID NO: 3.

20 [00754] 340. The AAV variant of embodiment 173, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 454 of the capsid protein of an AAV6 serotype.

25 [00755] 341. The AAV variant of embodiment 173, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 454 of the capsid protein of an AAV6 serotype.

[00756] 342. The AAV variant of embodiment 173, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 590 of the capsid protein of an AAV6 serotype.

30 [00757] 343. The AAV variant of embodiment 173, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 590 of the capsid protein of an AAV6 serotype.

- [00758] 344. The AAV variant of any one of embodiments 340 and 342, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 19 to SEQ ID NO: 27.
- 5 [00759] 345. The AAV variant of embodiment 173, wherein a peptide comprising the amino acid sequence of SEQ ID NO: 1-32 is inserted at amino acid position 588 of the capsid protein of an AAV2 serotype.
- [00760] 346. The AAV variant of embodiment 173, wherein a peptide comprising the amino acid sequence of SEQ ID NO: 68-110 is inserted at amino acid position 588 of the capsid protein of an AAV2 serotype.
- 10 [00761] 347. The AAV variant of embodiment 346, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 90 to SEQ ID NO: 110.
- [00762] 348. The AAV variant of embodiments 346, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 95, SEQ ID NO: 94, SEQ ID NO: 96, SEQ ID NO: 101, SEQ ID NO: 103, SEQ ID NO: 106, SEQ ID NO: 91 and SEQ ID NO: 102.
- 15 [00763] 349. The AAV variant of embodiments 345, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 4-7.
- 20 [00764] 350. The AAV variant of embodiment 173, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 589 of the capsid protein of an AAV3B serotype.
- [00765] 351. The AAV variant of embodiment 173, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 589 of the capsid protein of an AAV3B serotype.
- 25 [00766] 352. The AAV variant of embodiment 351, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 78, SEQ ID NO: 80, SEQ ID NO: 77, SEQ ID NO: 79, SEQ ID NO: 76 and SEQ ID NO: 83.
- 30 [00767] 353. The AAV variant of embodiment 350, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 8 to SEQ ID NO: 11.

- [00768] 354. The AAV variant of embodiment 173, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 578 of the capsid protein of an AAV5 serotype.
- [00769] 355. The AAV variant of embodiment 173, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 578 of the capsid protein of an AAV5 serotype.
- [00770] 356. The AAV variant of embodiment 354, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one SEQ ID NO: 28 to SEQ ID NO: 32.
- [00771] 357. The AAV variant of embodiment 173, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 591 of the capsid protein of an AAV8 serotype.
- [00772] 358. The AAV variant of embodiment 173, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 591 of the capsid protein of an AAV8 serotype.
- [00773] 359. The AAV variant of embodiment 173, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 266 of the capsid protein of an AAV9 serotype.
- [00774] 360. The AAV variant of embodiment 173, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 266 of the capsid protein of an AAV9 serotype.
- [00775] 361. The AAV variant of embodiment 173, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 455 of the capsid protein of an AAV9 serotype.
- [00776] 362. The AAV variant of embodiment 173, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 455 of the capsid protein of an AAV9 serotype.
- [00777] 363. The AAV variant of embodiment 173, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 589 of the capsid protein of an AAV9 serotype.
- [00778] 364. The AAV variant of embodiment 173, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 589 of the capsid protein of an AAV9 serotype.

- [00779] 365. The AAV variant of any one of embodiments 359, 361, and 363, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 12 to SEQ ID NO: 18.
- [00780] 366. The AAV variant of any one of embodiments 360, 362, and 364, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 86 to SEQ ID NO: 89.
- [00781] 367. The AAV variant of any one of embodiments 360, 362, and 364, wherein the peptide comprises the sequence of SEQ ID NO: 89.
- [00782] 368. The AAV vector of embodiment 247, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 590 of the capsid protein of an AAV1 serotype.
- [00783] 369. The AAV vector of embodiment 247, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 590 of the capsid protein of an AAV1 serotype.
- [00784] 370. The AAV vector of embodiment 369, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 68 to SEQ ID NO: 75.
- [00785] 371. The AAV vector of embodiment 369, wherein the peptide comprises the amino acid sequence SEQ ID NO: 71.
- [00786] 372. The AAV vector of embodiment 368, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 1, SEQ ID NO: 2 and SEQ ID NO: 3.
- [00787] 373. The AAV vector of embodiment 247, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 454 of the capsid protein of an AAV6 serotype.
- [00788] 374. The AAV vector of embodiment 247, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 454 of the capsid protein of an AAV6 serotype.
- [00789] 375. The AAV vector of embodiment 247, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 590 of the capsid protein of an AAV6 serotype.
- [00790] 376. The AAV vector of embodiment 247, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 590 of the capsid protein of an AAV6 serotype.

- [00791] 377. The AAV vector of any one of embodiments 373 and 375, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 19 to SEQ ID NO: 27.
- 5 [00792] 378. The AAV vector of embodiment 247, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 588 of the capsid protein of an AAV2 serotype.
- [00793] 379. The AAV vector of embodiment 247, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 588 of the capsid protein of an AAV2 serotype.
- 10 [00794] 380. The AAV vector of embodiment 379, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 90 to SEQ ID NO: 110.
- [00795] 381. The AAV vector of embodiments 379, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 95, SEQ ID NO: 94, SEQ ID NO: 96, SEQ ID NO: 101, SEQ ID NO: 103, SEQ ID NO: 106, SEQ ID NO: 91 and SEQ ID NO: 102.
- 15 [00796] 382. The AAV vector of embodiments 378, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 4-7.
- 20 [00797] 383. The AAV vector of embodiment 247, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 589 of the capsid protein of an AAV3B serotype.
- [00798] 384. The AAV vector of embodiment 247, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 589 of the capsid protein of an AAV3B serotype.
- 25 [00799] 385. The AAV vector of embodiment 384, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 78, SEQ ID NO: 80, SEQ ID NO: 77, SEQ ID NO: 79, SEQ ID NO: 76 and SEQ ID NO: 83.
- 30 [00800] 386. The AAV vector of embodiment 383, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 8 to SEQ ID NO: 11.

- [00801] 387. The AAV vector of embodiment 247, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 578 of the capsid protein of an AAV5 serotype.
- [00802] 388. The AAV vector of embodiment 247, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 578 of the capsid protein of an AAV5 serotype.
- [00803] 389. The AAV vector of embodiment 387, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one SEQ ID NO: 28 to SEQ ID NO: 32.
- [00804] 390. The AAV vector of embodiment 247, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 591 of the capsid protein of an AAV8 serotype.
- [00805] 391. The AAV vector of embodiment 247, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 591 of the capsid protein of an AAV8 serotype.
- [00806] 392. The AAV vector of embodiment 247, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 266 of the capsid protein of an AAV9 serotype.
- [00807] 393. The AAV vector of embodiment 247, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 266 of the capsid protein of an AAV9 serotype.
- [00808] 394. The AAV vector of embodiment 247, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 455 of the capsid protein of an AAV9 serotype.
- [00809] 395. The AAV vector of embodiment 247, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 455 of the capsid protein of an AAV9 serotype.
- [00810] 396. The AAV vector of embodiment 247, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 589 of the capsid protein of an AAV9 serotype.
- [00811] 397. The AAV vector of embodiment 247, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 589 of the capsid protein of an AAV9 serotype.

[00812] 398. The AAV vector of any one of embodiments 392, 394, and 396, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 12 to SEQ ID NO: 18.

5 [00813] 399. The AAV vector of any one of embodiments 393, 395, and 397, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 86 to SEQ ID NO: 89.

[00814] 400. The AAV vector of any one of embodiments 393, 395, and 397, wherein the peptide comprises the sequence of SEQ ID NO: 89.

10 [00815] 401. A capsid protein comprising an inserted peptide, wherein the peptide is inserted at

- (i) amino acid position 590 of an AAV1 capsid protein,
- (ii) amino acid position 454 or 590 of an AAV6 capsid protein,
- (iii) amino acid position 588 of an AAV2 capsid protein,
- (iv) amino acid position 589 of an AAV3B capsid protein,
- 15 (v) amino acid position 578 of an AAV5 capsid protein,
- (vi) amino acid position 591 of the an AAV8 capsid protein, or
- (vi) amino acid position 266, 455, or 589 of an AAV9 capsid protein,

wherein the positions correspond to the numbering of VP1 in the AAV serotype.

20 [00816] 402. The capsid protein of embodiment 401, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 590 of the capsid protein of an AAV1 serotype.

[00817] 403. The capsid protein of embodiment 401, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 590 of the capsid protein of an AAV1 serotype.

25 [00818] 404. The capsid protein of embodiment 403, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 68 to SEQ ID NO: 75.

[00819] 405. The capsid protein of embodiment 403, wherein the peptide comprises the amino acid sequence SEQ ID NO: 71.

30 [00820] 406. The capsid protein of embodiment 402, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 1, SEQ ID NO: 2 and SEQ ID NO: 3.

- [00821] 407. The capsid protein of embodiment 401, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 454 of the capsid protein of an AAV6 serotype.
- [00822] 408. The capsid protein of embodiment 401, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 454 of the capsid protein of an AAV6 serotype.
- [00823] 409. The capsid protein of embodiment 401, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 590 of the capsid protein of an AAV6 serotype.
- [00824] 410. The capsid protein of embodiment 401, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 590 of the capsid protein of an AAV6 serotype.
- [00825] 411. The capsid protein of any one of embodiments 407 and 409, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 19 to SEQ ID NO: 27.
- [00826] 412. The capsid protein of embodiment 401, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 588 of the capsid protein of an AAV2 serotype.
- [00827] 413. The capsid protein of embodiment 401, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 588 of the capsid protein of an AAV2 serotype.
- [00828] 414. The capsid protein of embodiment 413, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 90 to SEQ ID NO: 110.
- [00829] 415. The capsid protein of embodiments 413, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 95, SEQ ID NO: 94, SEQ ID NO: 96, SEQ ID NO: 101, SEQ ID NO: 103, SEQ ID NO: 106, SEQ ID NO: 91 and SEQ ID NO: 102.
- [00830] 416. The capsid protein of embodiments 412, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 4-7.
- [00831] 417. The capsid protein of embodiment 401, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 589 of the capsid protein of an AAV3B serotype.

[00832] 418. The capsid protein of embodiment 401, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 589 of the capsid protein of an AAV3B serotype.

5 [00833] 419. The capsid protein of embodiment 418, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 78, SEQ ID NO: 80, SEQ ID NO: 77, SEQ ID NO: 79, SEQ ID NO: 76 and SEQ ID NO: 83.

[00834] 420. The capsid protein of embodiment 417, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 8 to SEQ ID NO: 11.

[00835] 421. The capsid protein of embodiment 401, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 578 of the capsid protein of an AAV5 serotype.

15 [00836] 422. The capsid protein of embodiment 401, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 578 of the capsid protein of an AAV5 serotype.

[00837] 423. The capsid protein of embodiment 421, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one SEQ ID NO: 28 to SEQ ID NO: 32.

20 [00838] 424. The capsid protein of embodiment 401, wherein a peptide comprising the amino acid sequence of SEQ ID NO: 1-32 is inserted at amino acid position 591 of the capsid protein of an AAV8 serotype.

[00839] 425. The capsid protein of embodiment 401, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 591 of the capsid protein of an AAV8 serotype.

[00840] 426. The capsid protein of embodiment 401, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 266 of the capsid protein of an AAV9 serotype.

30 [00841] 427. The capsid protein of embodiment 401, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 266 of the capsid protein of an AAV9 serotype.

[00842] 428. The capsid protein of embodiment 401, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 455 of the capsid protein of an AAV9 serotype.

[00843] 429. The capsid protein of embodiment 401, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 455 of the capsid protein of an AAV9 serotype.

5 [00844] 430. The capsid protein of embodiment 401, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 589 of the capsid protein of an AAV9 serotype.

[00845] 431. The capsid protein of embodiment 401, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 589 of the capsid protein of an AAV9 serotype.

10 [00846] 432. The capsid protein of any one of embodiments 426, 428, and 430, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 12 to SEQ ID NO: 18.

[00847] 433. The capsid protein of any one of embodiments 427, 429, and 431, wherein the peptide comprises an amino acid sequence selected from the group
15 consisting of any one of SEQ ID NO: 86 to SEQ ID NO: 89.

[00848] 434. The capsid protein of any one of embodiments 427, 429, and 431, wherein the peptide comprises the sequence of SEQ ID NO: 89.

[00849] 435. A nucleic acid molecule encoding the capsid protein of any one of embodiments 401 to 434.

CLAIMS

What is claimed is:

1. A method of identifying an AAV capsid variant with a desired characteristic compared to a natural AAV serotype, comprising:
 - 5 (i) contacting a cell, cell line, or tissue with a library of AAV variants, wherein each member of the library comprises:
 - a) a nucleic acid encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein; and
 - 10 one or more of:
 - b) one or more silent mutations in the nucleic acid sequence flanking the peptide insertion site in the AAV variant capsid protein of a);
 - c) a nucleic acid encoding a localization signal;
 - d) a nucleic acid comprising a barcode; and
 - 15 e) a nucleic acid encoding a reporter protein;
 - (ii) allowing the AAV variants in said library to transduce the cell, cell line, or tissue;
 - (iii) recovering from the cell, cell line, or tissue the AAV variant; and
 - (iv) identifying the AAV capsid variant with the desired characteristic.
- 20 2. A method of identifying an AAV capsid variant with a desired characteristic compared to a natural AAV serotype, comprising:
 - (i) contacting a cell, cell line, or tissue with a library of AAV variants, wherein each member of the library comprises:
 - a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein; and one or more of:
 - 25 b) one or more silent mutations in the nucleic acid encoding the AAV variant capsid protein of a) in the nucleic acid sequence flanking the peptide insertion site;
 - 30 c) a nucleic acid encoding a localization signal;
 - d) a nucleic acid comprising a barcode; and
 - e) a nucleic acid encoding a reporter protein;

- (ii) allowing the AAV variants in said library to transduce the cell, cell line, or tissue;
 - (iii) recovering from the cell, cell line, or tissue the AAV variant; and
 - (iv) identifying the AAV capsid variant with the desired characteristic.
- 5 3. The method of claim 1, wherein each member of the library comprises one or more silent mutations in the nucleic acid sequence flanking the peptide insertion site in the AAV variant capsid protein of a).
4. The method of claim 2, wherein each member of the library comprises one or more silent mutations in the nucleic acid encoding the AAV variant capsid protein of a) in
- 10 the nucleic acid sequence flanking the peptide insertion site.
5. The method of any one of claims 1-4, wherein each member of the library comprises a nucleic acid encoding a localization signal.
6. The method of any one of claims 1-5, wherein each member of the library comprises a nucleic acid comprising a barcode.
- 15 7. The method of any one of claims 1-6, wherein each member of the library comprises a nucleic acid encoding a reporter protein.
8. The method of any one of claims 1-7, wherein the nucleic acid encoding an AAV variant capsid protein, and the nucleic acid encoding a localization signal, the nucleic acid comprising a barcode, and/or the nucleic acid encoding a reporter protein, are
- 20 located in separate nucleic acid molecules.
9. The method of any one of claims 1-7, wherein the nucleic acid encoding an AAV variant capsid protein, the nucleic acid encoding a localization signal, the nucleic acid comprising a barcode, and/or the nucleic acid encoding a reporter protein, are located in one nucleic acid molecule.
- 25 10. The method of claim 9, wherein the nucleic acid encoding an AAV variant capsid protein, and the nucleic acid encoding a localization signal, the nucleic acid comprising a barcode, and/or the nucleic acid encoding a reporter protein, are linked to each other in any order.

11. The method of claim 10, wherein each member of the library comprises: a 5'ITR sequence, the nucleic acid comprising a barcode, the nucleic acid encoding a reporter protein, the nucleic acid encoding an AAV variant capsid protein, and a 3'ITR sequence, in that order.
- 5 12. The method of any one of claims 1-11, wherein the library of AAV variants comprises AAV variant capsid proteins derived from two or more AAV serotypes.
13. The method of any one of claims 1-12, wherein the AAV serotype of the library of AAV variants is selected from one or more of: AAV1, AAV2, AAV3B, AAV5, AAV6, AAV8, AAV9, AAV3, AAV4, AAV7, AAV11, AAVrh10, AAVrh39, and AAVrh74.
- 10 14. The method of any one of claims 1-13, wherein the nucleic acid encoding the reporter protein and the nucleic acid encoding an AAV variant capsid are each independently operatively linked to a promoter.
15. The method of any one of claims 1-14, wherein the desired characteristic is enhanced cell or tissue tropism.
- 15 16. A method of identifying an AAV capsid variant with a desired characteristic compared to a natural AAV serotype, comprising:
- 20 (i) inserting a plurality of nucleic acids encoding peptides, into a population of nucleic acids encoding a hypervariable and/or surface-exposed loop of an AAV capsid protein to create a library of nucleic acids encoding AAV variant capsid proteins;
- (ii) linking each nucleic acid encoding an AAV variant capsid protein in said library to one or more of:
- 25 (a) a nucleic acid comprising a barcode,
- (b) a nucleic acid encoding a reporter protein, and
- (c) a nucleic acid encoding a localization signal;
- (iii) manufacturing a library of AAV variants in producer cells by providing adenovirus helper and AAV rep functions *in trans*;
- (iv) purifying the library of AAV variants;
- (v) contacting a cell, cell line, or tissue with the library of AAV variants;
- 30 (vi) recovering the AAV variants from the target cell, cell line, or tissue; and
- (vii) identifying the AAV capsid variant with the desired characteristic.

17. The method of claim 16, wherein each nucleic acid encoding an AAV variant capsid protein in said library is linked to a nucleic acid comprising a barcode.
18. The method of any one of claims 1-17, wherein each member of the library comprises a first nucleic acid comprising a first barcode and a second nucleic acid comprising a second barcode.
19. The method of claim 18, wherein the first nucleic acid comprising the first barcode and the second nucleic acid comprising the second barcode are different.
20. The method of claim 18 or 19, wherein the first nucleic acid comprising the first barcode comprises a sequence selected from any one of sequences SEQ ID NO: 111-154.
21. The method of claim 18 or 19, wherein the first nucleic acid comprising the first barcode is selected from any one of sequences SEQ ID NO: 111-154.
22. The method of claim 18 or 19, wherein the second nucleic acid comprising the second barcode comprises a sequence selected from any one of sequences SEQ ID NO: 155-198.
23. The method of claim 18 or 19, wherein the second nucleic acid comprising the second barcode is selected from any one of sequences SEQ ID NO: 155-198.
24. The method of any one of claims 18-23, wherein each of the first nucleic acid comprising the first barcode and the second nucleic acid comprising the second barcode is independently operatively linked to a promoter.
25. The method of claim 24, wherein the promoter operatively linked to the first nucleic acid comprising the first barcode and the promoter operatively linked to the second nucleic acid comprising the second barcode is each independently an RNA Pol II promoter.
26. The method of claim 24, wherein the promoter operatively linked to the first nucleic acid comprising the first barcode and the promoter operatively linked to the nucleic acid comprising the second barcode is each independently an RNA Pol III promoter.

27. The method of claim 24, wherein the promoter operatively linked to the first nucleic acid comprising the first barcode is an RNA Pol II promoter and the promoter operatively linked to the second nucleic acid comprising the second barcode is an RNA Pol III promoter.
- 5 28. The method of any one of claims 25-27, wherein each RNA Pol II promoter is independently selected from the group consisting of: human synapsin promoter (hSyn1), transthyretin promoter (TTR), cytokeratin 18, cytokeratin 19, unc-45 myosin chaperon B (unc45b) promoter, cardiac troponin T (cTnT) promoter, glial fibrillary acidic protein (GFAP) promoter, myelin basic protein (MBP) promoter, and methyl
10 CpG-binding protein 2 (Mecp2) promoter.
29. The method of any one of claims 26-27, wherein each RNA Pol III promoter is independently selected from the group consisting of U6 promoter, H1 promoter and 7SK promoter.
30. The method of any one of claims 16-29, wherein each nucleic acid encoding an
15 AAV variant capsid protein in said library is linked to a nucleic acid encoding a reporter protein.
31. The method of any one of claims 16-30, wherein each nucleic acid encoding an AAV variant capsid protein in said library is linked to a nucleic acid encoding a localization signal.
- 20 32. The method of any one of claims 16-31, wherein each nucleic acid encoding an AAV variant capsid protein further comprises one or more silent mutations in the nucleic acid sequence flanking the peptide insertion site.
33. The method of any one of claims 16-32, wherein step (iv) further comprises combining libraries of variant AAVs based on two or more AAV serotypes to generate
25 a single pool.
34. The method of any one of claims 16-33, wherein the population of nucleic acid sequences encoding a hypervariable and/or surface-exposed loop of an AAV capsid protein comprises sequences derived from two or more AAV serotypes.

35. The method of any one of claims 16-34, wherein the AAV serotype is selected from one or more of: AAV1, AAV2, AAV3B, AAV5, AAV6, AAV8, AAV9, AAV3, AAV4, AAV7, AAV11, AAVrh10, AAVrh39, and AAVrh74.
36. The method of any one of claims 16-35, wherein the helper functions comprise one
5 or more of E2A, E4, VA, E1A, and E1B.
37. The method of any one of claims 16-36, wherein the AAV rep function comprises rep78, rep 68, rep 52 and rep40 genes.
38. The method of claim 37, wherein the start codon of the rep78 and/or rep68 gene is modified from ACG to ATG.
- 10 39. The method of any one of claims 16-38, wherein the producer cells are HEK293 cells.
40. The method of any one of claims 16-39, wherein the nucleic acid encoding an AAV variant capsid protein, the nucleic acid comprising a barcode, the nucleic acid encoding a reporter protein, and/or a nucleic acid encoding a localization signal are linked to each
15 other in any order.
41. The method of any one of claims 16-40, wherein each member of the library comprises: a 5'ITR sequence, the nucleic acid comprising a barcode, the nucleic acid encoding a reporter protein, the nucleic acid encoding an AAV variant capsid protein, and a 3'ITR sequence, in that order.
- 20 42. The method of any one of claims 16-41, wherein the nucleic acid encoding a reporter protein and the nucleic acid encoding an AAV variant capsid are each independently operatively linked to a promoter.
43. The method of any one of claims 16-42, wherein the desired characteristic is enhanced cell or tissue tropism.
- 25 44. The method of any one of claims 1-43, wherein the peptide has a length of 4-15 amino acids.
45. The method of any one of claims 1-44, wherein the peptide has a length of 6-15 amino acids.

46. The method of claim 45, wherein the peptide has a length of 7, 10, or 15 amino acids.
47. The method of claim 46, wherein the peptide has a length of 7 amino acids.
48. The method of any one of claims 1-47, wherein the peptide is inserted into a region
5 selected from the group consisting of VR-I, VR-II, VR-III, VR-IV, VR-V, VR-VI, VR-VII, VR-VIII and VR-IX region of the capsid protein.
49. The method of claim 48, wherein the peptide is inserted into the VR-I of the capsid protein.
50. The method of claim 48, wherein the peptide is inserted into the VR-IV of the capsid
10 protein.
51. The method of claim 48, wherein the peptide is inserted into the VR-VIII of the capsid protein.
52. The method of any one of claims 1-49, wherein the peptide is inserted into the capsid protein VP1, VP2, or VP3.
- 15 53. The method of any one of claims 1-50, wherein the peptide is inserted at a location between amino acid residues 450 and 600 of the capsid protein.
54. The method of any one of claims 1-51, wherein
- (i) the AAV serotype is AAV1 and the peptide is inserted at amino acid position 590 of the capsid protein,
 - 20 (ii) the AAV serotype is AAV6 and the peptide is inserted at amino acid position 454 or 590 of the capsid protein,
 - (iii) the AAV serotype is AAV2 and the peptide is inserted at amino acid position 588 of the capsid protein,
 - (iv) the AAV serotype is AAV3B and the peptide is inserted at amino acid
25 position 589 of the capsid protein,
 - (v) the AAV serotype is AAV5 and the peptide is inserted at amino acid position 578 of the capsid protein,
 - (vi) the AAV serotype is AAV8 and the peptide is inserted at amino acid position 591 of the capsid protein, or

(vii) the AAV serotype is AAV9 and the peptide is inserted at amino acid position 266, 455, or 589 of the capsid protein,

wherein the positions correspond to the numbering of VP1 in the AAV serotype.

5 55. The method of any one of claims 1-54, wherein the reporter protein is a fluorescent protein.

56. The method of claim 55, wherein the reporter protein is selected from the group consisting of: EGFP, mCherry, mClover3, mRuby3, mApple, iRFP, tdTomato, mVenus, YFP, RFP, firefly luciferase, and nanoluciferase.

10 57. The method of any one of claims 1-56, wherein the nucleic acid encoding an AAV variant capsid protein is operatively linked to a p40 promoter.

58. The method of any one of claims 1-57, wherein the nucleic acid encoding a reporter protein is operatively linked to a cell type and/or tissue specific promoter.

15 59. The method of claim 58, wherein the cell type and/or tissue specific promoter is selected from the group consisting of: human synapsin promoter (hSyn1), transthyretin promoter (TTR), cytokeratin 18, cytokeratin 19, unc-45 myosin chaperon B (unc45b) promoter, cardiac troponin T (cTnT) promoter, glial fibrillary acidic protein (GFAP) promoter, myelin basic protein (MBP) promoter, and methyl CpG-binding protein 2 (Mecp2) promoter.

20 60. The method of claim 59, wherein the cell type and/or tissue specific promoter is the hSyn1 promoter.

61. The method of claim 60, wherein the cell type and/or tissue specific promoter is the TTR promoter.

62. The method of any one of claims 1-61, wherein the reporter protein is fused to the localization signal.

25 63. The method of claim 62, wherein the localization signal is fused N-terminally, C-terminally or both N-terminally and C-terminally to the reporter protein.

64. The method of any one of claims 1-63, wherein the localization signal is a nuclear localization signal (NLS), a nuclear envelope binding domain or a histone binding domain.
65. The method of claim 64, wherein the NLS is the SV40 NLS.
- 5 66. The method of claim 64, wherein the nuclear envelope binding domain is a KASH domain.
67. The method of claim 64, wherein the histone binding domain is H2B.
68. The method of any one of claims 1-67, wherein the nucleic acid comprising the barcode is 5-18 nucleotides long.
- 10 69. The method of any one of claims 1-68, wherein the nucleic acid comprising the barcode comprises a sequence selected from any one of sequences SEQ ID NO: 111-154.
70. The method of any one of claims 1-68, wherein the nucleic acid comprising the barcode comprises a sequence selected from any one of sequences SEQ ID NO: 155-15 198.
71. The method of any one of claims 1-68, wherein the nucleic acid comprising the barcode is selected from any one of sequences SEQ ID NO: 111-154.
72. The method of any one of claims 1-68, wherein the nucleic acid comprising the barcode is selected from any one of sequences SEQ ID NO: 155-198.
- 20 73. The method of any one of claims 1-72, wherein the AAV capsid variant with the desired characteristic is identified through sequencing of the associated one or more barcodes.
74. The method of any one of claims 1-73, wherein the AAV capsid variant with the desired characteristic is identified by purification and sequencing of the AAV genome.
- 25 75. The method of any one of claims 1-74, wherein the cell, cell line or tissue is selected from the group consisting of CNS, heart, lung, trachea, esophagus, muscle, bone,

cartilage, stomach, pancreas, intestine, liver, bladder, kidney, ureter, urethra, uterus, fallopian tube, ovary, testes, prostate, eye, blood, lymph, and oral mucosa.

76. The method of any one of claims 1-74, wherein the cell is selected from: neurons, glial cells, astrocytes, oligodendroglia, microglia, Schwann cells, ependymal cells, 5 hepatocytes, stellate fat storing cells, Kupffer cells, liver endothelial cells, epithelial cells, cardiomyocytes, smooth muscle cells, T-cells, B cells, hematopoietic stem cells, and embryonic stem cells.

77. A library of AAV variants, wherein each member of said library comprises:

- 10 a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein; and
- one or more of:
- b) one or more silent mutations in the nucleic acid sequence flanking the peptide insertion site in the AAV variant capsid protein of a);
- 15 c) a nucleic acid encoding a localization signal;
- d) a nucleic acid comprising a barcode; and
- e) a nucleic acid encoding a reporter protein.

78. A library of AAV variants, wherein each member of said library comprises:

- 20 a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein; and
- one or more of:
- b) one or more silent mutations in the nucleic acid encoding the AAV variant capsid protein of a) in the nucleic acid sequence flanking the peptide insertion site;
- 25 c) a nucleic acid encoding a localization signal;
- d) a nucleic acid comprising a barcode; and
- e) a nucleic acid encoding a reporter protein.

79. The library of claim 77, wherein each member of the library comprises one or more silent mutations in the nucleic acid sequence flanking the peptide insertion site in the 30 AAV variant capsid protein of a).

80. The library of claim 78, wherein each member of the library comprises one or more silent mutations in the nucleic acid encoding the AAV variant capsid protein of a) in the nucleic acid sequence flanking the peptide insertion site.
81. The library of any one of claims 77-80, wherein each member of the library
5 comprises a nucleic acid encoding a localization signal.
82. The library of any one of claims 77-81, wherein each member of the library comprises a nucleic acid comprising a barcode.
83. The library of any one of claims 77-82, wherein each member of the library comprises a first nucleic acid comprising a first barcode and a second nucleic acid
10 comprising a second barcode.
84. The library of claim 83, wherein the first nucleic acid comprising the first barcode and the second nucleic acid comprising the second barcode are different.
85. The library of claim 84, wherein the first nucleic acid comprising the first barcode sequence comprises a sequence selected from any one of sequences SEQ ID NO: 111-
15 154.
86. The library of claim 84, wherein the first nucleic acid comprising the first barcode sequence is selected from any one of sequences SEQ ID NO: 111-154.
87. The library of claim 84, wherein the second nucleic acid comprising the second barcode sequence comprises a sequence selected from any one of sequences SEQ ID
20 NO: 155-198.
88. The library of claim 84, wherein the second nucleic acid comprising the second barcode sequence is selected from any one of sequences SEQ ID NO: 155-198.
89. The library of any one of claims 83-88, wherein each of the first nucleic acid comprising the first barcode and the second nucleic acid comprising the second barcode
25 is independently operatively linked to a promoter.
90. The library of claim 89, wherein the promoter operatively linked to the first nucleic acid comprising the first barcode and the promoter operatively linked to the second

nucleic acid comprising the second barcode is each independently an RNA Pol II promoter.

91. The library of claim 89, wherein the promoter operatively linked to the first nucleic acid comprising the first barcode and the promoter operatively linked to the second
5 nucleic acid comprising the second barcode is each independently an RNA Pol III promoter.

92. The library of claim 89, wherein the promoter operatively linked to the first nucleic acid comprising the first barcode is operatively linked to an RNA Pol II promoter and the promoter operatively linked to the second nucleic acid comprising the second
10 barcode is an RNA Pol III promoter.

93. The library of any one of claims 90-91, wherein the RNA Pol II promoter is selected from the group consisting of: human synapsin promoter (hSyn1), transthyretin promoter (TTR), cytokeratin 18, cytokeratin 19, unc-45 myosin chaperon B (unc45b) promoter, cardiac troponin T (cTnT) promoter, glial fibrillary acidic protein (GFAP)
15 promoter, myelin basic protein (MBP) promoter, and methyl CpG-binding protein 2 (Mecp2) promoter.

94. The library of any one of claims 91-93, wherein the RNA Pol III promoter is selected from the group consisting of U6 promoter, H1 promoter and 7SK promoter.

95. The library of any one of claims 77-94, wherein each member of the library
20 comprises a nucleic acid encoding a reporter protein.

96. The library of any one of claims 77-95, wherein the nucleic acid encoding an AAV variant capsid protein, and the nucleic acid encoding a localization signal, the nucleic acid comprising a barcode, and/or the nucleic acid encoding a reporter protein, are located in separate nucleic acid molecules.

25 97. The library of any one of claims 77-95, wherein the nucleic acid encoding an AAV variant capsid protein, the nucleic acid encoding a localization signal, the nucleic acid comprising a barcode, and/or the nucleic acid encoding a reporter protein, are located in one nucleic acid molecule.

98. The library of claim 97, wherein the nucleic acid encoding an AAV variant capsid protein, and the nucleic acid encoding a localization signal, the nucleic acid comprising a barcode, and/or the nucleic acid encoding a reporter protein, are linked to each other in any order.
- 5 99. The library of claim 97, wherein each member of the library comprises: a 5'ITR sequence, the nucleic acid comprising a barcode, the nucleic acid encoding a reporter protein, the nucleic acid encoding an AAV variant capsid protein, and a 3'ITR sequence, in that order.
100. The library of any one of claims 77-99, wherein the AAV variants are derived
10 from one or more of: AAV1, AAV2, AAV3B, AAV5, AAV6, AAV8, AAV9, AAV3, AAV4, AAV7, AAV11, AAVrh10, AAVrh39, and AAVrh74.
101. The library of claim 100, wherein the library of AAV variants comprises AAV variant capsid proteins derived from two or more AAV serotypes.
102. The library of any one of claims 77-101, wherein the peptide has a length of 4-15
15 amino acids.
103. The library of claim 102, wherein the peptide has a length of 6-15 amino acids.
104. The library of claim 103, wherein the peptide has a length of 7, 10, or 15 amino acids.
105. The library of claim 104, wherein the peptide has a length of 7 amino acids.
- 20 106. The library of any one of claims 77-105, wherein the peptide comprises at least 4 contiguous amino acids of an amino acid sequence set forth in any one of SEQ ID NO: 1-32.
107. The library of claim 106, wherein the peptide comprises an amino acid sequence set forth in any one of SEQ ID NO: 1-32.
- 25 108. The library of any one of claims 77-106, wherein the peptide comprises at least 4 contiguous amino acids of an amino acid sequence set forth in any one of SEQ ID NO: 68-110.

109. The library of claim 108, wherein the peptide comprises an amino acid sequence set forth in any one of SEQ ID NO: 68-110.
110. The library of any one of claims 77-109, wherein the peptide is inserted into a region selected from the group consisting of VR-I, VR-II, VR-III, VR-IV, VR-V, VR-VI, VR-VII, VR-VIII and VR-IX region of the capsid protein.
111. The library of claim 110, wherein the peptide is inserted into the VR-I of the capsid protein.
112. The library of claim 110, wherein the peptide is inserted into the VR-IV of the capsid protein.
113. The library of claim 110, wherein the peptide is inserted into the VR-VIII of the capsid protein.
114. The library of any one of claims 77-113, wherein the peptide is inserted into the capsid protein VP1, VP2, or VP3.
115. The library of any one of claims 77-114, wherein the peptide is inserted at a location between amino acid residues 450 and 600 of the capsid protein.
116. The library of any one of claims 77-115, wherein
- (i) the AAV serotype is AAV1 and the peptide is inserted at amino acid position 590 of the capsid protein,
 - (ii) the AAV serotype is AAV6 and the peptide is inserted at amino acid position 454 or 590 of the capsid protein,
 - (iii) the AAV serotype is AAV2 and the peptide is inserted at amino acid position 588 of the capsid protein,
 - (iv) the AAV serotype is AAV3B and the peptide is inserted at amino acid position 589 of the capsid protein,
 - (v) the AAV serotype is AAV5 and the peptide is inserted at amino acid position 578 of the capsid protein,
 - (vi) the AAV serotype is AAV8 and the peptide is inserted at amino acid position 591 of the capsid protein, or
 - (vii) the AAV serotype is AAV9 and the peptide is inserted at amino acid position 266, 455, or 589 of the capsid protein,

wherein the positions correspond to the numbering of VP1 in the AAV serotype.

117. The library of any one of claims 77-116, wherein the reporter protein is a fluorescent protein.

118. The library of claim 117, wherein the reporter protein is selected from the group consisting of: EGFP, mCherry, mClover3, mRuby3, mApple, iRFP, tdTomato, mVenus, YFP, RFP, firefly luciferase, and nanoluciferase.

119. The library of any one of claims 77-118, wherein the nucleic acid encoding an AAV variant capsid protein is operatively linked to a p40 promoter.

120. The library of any one of claims 77-119, wherein the nucleic acid encoding a reporter protein is operatively linked to a cell type and/or tissue specific promoter.

121. The library of claim 120, wherein the cell type and/or tissue specific promoter is selected from the group consisting of: human synapsin promoter (hSyn1), transthyretin promoter (TTR), cytokeratin 18, cytokeratin 19, unc-45 myosin chaperon B (unc45b) promoter, cardiac troponin T (cTnT) promoter, glial fibrillary acidic protein (GFAP) promoter, myelin basic protein (MBP) promoter, and methyl CpG-binding protein 2 (Mecp2) promoter.

122. The library of claim 121, wherein the cell type and/or tissue specific promoter is the hSyn1 promoter.

123. The library of claim 121, wherein the cell type and/or tissue specific promoter is the TTR promoter.

124. The library of any one of claims 77-123, wherein the reporter protein is fused to the localization signal.

125. The library of claim 124, wherein the localization signal is fused N-terminally, C-terminally or both N-terminally and C-terminally to the reporter protein.

126. The library of any one of claims 77-125, wherein the localization signal is a nuclear localization signal (NLS), a nuclear envelope binding domain or a histone binding domain.

127. The library of claim 126, wherein the NLS is the SV40 NLS.
128. The library of claim 126, wherein the nuclear envelope binding domain is a KASH domain.
129. The library of claim 126, wherein the histone binding domain is H2B.
- 5 130. The library of any one of claims 77-129, wherein the nucleic acid comprising the barcode is 5-18 nucleotides long.
131. The library of any one of claims 77-130, wherein the nucleic acid comprising the barcode comprises a sequence selected from any one of sequences SEQ ID NO: 111-154.
- 10 132. The library of any one of claims 77-130, wherein the nucleic acid comprising the barcode comprises a sequence selected from any one of sequences SEQ ID NO: 155-198.
133. The library of any one of claims 77-132, wherein the nucleic acid comprising the barcode is selected from any one of sequences SEQ ID NO: 111-154.
- 15 134. The library of any one of claims 77-132, wherein the nucleic acid comprising the barcode is selected from any one of sequences SEQ ID NO: 155-198.
135. An AAV variant comprising:
- a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein; and
 - 20 one or more of:
 - b) one or more silent mutations in the nucleic acid sequence flanking the peptide insertion site in the AAV variant capsid protein of a);
 - c) a nucleic acid encoding a localization signal;
 - 25 d) a nucleic acid comprising a barcode; and
 - e) a nucleic acid encoding a reporter protein.
136. An AAV variant comprising:
- a) an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein; and

one or more of:

- b) one or more silent mutations in the nucleic acid encoding the AAV variant capsid protein of a) in the nucleic acid sequence flanking the peptide insertion site;
- 5 c) a nucleic acid encoding a localization signal;
- d) a nucleic acid comprising a barcode; and
- e) a nucleic acid encoding a reporter protein.

137. The variant of claim 135, wherein the variant comprises one or more silent mutations in the nucleic acid sequence flanking the peptide insertion site in the AAV
10 variant capsid protein of a).

138. The variant of claim 136, wherein the variant comprises one or more silent mutations in the nucleic acid encoding the AAV variant capsid protein of a) in the nucleic acid sequence flanking the peptide insertion site.

139. The variant of any one of claims 135-136, wherein the variant comprises a nucleic
15 acid encoding a localization signal.

140. The variant of any one of claim 135-139, wherein the variant comprises a nucleic acid comprising a barcode.

141. The variant of any one of claims 138-139, wherein the variant comprises a first nucleic acid comprising a first barcode and a second nucleic acid comprising a second
20 barcode.

142. The variant of claim 141, wherein the first nucleic acid comprising the first barcode and the second nucleic acid comprising the second barcode are different.

143. The variant of claim 142, wherein the first nucleic acid comprising the first barcode sequence comprises a sequence selected from any one of sequences SEQ ID
25 NO: 111-154.

144. The variant of claim 142, wherein the first nucleic acid comprising the first barcode sequence is selected from any one of sequences SEQ ID NO: 111-154.

145. The variant of claim 142, wherein the second nucleic acid comprising the second barcode sequence comprises a sequence selected from any one of sequences SEQ ID NO: 155-198.

146. The variant of claim 142, wherein the second nucleic acid comprising the second barcode sequence is selected from any one of sequences SEQ ID NO: 155-198.

147. The variant of any one of claims 142-146, wherein each of the first nucleic acid comprising the first barcode and the second nucleic acid comprising the second barcode is independently operatively linked to a promoter.

148. The variant of claim 147, wherein the promoter operatively linked to the first nucleic acid comprising the first barcode and the promoter operatively linked to the second nucleic acid comprising the second barcode is each independently an RNA Pol II promoter.

149. The variant of claim 147, wherein the promoter operatively linked to the first nucleic acid comprising the first barcode and the promoter operatively linked to the second nucleic acid comprising the second barcode is each independently an RNA Pol III promoter.

150. The variant of claim 147, wherein the promoter operatively linked to the first nucleic acid comprising the first barcode is operatively linked to an RNA Pol II promoter and the promoter operatively linked to the second nucleic acid comprising the second barcode is an RNA Pol III promoter.

151. The variant of any one of claims 148-150, wherein the RNA Pol II promoter is selected from the group consisting of: human synapsin promoter (hSyn1), transthyretin promoter (TTR), cytokeratin 18, cytokeratin 19, unc-45 myosin chaperon B (unc45b) promoter, cardiac troponin T (cTnT) promoter, glial fibrillary acidic protein (GFAP) promoter, myelin basic protein (MBP) promoter, and methyl CpG-binding protein 2 (Mecp2) promoter.

152. The variant of any one of claims 149-151, wherein the RNA Pol III promoter is selected from the group consisting of U6 promoter, H1 promoter and 7SK promoter.

153. The variant of any one of claim 135-152, wherein the variant comprises a nucleic acid encoding a reporter protein.
154. The variant of any one of claims 135-153, wherein the nucleic acid encoding an AAV variant capsid protein, and the nucleic acid encoding a localization signal, the
5 nucleic acid comprising a barcode, and/or the nucleic acid encoding a reporter protein, are located in separate nucleic acid molecules.
155. The variant of any one of claims 135-154, wherein the nucleic acid encoding an AAV variant capsid protein, the nucleic acid encoding a localization signal, the nucleic acid comprising a barcode, and/or the nucleic acid encoding a reporter protein, are
10 located in one nucleic acid molecule.
156. The variant of claim 155, wherein the nucleic acid encoding an AAV variant capsid protein, and the nucleic acid encoding a localization signal, the nucleic acid comprising a barcode, and/or the nucleic acid encoding a reporter protein, are linked to each other in any order.
157. The variant of claim 156, wherein the variant comprises: a 5'ITR sequence, the nucleic acid comprising a barcode, the nucleic acid encoding a reporter protein, the nucleic acid encoding an AAV variant capsid protein, and a 3'ITR sequence, in that order.
158. The variant of any one of claims 135-157, wherein the AAV variant is derived
20 from the group consisting of: AAV1, AAV2, AAV3B, AAV5, AAV6, AAV8, AAV9, AAV3, AAV4, AAV7, AAV11, AAVrh10, AAVrh39, and AAVrh74.
159. The variant of any one of claims 135-158, wherein the peptide has a length of 4-15 amino acids.
160. The variant of claim 159, wherein the peptide has a length of 6-15 amino acids.
161. The variant of claim 160, wherein the peptide has a length of 7, 10, or 15 amino
25 acids.
162. The variant of claim 161, wherein the peptide has a length of 7 amino acids.

163. The variant of any one of claims 135-162, wherein the inserted peptide comprises at least 4 contiguous amino acids of an amino acid sequence set forth in any one of SEQ ID NO: 1-32.
164. The variant of claim 163, wherein the peptide comprises an amino acid sequence set forth in any one of SEQ ID NO: 1-32.
165. The variant of any one of claims 135-162, wherein the inserted peptide comprises at least 4 contiguous amino acids of an amino acid sequence set forth in any one of SEQ ID NO: 68-110.
166. The variant of claim 165, wherein the peptide comprises an amino acid sequence set forth in any one of SEQ ID NO: 68-110.
167. The variant of any one of claims 135-166, wherein the peptide is inserted into a region selected from the group consisting of VR-I, VR-II, VR-III, VR-IV, VR-V, VR-VI, VR-VII, VR-VIII and VR-IX region of the capsid protein.
168. The variant of claim 167, wherein the peptide is inserted into the VR-I of the capsid protein.
169. The variant of claim 167, wherein the peptide is inserted into the VR-IV of the capsid protein.
170. The variant of claim 168, wherein the peptide is inserted into VR-VIII of the capsid protein.
171. The variant of any one of claims 135-170, wherein the peptide is inserted into the capsid protein VP1, VP2, or VP3.
172. The variant of any one of claims 135-171, wherein the peptide is inserted at a location between amino acid residues 450 and 600 of the capsid protein.
173. The variant of any one of claims 135-172, wherein
- (i) the AAV serotype is AAV1 and the peptide is inserted at amino acid position 590 of the capsid protein,
 - (ii) the AAV serotype is AAV6 and the peptide is inserted at amino acid position 454 or 590 of the capsid protein,

- (iii) the AAV serotype is AAV2 and the peptide is inserted at amino acid position 588 of the capsid protein,
- (iv) the AAV serotype is AAV3B and the peptide is inserted at amino acid position 589 of the capsid protein,
- 5 (v) the AAV serotype is AAV5 and the peptide is inserted at amino acid position 578 of the capsid protein,
- (vi) the AAV serotype is AAV8 and the peptide is inserted at amino acid position 591 of the capsid protein, or
- (vii) the AAV serotype is AAV9 and the peptide is inserted at amino acid position 266, 455, or 589 of the capsid protein,
- 10 wherein the positions correspond to the numbering of VP1 in the AAV serotype.

174. The variant of any one of claims 135-173, wherein the reporter protein is a fluorescent protein.

175. The variant of claim 174, wherein the reporter protein is selected from the group consisting of: EGFP, mCherry, mClover3, mRuby3, mApple, iRFP, tdTomato, mVenus, YFP, RFP, firefly luciferase, and nanoluciferase.
- 15

176. The variant of any one of claims 135-175, wherein the nucleic acid encoding an AAV variant capsid protein is operatively linked to a p40 promoter.

177. The variant of any one of claims 138-176, wherein the nucleic acid encoding a reporter protein is operatively linked to a cell type and/or tissue specific promoter.
- 20

178. The variant of claim 177, wherein the cell type and/or tissue specific promoter is selected from the group consisting of: human synapsin promoter (hSyn1), transthyretin promoter (TTR), cytokeratin 18, cytokeratin 19, unc-45 myosin chaperon B (unc45b) promoter, cardiac troponin T (cTnT) promoter, glial fibrillary acidic protein (GFAP) promoter, myelin basic protein (MBP) promoter, and methyl CpG-binding protein 2 (Mecp2) promoter.
- 25

179. The variant of claim 178, wherein the cell type and/or tissue specific promoter is the hSyn1 promoter.

180. The variant of claim 178, wherein the cell type and/or tissue specific promoter is the TTR promoter.
- 30

181. The variant of any one of claims 135-180, wherein the reporter protein is fused to the localization signal.

182. The variant of claim 181, wherein the localization signal is fused N-terminally, C-terminally or both N-terminally and C-terminally to the reporter protein.

5 183. The variant of any one of claims 135-182, wherein the localization signal is a nuclear localization signal (NLS), a nuclear envelope binding domain or a histone binding domain.

184. The variant of claim 183, wherein the NLS is the SV40 NLS.

10 185. The variant of claim 183, wherein the nuclear envelope binding domain is a KASH domain.

186. The variant of claim 183, wherein the histone binding domain is H2B.

187. The variant of any one of claims 135-186, wherein the nucleic acid comprising the barcode is 5-18 nucleotides long.

15 188. The variant of any one of claims 135-187, wherein the nucleic acid comprising the barcode comprises a sequence selected from any one of sequences SEQ ID NO: 111-154.

189. The variant of claim 188, wherein the nucleic acid comprising the barcode is selected from any one of sequences SEQ ID NO: 111-154.

20 190. The variant of any one of claims 135-187, wherein the nucleic acid comprising the barcode comprises a sequence selected from any one of sequences SEQ ID NO: 155-198.

191. The variant of claim 190, wherein the nucleic acid comprising the barcode is selected from any one of sequences SEQ ID NO: 155-198.

25 192. The variant of any one of claims 135-191, wherein the AAV variant is derived from AAV1.

193 The variant of claim 192, wherein the variant comprises a peptide comprising an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 68 to SEQ ID NO: 75.

194. The variant of claim 192, wherein the variant comprises a peptide comprising an amino acid sequence selected from the group consisting of SEQ ID NO: 1, SEQ ID NO: 2 and SEQ ID NO: 3.

195. The variant of claim 192, wherein the variant comprises a peptide comprising the amino acid sequence SEQ ID NO: 71.

196. The variant of any one of claims 135-191, wherein the AAV variant is derived from AAV2.

197. The variant of claim 196, wherein the variant comprises a peptide comprising an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 90 to SEQ ID NO: 110.

198. The variant of claim 196, wherein the variant comprises a peptide comprising any one of the sequences selected from the group consisting of SEQ ID NO: 95, SEQ ID NO: 94, SEQ ID NO: 96, SEQ ID NO: 101, SEQ ID NO: 103, SEQ ID NO: 106, SEQ ID NO: 91 and SEQ ID NO: 102.

199. The variant of claim 196, wherein the variant comprises a peptide comprising an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 4-7.

200. The variant of any one of claims 135-191, wherein the AAV variant is derived from AAV3B.

201. The variant of claim 200, wherein the variant comprises a peptide comprising any one of the sequences selected from the group consisting of SEQ ID NO: 78, SEQ ID NO: 80, SEQ ID NO: 77, SEQ ID NO: 79, SEQ ID NO: 76 and SEQ ID NO: 83.

202. The variant of claim 200, wherein the variant comprises a peptide comprising an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 8 to SEQ ID NO: 11.

203. The variant of any one of claims 135-191, wherein the AAV variant is derived from AAV5.

204. The variant of claim 203, wherein the variant comprises a peptide comprising an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 28
5 to SEQ ID NO: 32.

205. The variant of any one of claims 135-191, wherein the AAV variant is derived from AAV6.

206. The variant of claim 205, wherein the variant comprises a peptide comprising an amino acid sequence selected from the group consisting of consisting of any one of
10 SEQ ID NO: 19 to SEQ ID NO: 27.

207. The variant of any one of claims 135-191, wherein the AAV variant is derived from AAV9.

208. The variant of claim 207, wherein the variant comprises a peptide comprising an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 12
15 to SEQ ID NO: 18.

209. The variant of claim 207, wherein the variant comprises a peptide comprising an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 86 to SEQ ID NO: 89.

210. The variant of claim 207, wherein the variant comprises a peptide comprising the sequence SEQ ID NO: 89.
20

211. A nucleic acid molecule comprising:

- a) a nucleic acid sequence encoding an AAV variant capsid protein comprising a peptide inserted into a hypervariable and/or surface-exposed loop of the variant capsid protein; and
25 one or more of:
- b) a nucleic acid sequence encoding a variant capsid protein comprising one or more silent mutations in the nucleotide sequence flanking the peptide insertion site in the hypervariable and/or surface-exposed loop of the variant capsid protein;

- c) a nucleic acid sequence encoding a localization signal;
- d) a nucleic acid sequence comprising a barcode; and
- e) a nucleic acid sequence encoding a reporter protein.

5 212. The nucleic acid molecule of claim 211, wherein the nucleic acid sequence encoding an AAV variant capsid protein comprises one or more silent mutations in the nucleic acid sequence flanking the peptide insertion site in the AAV variant capsid protein of a).

213. The nucleic acid molecule of claim 212, wherein the nucleic acid molecule
10 comprises a nucleic acid encoding a localization signal.

214. The nucleic acid molecule of claim 212, wherein the nucleic acid molecule comprises a nucleic acid comprising a barcode.

215. The nucleic acid molecule of claims 211-214, wherein the nucleic acid molecule comprises a first nucleic acid comprising a first barcode and a second nucleic acid
15 comprising a second barcode.

216. The nucleic acid molecule of claim 215, wherein the first nucleic acid comprising the first barcode and the second nucleic acid comprising the second barcode are different.

217. The nucleic acid molecule of claim 216, wherein the first nucleic acid comprising
20 the first barcode sequence comprises a sequence selected from any one of sequences SEQ ID NO: 111-154.

218. The nucleic acid molecule of claim 217, wherein the first nucleic acid comprising the first barcode sequence is selected from any one of sequences SEQ ID NO: 111-154.

219. The nucleic acid molecule of claim 216, wherein the second nucleic acid
25 comprising the second barcode sequence comprises a sequence selected from any one of sequences SEQ ID NO: 155-198.

220. The nucleic acid molecule of claim 217, wherein the second nucleic acid comprising the second barcode sequence is selected from any one of sequences SEQ ID NO: 155-198.

221. The nucleic acid molecule of any one of claims 215-220, wherein each of the first nucleic acid comprising the first barcode and the second nucleic acid comprising the second barcode is independently operatively linked to a promoter.

222. The nucleic acid molecule of claim 221, wherein the promoter operatively linked to the first nucleic acid comprising the first barcode and the promoter operatively linked to the second nucleic acid comprising the second barcode is each independently an RNA Pol II promoter.

223. The nucleic acid molecule of claim 221, wherein the promoter operatively linked to the first nucleic acid comprising the first barcode and the promoter operatively linked to the second nucleic acid comprising the second barcode is each independently an RNA Pol III promoter.

224. The nucleic acid molecule of claim 221, wherein the promoter operatively linked to the first nucleic acid comprising the first barcode is operatively linked to an RNA Pol II promoter and the promoter operatively linked to the second nucleic acid comprising the second barcode is an RNA Pol III promoter.

225. The nucleic acid molecule of any one of claims 222-224, wherein the RNA Pol II promoter is selected from the group consisting of: human synapsin promoter (hSyn1), transthyretin promoter (TTR), cytokeratin 18, cytokeratin 19, unc-45 myosin chaperon B (unc45b) promoter, cardiac troponin T (cTnT) promoter, glial fibrillary acidic protein (GFAP) promoter, myelin basic protein (MBP) promoter, and methyl CpG-binding protein 2 (Mecp2) promoter.

226. The nucleic acid molecule of any one of claims 223-224, wherein the RNA Pol III promoter is selected from the group consisting of U6 promoter, H1 promoter and 7SK promoter.

227. The nucleic acid molecule of any one of claims 211-226, where the nucleic acid molecule comprises a nucleic acid encoding a reporter protein.

228. The nucleic acid molecule of any one of claims 211-227, wherein the AAV variants are derived from one or more of: AAV1, AAV2, AAV3B, AAV5, AAV6, AAV8, AAV9, AAV3, AAV4, AAV7, AAV11, AAVrh10, AAVrh39, and AAVrh74.

229. The nucleic acid molecule of any one of claims 211-228, wherein the inserted peptide has a length of 4-15 amino acids.
230. The nucleic acid molecule of claim 229, wherein the inserted peptide comprises at least 4 contiguous amino acids of an amino acid sequence set forth in any one of SEQ ID NO: 1-32.
231. The nucleic acid molecule of claim 229, wherein the inserted peptide comprises at least 4 contiguous amino acids of an amino acid sequence set forth in any one of SEQ ID NO: 68-110.
232. The nucleic acid molecule of any one of claims 211-231, wherein the nucleic acid encoding a reporter protein is operatively linked to a cell type and/or tissue specific promoter.
233. The nucleic acid molecule of claim 232, wherein the cell type and/or tissue specific promoter is the hSyn1 promoter.
234. The nucleic acid molecule of any one of claims 211-233, wherein the nucleic acid comprising the barcode comprises a sequence selected from any one of sequences SEQ ID NO: 111-154.
235. The nucleic acid molecule of any one of claims 211-233, wherein the nucleic acid comprising the barcode comprises a sequence selected from any one of sequences SEQ ID NO: 155-198.
236. Use of an AAV variant according to any one of claims 135-210 to deliver a transgene to a target cell or tissue.
237. An AAV vector comprising a nucleic acid molecule encoding a peptide that comprises at least 4 contiguous amino acids of an amino acid sequence set forth in any one of SEQ ID NO: 1-32.
238. The AAV vector of claim 237, wherein the nucleic acid encodes a peptide that comprises an amino acid sequence set forth in any one of SEQ ID NO: 1-32.
239. The AAV vector of claim 237 or 238, wherein the nucleic acid encodes a peptide having a sequence of any of one of SEQ ID NO: 1-32.

240. An AAV vector comprising a nucleic acid molecule encoding a peptide that comprises at least 4 contiguous amino acids of an amino acid sequence set forth in any one of SEQ ID NO:68-110.
241. The AAV vector of claim 240, wherein the nucleic acid encodes a peptide that
5 comprises an amino acid sequence set forth in any one of SEQ ID NO: 68-110.
242. The AAV vector of claim 240 or 241, wherein the nucleic acid encodes a peptide having the sequence of any of one of SEQ ID NO: 68-110.
243. The AAV vector of claim 240, wherein the nucleic acid encodes a peptide that comprises an amino acid sequence set forth in any one of SEQ ID NO: 71, 76-80, 83,
10 89, 91, 94-96, 101-103 and 106.
244. The AAV vector of any one of claims 237-243, wherein the peptide is a part of a capsid protein.
245. The AAV vector of claim 244, wherein the capsid protein is VP1, VP2, or VP3.
246. The AAV vector of any one of claims 237-245, wherein the peptide is inserted at
15 a location between amino acid residues 450 and 600 of the capsid protein.
247. The AAV vector of claim 246, wherein the peptide is inserted at
- (i) amino acid position 590 of an AAV1 capsid protein,
 - (ii) amino acid position 454 or 590 of an AAV6 capsid protein,
 - (iii) amino acid position 588 of an AAV2 capsid protein,
 - 20 (iv) amino acid position 589 of an AAV3B capsid protein,
 - (v) amino acid position 578 of an AAV5 capsid protein,
 - (vi) amino acid position 591 of the an AAV8 capsid protein, or
 - (vi) amino acid position 266, 455, or 589 of an AAV9 capsid protein,
- wherein the positions correspond to the numbering of VP1 in the AAV serotype.
248. A pharmaceutical composition comprising the AAV vector of any one of claims
25 237-247 and a pharmaceutically acceptable carrier.
249. A peptide comprising an amino acid sequence set forth in any one of SEQ ID NO: 1-32.

250. A peptide comprising an amino acid sequence set forth in any one of SEQ ID NO: 68-110.
251. A peptide comprising an amino acid sequence set forth in any one of SEQ ID NO: 71, 76-80, 83, 89, 91, 94-96, 101-103 and 106.
- 5 252. A peptide comprising an amino acid sequence set forth in any one of SEQ ID NO: 71, 76-80, 83 and 94-96.
253. A peptide comprising an amino acid sequence set forth in any one of SEQ ID NO: 89, 91, 101-103 and 106.
254. A peptide comprising an amino acid sequence set forth in any one of SEQ ID NO:
10 68 to SEQ ID NO: 75.
255. A peptide comprising an amino acid sequence set forth in any one of SEQ ID NO: 1, SEQ ID NO: 2 and SEQ ID NO: 3.
256. A peptide comprising an amino acid sequence set forth in SEQ ID NO: 71.
257. A peptide comprising an amino acid sequence set forth in any one of SEQ ID NO:
15 90 to SEQ ID NO: 110.
258. A peptide comprising an amino acid sequence set forth in any one of SEQ ID NO: 95, SEQ ID NO: 94, SEQ ID NO: 96, SEQ ID NO: 101, SEQ ID NO: 103, SEQ ID NO: 106, SEQ ID NO: 91 and SEQ ID NO: 102.
259. A peptide comprising an amino acid sequence set forth in any one of SEQ ID NO:
20 4-7.
260. A peptide comprising an amino acid sequence set forth in any one of SEQ ID NO: 78, SEQ ID NO: 80, SEQ ID NO: 77, SEQ ID NO: 79, SEQ ID NO: 76 and SEQ ID NO: 83.
261. A peptide comprising an amino acid sequence set forth in any one of SEQ ID NO:
25 8 to SEQ ID NO: 11.
262. A peptide comprising an amino acid sequence set forth in any one of SEQ ID NO: 28 to SEQ ID NO: 32.

263. A peptide comprising an amino acid sequence set forth in any one of SEQ ID NO: 19 to SEQ ID NO: 27.
264. A peptide comprising an amino acid sequence set forth in any one of SEQ ID NO: 12 to SEQ ID NO: 18.
- 5 265. A peptide comprising an amino acid sequence set forth in any one of SEQ ID NO: 86 to SEQ ID NO: 89.
266. A peptide comprising an amino acid sequence set forth in SEQ ID NO: 89.
267. The peptide of any one of claims 249-266, wherein the peptide is part of an AAV vector.
- 10 268. The peptide of claim 267, wherein the peptide is part of a capsid protein of the AAV vector.
269. A nucleic acid molecule encoding the peptide of any one of claims 249-268.
270. A capsid protein comprising a peptide comprising at least 4 contiguous amino acids of an amino acid sequence set forth in any one of SEQ ID NO: 1-32.
- 15 271. A capsid protein comprising a peptide comprising at least 4 contiguous amino acids of an amino acid sequence set forth in any one of SEQ ID NO:68-110.
272. The capsid protein of claim 270, wherein the peptide comprises the amino acid sequence set forth in any one of SEQ ID NO: 1-32.
273. The capsid protein of claim 271, wherein the peptide comprises the amino acid
20 sequence set forth in any one of SEQ ID NO: 68-110.
274. The capsid protein of claim 270, comprising the amino acid sequence set forth in any one of SEQ ID NO: 1-32.
275. The capsid protein of claim 271, comprising the amino acid sequence set forth in any one of SEQ ID NO:68-110.

276. The capsid protein of claim 271, wherein the peptide comprises an amino acid sequence set forth in any one of SEQ ID NO: 71, 76-80, 83, 89, 91, 94-96, 101-103 and 106.
277. The capsid protein of claim 271, wherein the peptide comprises an amino acid
5 sequence set forth in any one of SEQ ID NO: 71, 76-80, 83 and 94-96.
278. The capsid protein of claim 271, wherein the peptide comprises an amino acid sequence set forth in any one of SEQ ID NO: 89, 91, 101-103 and 106.
279. The capsid protein of claim 271, wherein the peptide comprises an amino acid sequence set forth in any one of SEQ ID NO: 68 to SEQ ID NO: 75.
- 10 280. The capsid protein of claim 270, wherein the peptide comprises an amino acid sequence set forth in any one of SEQ ID NO: 1, SEQ ID NO: 2 and SEQ ID NO: 3.
281. The capsid protein of claim 271, wherein the peptide comprises an amino acid sequence set forth in SEQ ID NO: 71.
282. The capsid protein of claim 271, wherein the peptide comprises an amino acid
15 sequence set forth in any one of SEQ ID NO: 90 to SEQ ID NO: 110.
283. The capsid protein of claim 271, wherein the peptide comprises an amino acid sequence set forth in any one of SEQ ID NO: 95, SEQ ID NO: 94, SEQ ID NO: 96, SEQ ID NO: 101, SEQ ID NO: 103, SEQ ID NO: 106, SEQ ID NO: 91 and SEQ ID NO: 102.
- 20 284. The capsid protein of claim 270, wherein the peptide comprises an amino acid sequence set forth in any one of SEQ ID NO: 4-7.
285. The capsid protein of claim 271, wherein the peptide comprises an amino acid sequence set forth in any one of SEQ ID NO: 78, SEQ ID NO: 80, SEQ ID NO: 77, SEQ ID NO: 79, SEQ ID NO: 76 and SEQ ID NO: 83.
- 25 286. The capsid protein of claim 270, wherein the peptide comprises an amino acid sequence set forth in any one of SEQ ID NO: 8 to SEQ ID NO: 11.

287. The capsid protein of claim 270, wherein the peptide comprises an amino acid sequence set forth in any one of SEQ ID NO: 28 to SEQ ID NO: 32.
288. The capsid protein of claim 270, wherein the peptide comprises an amino acid sequence set forth in any one of SEQ ID NO: 19 to SEQ ID NO: 27.
- 5 289. The capsid protein of claim 270, wherein the peptide comprises an amino acid sequence set forth in any one of SEQ ID NO: 12 to SEQ ID NO: 18.
290. The capsid protein of claim 271, wherein the peptide comprises an amino acid sequence set forth in any one of SEQ ID NO: 86 to SEQ ID NO: 89.
291. The capsid protein of claim 271, wherein the peptide comprises an amino acid
10 sequence set forth in SEQ ID NO: 89.
292. A nucleic acid molecule encoding the capsid protein of any one of claims 269-291.
293. A method of delivering a nucleic acid to a target cell or tissue of a subject, comprising: administering a composition comprising an AAV vector according to any
15 one of claims 237-247.
294. The method of claim 293, wherein the capsid protein comprises an amino acid sequence set forth in any one of SEQ ID NO: 1-32.
295. The method of claim 293, wherein the capsid protein comprises an amino acid sequence set forth in any one of SEQ ID NO: 68-110.
- 20 296. The method of any one of claims 293-295, wherein the target cell, cell line or tissue is selected from the group consisting of CNS, heart, lung, trachea, esophagus, muscle, bone, cartilage, stomach, pancreas, intestine, liver, bladder, kidney, ureter, urethra, uterus, fallopian tube, ovary, testes, prostate, eye, blood, lymph, and oral mucosa.
- 25 297. The method of any one of claims 293-295, wherein the target cell is selected from the group consisting of neurons, glial cells, astrocytes, oligodendroglia, microglia, Schwann cells, ependymal cells, hepatocytes, stellate fat storing cells, Kupffer cells,

liver endothelial cells, epithelial cells, cardiomyocytes, smooth muscle cells, T-cells, B cells, hematopoietic stem cells, and embryonic stem cells.

298. The method of claim 296, wherein the target cell or tissue is from liver.

299. The method of claim 296, wherein the target cell or tissue is from CNS.

5 300. A pharmaceutical composition comprising the variant of any one of claims 135-211 and a pharmaceutically acceptable carrier.

301. The library of claim 116, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 590 of the capsid protein of an AAV1 serotype.

10 302. The library of claim 116, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 590 of the capsid protein of an AAV1 serotype.

303. The library of claim 302, wherein the peptide comprises an amino acid sequence of any one of SEQ ID NO: 68-75.

15 304. The library of claim 302, wherein the peptide comprises the amino acid sequence SEQ ID NO: 71.

305. The library of claim 301, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 1, SEQ ID NO: 2 and SEQ ID NO: 3.

20 306. The library of claim 116, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 454 of the capsid protein of an AAV6 serotype.

25 307. The library of claim 116, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 454 of the capsid protein of an AAV6 serotype.

308. The library of claim 116, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 590 of the capsid protein of an AAV6 serotype.

5 309. The library of claim 116, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 590 of the capsid protein of an AAV6 serotype.

310. The library of any one of claims 306 and 308, wherein the peptide comprises an amino acid sequence of any one of SEQ ID NO: 19 to SEQ ID NO: 27.

10 311. The library of claim 116, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 588 of the capsid protein of an AAV2 serotype.

312. The library of claim 116, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 588 of the capsid protein of an AAV2 serotype.

15 313. The library of claim 312, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 90 to SEQ ID NO: 110.

314. The library of claims 312, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 95, SEQ ID NO: 94, SEQ ID NO: 96, SEQ ID NO: 101, SEQ ID NO: 103, SEQ ID NO: 106, SEQ ID NO: 91 and
20 SEQ ID NO: 102.

315. The library of claims 311, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 4-7.

316. The library of claim 116, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 589 of the capsid
25 protein of an AAV3B serotype.

317. The library of claim 116, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 589 of the capsid protein of an AAV3B serotype.

318. The library of claim 317, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 76- 85.
319. The library of claim 317, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 78, SEQ ID NO: 80, SEQ ID NO: 77, SEQ ID NO: 79, SEQ ID NO: 76 and SEQ ID NO: 83.
320. The library of claim 316, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 8 to SEQ ID NO: 11.
321. The library of claim 116, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 578 of the capsid protein of an AAV5 serotype.
322. The library of claim 116, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 578 of the capsid protein of an AAV5 serotype.
323. The library of claim 321, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one SEQ ID NO: 28 to SEQ ID NO: 32.
324. The library of claim 116, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 591 of the capsid protein of an AAV8 serotype.
325. The library of claim 116, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 591 of the capsid protein of an AAV8 serotype.
326. The library of claim 116, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 266 of the capsid protein of an AAV9 serotype.
327. The library of claim 116, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 266 of the capsid protein of an AAV9 serotype.

328. The library of claim 116, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 455 of the capsid protein of an AAV9 serotype.
329. The library of claim 116, wherein a peptide comprising the amino acid sequence
5 of any one of SEQ ID NO: 68-110 is inserted at amino acid position 455 of the capsid protein of an AAV9 serotype.
330. The library of claim 116, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 589 of the capsid protein of an AAV9 serotype.
- 10 331. The library of claim 116, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 589 of the capsid protein of an AAV9 serotype.
332. The library of any one of claims 326, 328, and 330, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO:
15 12 to SEQ ID NO: 18.
333. The library of any one of claims 327, 329, and 331, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 86 to SEQ ID NO: 89.
334. The library of any one of claims 327, 329, and 331, wherein the peptide comprises
20 the sequence of SEQ ID NO: 89.
335. The AAV variant of claim 173, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 590 of the capsid protein of an AAV1 serotype.
336. The AAV variant of claim 173, wherein a peptide comprising the amino acid
25 sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 590 of the capsid protein of an AAV1 serotype.
337. The AAV variant of claim 336, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 68 to SEQ ID NO: 75.

338. The AAV variant of claim 336, wherein the peptide comprises the amino acid sequence SEQ ID NO: 71.

339. The AAV variant of claim 335, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 1, SEQ ID NO:
5 2 and SEQ ID NO: 3.

340. The AAV variant of claim 173, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 454 of the capsid protein of an AAV6 serotype.

341. The AAV variant of claim 173, wherein a peptide comprising the amino acid
10 sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 454 of the capsid protein of an AAV6 serotype.

342. The AAV variant of claim 173, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 590 of the capsid protein of an AAV6 serotype.

15 343. The AAV variant of claim 173, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 590 of the capsid protein of an AAV6 serotype.

344. The AAV variant of any one of claims 340 and 342, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO:
20 19 to SEQ ID NO: 27.

345. The AAV variant of claim 173, wherein a peptide comprising the amino acid sequence of SEQ ID NO: 1-32 is inserted at amino acid position 588 of the capsid protein of an AAV2 serotype.

346. The AAV variant of claim 173, wherein a peptide comprising the amino acid
25 sequence of SEQ ID NO: 68-110 is inserted at amino acid position 588 of the capsid protein of an AAV2 serotype.

347. The AAV variant of claim 346, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 90 to SEQ ID NO: 110.

348. The AAV variant of claims 346, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 95, SEQ ID NO: 94, SEQ ID NO: 96, SEQ ID NO: 101, SEQ ID NO: 103, SEQ ID NO: 106, SEQ ID NO: 91 and SEQ ID NO: 102.
- 5 349. The AAV variant of claims 345, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 4-7.
350. The AAV variant of claim 173, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 589 of the capsid protein of an AAV3B serotype.
- 10 351. The AAV variant of claim 173, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 589 of the capsid protein of an AAV3B serotype.
352. The AAV variant of claim 351, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 78, SEQ ID NO: 80, SEQ ID NO: 77, SEQ ID NO: 79, SEQ ID NO: 76 and SEQ ID NO: 83.
- 15 353. The AAV variant of claim 350, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 8 to SEQ ID NO: 11.
354. The AAV variant of claim 173, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 578 of the capsid protein of an AAV5 serotype.
- 20 355. The AAV variant of claim 173, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 578 of the capsid protein of an AAV5 serotype.
356. The AAV variant of claim 354, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one SEQ ID NO: 28 to SEQ ID NO: 32.
- 25

357. The AAV variant of claim 173, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 591 of the capsid protein of an AAV8 serotype.
358. The AAV variant of claim 173, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 591 of the capsid protein of an AAV8 serotype.
359. The AAV variant of claim 173, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 266 of the capsid protein of an AAV9 serotype.
360. The AAV variant of claim 173, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 266 of the capsid protein of an AAV9 serotype.
361. The AAV variant of claim 173, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 455 of the capsid protein of an AAV9 serotype.
362. The AAV variant of claim 173, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 455 of the capsid protein of an AAV9 serotype.
363. The AAV variant of claim 173, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 589 of the capsid protein of an AAV9 serotype.
364. The AAV variant of claim 173, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 589 of the capsid protein of an AAV9 serotype.
365. The AAV variant of any one of claims 359, 361, and 363, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 12 to SEQ ID NO: 18.

366. The AAV variant of any one of claims 360, 362, and 364, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 86 to SEQ ID NO: 89.

5 367. The AAV variant of any one of claims 360, 362, and 364, wherein the peptide comprises the sequence of SEQ ID NO: 89.

368. The AAV vector of claim 247, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 590 of the capsid protein of an AAV1 serotype.

10 369. The AAV vector of claim 247, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 590 of the capsid protein of an AAV1 serotype.

370. The AAV vector of claim 369, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 68 to SEQ ID NO: 75.

15 371. The AAV vector of claim 369, wherein the peptide comprises the amino acid sequence SEQ ID NO: 71.

372. The AAV vector of claim 368, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 1, SEQ ID NO: 2 and SEQ ID NO: 3.

20 373. The AAV vector of claim 247, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 454 of the capsid protein of an AAV6 serotype.

25 374. The AAV vector of claim 247, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 454 of the capsid protein of an AAV6 serotype.

375. The AAV vector of claim 247, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 590 of the capsid protein of an AAV6 serotype.

376. The AAV vector of claim 247, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 590 of the capsid protein of an AAV6 serotype.
377. The AAV vector of any one of claims 373 and 375, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 19 to SEQ ID NO: 27.
378. The AAV vector of claim 247, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 588 of the capsid protein of an AAV2 serotype.
379. The AAV vector of claim 247, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 588 of the capsid protein of an AAV2 serotype.
380. The AAV vector of claim 379, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 90 to SEQ ID NO: 110.
381. The AAV vector of claims 379, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 95, SEQ ID NO: 94, SEQ ID NO: 96, SEQ ID NO: 101, SEQ ID NO: 103, SEQ ID NO: 106, SEQ ID NO: 91 and SEQ ID NO: 102.
382. The AAV vector of claims 378, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 4-7.
383. The AAV vector of claim 247, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 589 of the capsid protein of an AAV3B serotype.
384. The AAV vector of claim 247, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 589 of the capsid protein of an AAV3B serotype.

385. The AAV vector of claim 384, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 78, SEQ ID NO: 80, SEQ ID NO: 77, SEQ ID NO: 79, SEQ ID NO: 76 and SEQ ID NO: 83.

5 386. The AAV vector of claim 383, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 8 to SEQ ID NO: 11.

387. The AAV vector of claim 247, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 578 of the capsid protein of an AAV5 serotype.

10 388. The AAV vector of claim 247, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 578 of the capsid protein of an AAV5 serotype.

15 389. The AAV vector of claim 387, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one SEQ ID NO: 28 to SEQ ID NO: 32.

390. The AAV vector of claim 247, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 591 of the capsid protein of an AAV8 serotype.

20 391. The AAV vector of claim 247, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 591 of the capsid protein of an AAV8 serotype.

392. The AAV vector of claim 247, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 266 of the capsid protein of an AAV9 serotype.

25 393. The AAV vector of claim 247, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 266 of the capsid protein of an AAV9 serotype.

394. The AAV vector of claim 247, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 455 of the capsid protein of an AAV9 serotype.

5 395. The AAV vector of claim 247, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 455 of the capsid protein of an AAV9 serotype.

396. The AAV vector of claim 247, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 589 of the capsid protein of an AAV9 serotype.

10 397. The AAV vector of claim 247, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 589 of the capsid protein of an AAV9 serotype.

398. The AAV vector of any one of claims 392, 394, and 396, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of
15 SEQ ID NO: 12 to SEQ ID NO: 18.

399. The AAV vector of any one of claims 393, 395, and 397, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 86 to SEQ ID NO: 89.

400. The AAV vector of any one of claims 393, 395, and 397, wherein the peptide
20 comprises the sequence of SEQ ID NO: 89.

401. A capsid protein comprising an inserted peptide, wherein the peptide is inserted at

- (i) amino acid position 590 of an AAV1 capsid protein,
- (ii) amino acid position 454 or 590 of an AAV6 capsid protein,
- (iii) amino acid position 588 of an AAV2 capsid protein,
- 25 (iv) amino acid position 589 of an AAV3B capsid protein,
- (v) amino acid position 578 of an AAV5 capsid protein,

(vi) amino acid position 591 of the an AAV8 capsid protein, or

(vi) amino acid position 266, 455, or 589 of an AAV9 capsid protein,

wherein the positions correspond to the numbering of VP1 in the AAV serotype.

5 402. The capsid protein of claim 401, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 590 of the capsid protein of an AAV1 serotype.

403. The capsid protein of claim 401, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 590 of
10 the capsid protein of an AAV1 serotype.

404. The capsid protein of claim 403, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 68 to SEQ ID NO: 75.

405. The capsid protein of claim 403, wherein the peptide comprises the amino acid
15 sequence SEQ ID NO: 71.

406. The capsid protein of claim 402, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 1, SEQ ID NO: 2 and SEQ ID NO: 3.

407. The capsid protein of claim 401, wherein a peptide comprising the amino acid
20 sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 454 of the capsid protein of an AAV6 serotype.

408. The capsid protein of claim 401, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 454 of the capsid protein of an AAV6 serotype.

25 409. The capsid protein of claim 401, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 590 of the capsid protein of an AAV6 serotype.

410. The capsid protein of claim 401, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 590 of the capsid protein of an AAV6 serotype.
- 5 411. The capsid protein of any one of claims 407 and 409, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 19 to SEQ ID NO: 27.
412. The capsid protein of claim 401, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 588 of the capsid protein of an AAV2 serotype.
- 10 413. The capsid protein of claim 401, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 588 of the capsid protein of an AAV2 serotype.
414. The capsid protein of claim 413, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 90 to SEQ ID
15 NO: 110.
415. The capsid protein of claims 413, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 95, SEQ ID NO: 94, SEQ ID NO: 96, SEQ ID NO: 101, SEQ ID NO: 103, SEQ ID NO: 106, SEQ ID NO: 91 and SEQ ID NO: 102.
- 20 416. The capsid protein of claims 412, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 4-7.
417. The capsid protein of claim 401, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 589 of the capsid protein of an AAV3B serotype.
- 25 418. The capsid protein of claim 401, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 589 of the capsid protein of an AAV3B serotype.

419. The capsid protein of claim 418, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 78, SEQ ID NO: 80, SEQ ID NO: 77, SEQ ID NO: 79, SEQ ID NO: 76 and SEQ ID NO: 83.
- 5 420. The capsid protein of claim 417, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 8 to SEQ ID NO: 11.
421. The capsid protein of claim 401, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 578 of the capsid protein of an AAV5 serotype.
- 10 422. The capsid protein of claim 401, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 578 of the capsid protein of an AAV5 serotype.
423. The capsid protein of claim 421, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one SEQ ID NO: 28 to SEQ ID NO: 32.
- 15 424. The capsid protein of claim 401, wherein a peptide comprising the amino acid sequence of SEQ ID NO: 1-32 is inserted at amino acid position 591 of the capsid protein of an AAV8 serotype.
425. The capsid protein of claim 401, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 591 of the capsid protein of an AAV8 serotype.
- 20 426. The capsid protein of claim 401, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 266 of the capsid protein of an AAV9 serotype.
- 25 427. The capsid protein of claim 401, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 266 of the capsid protein of an AAV9 serotype.

428. The capsid protein of claim 401, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 455 of the capsid protein of an AAV9 serotype.

5 429. The capsid protein of claim 401, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 455 of the capsid protein of an AAV9 serotype.

430. The capsid protein of claim 401, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 1-32 is inserted at amino acid position 589 of the capsid protein of an AAV9 serotype.

10 431. The capsid protein of claim 401, wherein a peptide comprising the amino acid sequence of any one of SEQ ID NO: 68-110 is inserted at amino acid position 589 of the capsid protein of an AAV9 serotype.

15 432. The capsid protein of any one of claims 426, 428, and 430, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 12 to SEQ ID NO: 18.

433. The capsid protein of any one of claims 427, 429, and 431, wherein the peptide comprises an amino acid sequence selected from the group consisting of any one of SEQ ID NO: 86 to SEQ ID NO: 89.

20 434. The capsid protein of any one of claims 427, 429, and 431, wherein the peptide comprises the sequence of SEQ ID NO: 89.

435. A nucleic acid molecule encoding the capsid protein of any one of claims 401 to 434.