

PRODUCER CELLS FOR REPLICATION COMPETENT RETROVIRAL VECTORS**CROSS REFERENCE TO RELATED APPLICATIONS**

[0001] This application claims priority under 35 U.S.C. §119 from Provisional Application Serial No. 61/218,063, filed June 17, 2009, the disclosure of which is incorporated herein by reference.

TECHNICAL FIELD

[0002] The disclosure relates to methods for producing recombinant replication competent retroviral vectors, cell lines useful for producing such vectors, and methods of making and using the cell lines.

BACKGROUND

[0003] The life cycle of retroviruses involves a stage when the virus' genetic material is inserted into the genome of a host cell. This step is essential because the inserted viral nucleic acid, the provirus, is replicated through the host cell machinery.

[0004] As part of this process the RNA genome of the retrovirus is replicated through a double-stranded DNA intermediate prior to insertion into the genome of the host cell. The initial conversion of the viral RNA molecule into a double-stranded DNA (dsDNA) molecule is performed by a reverse-transcriptase. The dsDNA is then integrated into the host cell genome by an integrase to further be replicated by the host cellular machinery. The reverse transcriptase and the integrase required for the conversion of the RNA into dsDNA and for the integration into the host genome are carried within the viral particle during infection. The proviral DNA is finally transcribed using the host machinery into multiple RNA copies. These RNA molecules are then translated into viral peptides or proteins or integrated into viral particles which are released from the cell into the medium or extracellular milieu.

[0005] A retroviral RNA genome usually comprises 6 typical regions leading to the expression of multiple proteins. These regions include the *gag*, *pol* and *env* gene sequences associated with a packaging signal, a psi (ψ) signal and flanked by 5' and/or 3' long terminal repeats (LTR) regions. The *gag* gene leads to the expression of the protein components of the nucleoprotein core of the virus,

while the *pol* gene products are involved in the synthesis polynucleotides and recombination. The *env* gene codes for the envelope components of the retrovirus particle. 5' and 3' LTR regions include promoters and assist in the integration of the viral genome into the chromosomal DNA of the host cell. The *psi* signal refers to the retroviral packaging signal that controls the efficient packaging of the RNA into the viral particle.

[0006] Because of their ability to form proviruses, retroviruses are useful to modify the genome of a target or host cell and various modifications have been made to retroviruses for use in gene therapy. Gene therapy using retroviral vectors is generally performed by adding a heterologous polynucleotide to the viral genome which encodes or produces a polypeptide or transcript of interest, packaging the recombinant genome into a viral particle and infecting a target host cell. The target cell will then incorporate the exogenous gene as being a part of a provirus.

[0007] Most retroviral vectors have been rendered "defective" to avoid uncontrolled spread and production of virions. However, little is reported about the development of replication competent retroviral vector systems.

SUMMARY

[0008] The disclosure describes cell lines and viral particle producing cells useful for producing recombinant replication competent retroviral vectors for gene therapy.

[0008a] In one aspect, the present invention refers to a retrovirus producing HT1080 cell line that produces a replication competent retrovirus particle, said HT1080 cell line stably expresses a recombinant retroviral genome comprising a *gag* gene, *pol* gene, *env* gene, a heterologous polynucleotide, and retroviral *psi* (Ψ) factor for the assembly of the recombinant retroviral genome, wherein the HT1080 cell line been adapted to being grown and continuously passaged in serum free media and in suspension.

[0008b] In another aspect, the present invention refers to a method of producing the retrovirus producing HT1080 cell line as disclosed herein comprising:

transforming a 293 cell line with a plasmid encoding a retroviral vector comprising from 5' to 3':

a CMV-R-U5 fusion of the immediate early promoter from human cytomegalovirus to an MLV R-U5 region;

a PBS, primer binding site for reverse transcriptase;

a 5' splice site;

ψ packaging signal;

a gag coding sequence for MLV group specific antigen;

a pol coding sequence for MLV polymerase polyprotein;

a 3' splice site;

a 4070A env coding sequence for envelope protein of MLV strain 4070A;

an internal ribosome entry site (IRES) from encephalomyocarditis virus or a nucleic acid regulatory domain;

a modified cytosine deaminase coding sequence;

a polypurine tract; and

a U3-R-U5 MLV long terminal repeat;

culturing the 293 cell to produce viral particles;

isolating the viral particles;

infecting an HT1080 cell line with the viral particles thereby affording a retrovirus producing HT1080 cell line that produces replication competent retrovirus particles, wherein the retrovirus producing HT1080 cell line is grown in serum free media and in suspension.

[0008c] In yet another aspect, the present invention refers to a method for producing a composition for gene therapy comprising culturing the cell line as disclosed herein to produce viral particles and substantially purifying the viral particles.

[0009] The disclosure describes retrovirus producing cell line for the production of a replication competent retrovirus particle, the cell line comprising a fibrosarcoma, an osteosarcoma or a thymoma cell line, said cell line stably expressing a recombinant retroviral genome comprising a gag gene, pol gene, env gene, a heterologous polynucleotide, and retroviral psi (Ψ) factor for the assembly of the recombinant retroviral genome. In one example, the replication competent retrovirus particle is stably expressed. In another example, the half life is greater than 7 days at 2-8°C. In yet another example, viral particles produced from the cell line show no loss of infectivity after 12 months of storage of the cell line at 65 C. In yet another example, the vector produced is approximately 100% stable for 3 months or longer and the

same vector produced from a cell line transiently transfected with the same replication competent retrovirus loses at least five-fold activity at 2 to 8 weeks under the same storage conditions, compared to initial titers. In yet another example the replication competent retrovirus comprises: a retroviral GAG protein; a retroviral POL protein; a retroviral envelope; a retroviral polynucleotide comprising Long-Terminal Repeat (LTR) sequences at the 3' end of the retroviral polynucleotide sequence, a promoter sequence at the 5' end of the retroviral polynucleotide, said promoter being suitable for expression in a mammalian cell, a gag nucleic acid domain, a pol nucleic acid domain and an env nucleic acid domain; a cassette comprising an internal ribosome entry site (IRES) or regulatory nucleic acid domain operably linked to a heterologous polynucleotide, wherein the cassette is positioned 5' to the 3' LTR and 3' to the env nucleic acid domain encoding the retroviral envelope; and cis-acting sequences necessary for reverse transcription, packaging and integration in a target cell,

[0010] wherein the RCR maintains higher replication competency after 6 passages compared to a pACE vector. In one example, the retroviral polynucleotide sequence is derived from murine leukemia virus (MLV), Moloney murine leukemia virus (MoMLV), or Gibbon ape leukemia virus (GALV), murine mammary tumor virus (MuMTV), Rous Sarcoma Virus (RSV), Gibbon ape leukemia virus (GALV), baboon endogenous virus (BEV), and the feline virus RD114. In a further example, the MLV is an amphotropic MLV. In yet another example, retrovirus is a gammaretrovirus. In one example, the promoter sequence is associated with a growth regulatory gene. In yet another example, the nucleic acid regulatory domain comprises a pol II promoter. In yet another example, the promoter sequence comprises a tissue-specific promoter sequence such as an androgen response element. In one example, the androgen response element is derived from a probasin promoter.

[0011] The retroviral vector produced by the producer cell line comprise various domain. For example, the promoter comprises a CMV promoter having a sequence as set forth in SEQ ID NO:19, 20 or 22 from nucleotide 1 to about nucleotide 582 and may include modification to one or more nucleic acid bases and which is capable

of directing and initiating transcription; a CMV-R-U5 domain polynucleotide comprises a sequence as set forth in SEQ ID NO:19, 20 or 22 from about nucleotide 1 to about nucleotide 1202 or sequences that are at least 95% identical to a sequence as set forth in SEQ ID NO:19, 20 or 22, wherein the polynucleotide promotes transcription of a nucleic acid molecule operably linked thereto; the gag nucleic acid domain comprises a sequence from about nucleotide number 1203 to about nucleotide 2819 of SEQ ID NO: 19 or 22 or a sequence having at least 95%, 98%, 99% or 99.8% identity thereto; the pol domain comprises a sequence from about nucleotide number 2820 to about nucleotide 6358 of SEQ ID NO:19 or 22 or a sequence having at least 95%, 98%, 99% or 99.9% identity thereto; the env domain comprises a sequence from about nucleotide number 6359 to about nucleotide 8323 of SEQ ID NO:19 or 22 or a sequence having at least 95%, 98%, 99% or 99.8% identity thereto; the IRES comprises a sequence from about nucleotide number 8327 to about nucleotide 8876 of SEQ ID NO:19 or 22 or a sequence having at least 95%, 98%, or 99% identity thereto; and the heterologous nucleic acid comprises a polynucleotide having a sequence as set forth in SEQ ID NO:3, 5, 11, 13, 15 or 17.

[0012] The disclosure also describes a cell free preparation comprising viral particles obtained from the retrovirus producing cell line described herein. In some examples a pharmaceutical preparation is prepared from the isolated viral particles.

[0013] The disclosure also describes a method of producing a vector producing cell line described herein comprising

transforming a 293 cell line with a plasmid encoding a retroviral vector comprising from 5' to 3': a CMV-R-U5 fusion of the immediate early promoter from human cytomegalovirus to an MLV R-U5 region; a PBS, primer binding site for reverse transcriptase; a 5' splice site; ψ packaging signal; a gag coding sequence for MLV group specific antigen; a pol coding sequence for MLV polymerase polyprotein; a 3' splice site; a 4070A env coding sequence for envelope protein of MLV strain 4070A; an internal ribosome entry site (IRES) from encephalomyocarditis virus or a nucleic acid regulatory domain; a modified cytosine deaminase coding sequence; a polypurine tract; and a U3-R-U5 MLV long terminal repeat; culturing the 293 cell to produce viral particles; isolating the viral

particles; infecting an HT1080 cell line with the viral particles thereby producing the viral particle producing cell line. The disclosure also describes a cell line generated by the foregoing method.

[0014] The disclosure also describes a method for producing a composition for gene therapy comprising culturing the cell line described herein to produce viral particles and substantially purifying the viral particles.

[0015] The disclosure also describes a cell bank comprising the cell line of the disclosure. In some examples, the cell line of the disclosure is grown in suspension. In some example, the cell line of the disclosure is grown in serum free medium. In some example, the cell line is grown in suspension in serum free medium.

[0016] An electronic copy of a sequence listing is submitted herewith and is incorporated herein in its entirety.

[0017] The details of one or more examples of the disclosure are set forth in the accompanying drawings and the description below. Other features, objects, and advantages of the disclosure will be apparent from the description and drawings, and from the claims.

DESCRIPTION OF DRAWINGS

[0018] **Figure 1** shows a general process of producing a producer cell line and bank of the disclosure.

[0019] **Figure 2** shows a graph of cell killing data showing that modified vectors are more effective compared to the original wildtype CD. The graph also shows that the modified backbone (T5.0007) is more effective at killing than the backbone of pACE-CD. Also shown is a table cataloguing the various vector constructs and their names.

[0020] **Figure 3A-F** shows (a) a schematic of a recombinant retroviral vector of the disclosure; (b and c) a plasmid map of a polynucleotide of the disclosure (CMV Promotor:1 - 582; R:583 - 650; U5:651 - 1202; Primer binding site (PBS):728 - 776; 5' slicing site:788 - 789; gag:1203 - 2819; pol:2820 - 6358; 3'splicing site:3314 - 3315; 4070A env: 6359 - 8323; EMCV IRES:8327 - 8876; yCD2:8877 - 9353; Poly purine tract (PPT):9386 - 9404; U3:9405 -

9854; R:9855 - 9921; U5:9922 - 9998; (d and e) a sequence of a polynucleotide of the disclosure (SEQ ID NO:19); (f) a schematic of a first and second generation RCR of the disclosure.

[0021] **Figure 4** shows that higher levels of yCD2 protein are observed compared to wild type yCD protein in infected U-87 cells.

[0022] **Figure 5** shows that a vector of the disclosure is genetically stable after 12 cycles of viral passages as assessed using PCR amplification. The figure also demonstrates that the vectors of the disclosure are more stable after longer passages compared to the vector pACE-CD (Kasahara *et al.*). In particular pAC3-CD is more stable than pACE-CD, demonstrating that the changed backbone has made the vector more stable. In addition pACE-yCD1 (T5.0001) and -yCD2 (T5-0002) are more stable than pAC-yCD.

[0023] **Figure 6A-B** shows cell killing activity. (A) cell killing assays; and (B) cytosine deaminase specific activity of cells infected with different vectors. (A) shows that cytosine deaminase and vector of the disclosure kill infected cells at least as well and perhaps better than the original pACE-CD when U87 infected cells are exposed to increasing levels of 5-FC. (B) shows that the specific CD activity of the disclosure (T5.0007, T5.0001 and T5.0002) are all increased compared to pACE-CD (T5.0000), and is in the order T5.0000<T5.0007<T5.0001<T5.0002.

[0024] **Figure 7** shows U-87 (human) tumors treated with CD vector of the disclosure (also referred to as "Toca 511", "pAC3-yCD2(V)" and "T5.0002" see, e.g., Figure 2) *in vivo* and explanted from mice treated with 4 cycles of 5-FC are still sensitive to the drug.

[0025] **Figure 8** shows dosing information in a human xenograft (U87) mouse model of brain cancer.

[0026] **Figure 9** shows dosing information and therapeutic effect in a syngeneic mouse model.

[0027] **Figure 10** shows Potency Dose Curves (see example 8) for Lot T003-002-40L (Undiluted and 1/100) at 12 months at $\leq -65^{\circ}\text{C}$.

[0028] **Figure 11** shows potency dose curves for 3 lots, M100-09 (High Dose), M101-09 (Mid Dose) and M102-09 (Low Dose) at 6 months at $\leq -65^{\circ}\text{C}$.

[0029] **Figure 12** shows daily titers from HT1080+T5.0002 clonal candidates for titer production from confluent cultures.

[0030] **Figure 13** shows viral spread of T5.0006 (GFP) Vector on three canine glioma cell lines at 1, 3 and 6 Days Post Infection.

[0031] **Figure 14** shows measured titer trends of lots T003-002-40L and GMP lots at $\leq -65^{\circ}\text{C}$ over 12 months.

[0032] **Figure 15** shows analyses of Toca 511 and Toca 621 transduction on the growth kinetics of S91 subQ tumor cells. S91 Tumors were injected with vector 10 days after implantation.

[0033] **Figure 16** shows spread of purified T5.0006 (GFP vector) made in a stable producer line through U87 subcutaneous tumors in nude mice, over time (0, 5, 9, 12, 26 days).

DETAILED DESCRIPTION

[0034] As used herein and in the appended claims, the singular forms "a," "and," and "the" include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to "a cell" includes a plurality of such cells and reference to "the vector" includes reference to one or more vectors, and so forth.

[0035] Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood to one of ordinary skill in the art to which this disclosure belongs. Although any methods and reagents similar or equivalent to those described herein can be used in the practice of the disclosed methods and compositions, the exemplary methods and materials are now described.

[0036] Also, the use of "or" means "and/or" unless stated otherwise. Similarly, "comprise," "comprises," "comprising" "include," "includes," and "including" are interchangeable and not intended to be limiting.

[0037] It is to be further understood that where descriptions of various embodiments use the term "comprising," those skilled in the art would understand that in some specific instances, an embodiment can be alternatively described using language "consisting essentially of" or "consisting of."

[0038] All publications mentioned herein are incorporated herein by reference in full for the purpose of describing and disclosing the methodologies, which are described in the publications, which might be used in connection with the description herein. The publications discussed above and throughout the text are provided

solely for their disclosure prior to the filing date of the present application. Nothing herein is to be construed as an admission that the inventors are not entitled to antedate such disclosure by virtue of prior disclosure.

[0039] The term "RCR" as used herein is intended to mean a replication-competent retrovirus (RCR). A replication-competent virus is a viral particle that has the capacity to replicate by itself in a host cell.

[0040] As used herein, the term "RCR plasmid vector" means a plasmid which includes all or part of a retroviral genome including 5' and 3' retroviral long-term repeat (LTR) sequences, a packaging signal (ψ), and may include one or more polynucleotides encoding a protein(s) or polypeptide(s) of interest, such as a therapeutic agent or a selectable marker. The term "therapeutic" is used in a generic sense and includes treating agents, prophylactic agents, and replacement agents.

[0041] The terms "transfecting" or "transfection" as used herein are intended to mean the transfer of at least one exogenous nucleic acid into a cell. The nucleic acid may be RNA, DNA or a combination of both. The exogenous nucleic acid refers to nucleic that is not found as a result of host cell division or host cell multiplication.

[0042] The term "virus" as used herein is intended to mean the physical virus or retrovirus particle.

[0043] The term "cell line" as used herein refers to cultured cells that can be passed (divided) more than once. The disclosure relates to cell lines that can be passed more than 2 times, up to 200 times, or more and includes any integer therebetween.

[0044] The expressions "stable expression" and "stably expressing" as used herein are intended to mean that the genetic material that is being stably expressed and/or is integrated permanently and stably in the genome of the host cell, and thus has the same expression potential over time as the native genetic material of the host cell.

[0045] The expressions "transient expression" and "transiently expressing" as used herein are intended to mean that the genetic material temporal expression period and/or is not integrated permanently and stably in the genome of the host cell, and thus does

not have the same expression potential over time as the native genetic material of the host cell.

[0046] As used herein, the term "heterologous" nucleic acid sequence or transgene refers to (i) a sequence that does not normally exist in a wild-type retrovirus, (ii) a sequence that originates from a foreign species, or (iii) if from the same species, it may be substantially modified from its original form. Alternatively, an unchanged nucleic acid sequence that is not normally expressed in a cell is a heterologous nucleic acid sequence.

[0047] The term "therapeutic" as used herein refers to an action that prevents, reverses, or slows the natural course of a disease, or its symptoms. A therapeutic action can be preventive, curative or merely palliative, and does not mean that the affected human or animal patient will not die from the disease.

[0048] In one embodiment, a producer cell line of the disclosure is capable of growth in suspension or in a serum-free medium. The producer cell line can also be grown both in serum-free medium and suspension simultaneously. Although serum-free medium and the capacity to grow in suspension are the typical conditions, cells of the disclosure (e.g., 293T cells) can be cultured in an adherent manner with regular serum-containing medium to achieve particular purposes. Such purposes can be, for example, to facilitate transfection of cells or to select cell clones.

[0049] The type of producer cells used to generate the retrovirus (described more fully below) is useful for the production replication competent viral particles for gene delivery and gene therapy.

[0050] The disclosure provides a method of generating a producer cell line comprising transforming or transfecting a first mammalian cell type with an RCR plasmid vector of the disclosure, culturing the first cell type to produce retroviral particles, obtaining a cell free media from the first cell type producing the retroviral particles, wherein the cell free media comprises retroviral particles, contacting a second mammalian cell type with the media to infect the second cell type and culturing the second cell type to produce a producer cell line that produces a replication competent

retroviral vector for use in transforming mammalian cells. The first cell type can be almost any mammalian cell type that is capable of producing virus after transfection and may include HeLa, COS, Chinese Hamster Ovary (CHO), and HT1080 cells, and the transfection can be with calcium phosphate or other agents such as lipid formulations known to those skilled in the art as useful for transfection.

[0051] In one embodiment, the first cell type is a human embryonic kidney cell. In another embodiment, the human embryonic kidney cell is a 293 cell (also often referred to as HEK 293 cells, 293 cells, or less precisely as HEK cells), which are a cell line originally derived from human embryonic kidney cells grown in tissue culture. HEK 293 cells were generated by transformation of cultures of normal human embryonic kidney cells with sheared adenovirus 5 DNA. HEK 293 cells are easy to grow and transfect very readily and have been widely-used in cell biology research for many years. They are also used by the biotechnology industry to produce therapeutic proteins and viruses for gene therapy.

[0052] In another embodiment, the first cell type is a mammalian cell transformed with an SV40 Large T-antigen. In a particular embodiment, 293T HEK cells are used. An important variant of this cell line is the 293T cell line which contains the SV40 Large T-antigen allowing for episomal replication of transfected plasmids containing the SV40 origin of replication. This allows for amplification of transfected plasmids and extended temporal expression of the desired gene products.

[0053] The term "human 293 cell" as used herein includes the HEK 293T cell line, the human 293 cell line (ATCC No. CRL 1573) (Graham, et al., J. Gen. Virol., Vol. 36, pgs. 59-72 (1977)), or a cell line formed by transfecting 293 cells with one or more expression vehicles (e.g., plasmid vectors) including polynucleotides encoding various *gag*, *pol*, and *env* proteins. The envelope may be an amphotropic envelope, an ecotropic envelope, a xenotropic envelope, a GALV envelope, an RD114 envelope, an FeLV envelope or other retroviral envelope. The envelope may also be an envelope from a heterologous source such as an alphavirus envelope. Such cells also may include other polynucleotides such as, for example,

polynucleotides encoding selectable markers. Examples of such cell lines include, but are not limited to, 293T/17 (ATCC No. CCRL 11268); Anjou 65 (ATCC No. CCRL 11269); Bosc 23 (CCRL 11270); and CAK8, also known as the Bing cell line (ATCC No. CCRL 11554).

[0054] The first cell type (e.g., HEK 293T cells) may be transformed with an RCR plasmid vector of the disclosure in any number of means including calcium phosphate and the like. Typical culture conditions for mammalian cells, particularly human 293 cells are known in the art.

[0055] Once transformed the first cell type is cultured under conditions for production of viral particles. Such conditions typically include refeeding cells in appropriate media, CO₂, and humidity. The culture conditions may also include the addition of antibiotics, anti-fungals, growth factors and the like. Typically the refeed medium is harvested after 24, 48, 72, or 96 hours, and such a procedure is known as a transient expression transfection procedure.

[0056] The media from the cultured cells above may be used directly in further culturing. Alternatively, the viral particles in the media of cultured cells may be isolated using any number of techniques known in the art including centrifugation, size exclusion techniques, anion exchange chromatography and the like.

[0057] Where the media is used directly, the media can be added to media used in the culture of the second cell type. Where the viral particles are first substantially purified, the particles may be washed or resuspended in an appropriate buffer or media or at particular concentration for infectivity before addition to the second cell type, leading to the generation of a stable expression producer cell line.

[0058] In one embodiment, the second cell type is a human fibroscarcoma cell line. In a specific embodiment, the cell line is an HT1080 cell line or a derivative thereof. HT1080 human fibrosarcoma cell line (ATCC, Catalog# CCL-121) can be obtained directly from the American Type Culture Collection (P.O. Box 1549, Manassas, VA). The method includes infecting the HT1080 cells with an RCR of the disclosure to provide a stably transfected host cell. The stably transfected host cell may be cultured to produce viral

particles for use in gene therapy or gene delivery or may be "banked" for later use, and may be a pool of transfected cells, or a cloned cell line. The banked cells may be frozen and stored using techniques known in the art.

[0059] Typically the cells will be cultured in serum-free media. In one embodiment, the cells are culture in an animal free media or a defined media used for preparation of biologics for delivery to humans.

[0060] Unexpectedly the process described above yield viral particles for gene therapy from the stable expression producer cell line that have increased stability compared to viral particle produced by a transient expression procedure.

[0061] RCR viral particle (e.g., AC3-yCD2 (V)) can be substantially purified from the media of the HT1080+T5.002 cells. The purified vector can be washed, diluted and resuspended in an appropriate pharmaceutically acceptable carrier. Alternatively, the purified vector may be stored either by freezing or lyophilization.

[0062] In one embodiment, AC3-yCD2 (V) will be administered as retroviral particles in solution. The final filled vector formulation is referred to as TOCA 511, and will be supplied as an aqueous sterile solution containing the following formulation excipients (in mg/mL): sucrose 10.0, mannitol 10.0, NaCl 5.3, Human Serum Albumin (HSA, Baxter) 1.0, and ascorbic acid 0.10.

[0063] As described further herein, any number of retroviral vectors of the disclosure may be used with the producer cell line and process described herein.

[0064] In specific examples provided herein, TOCA 511 is used to demonstrate the methods and compositions of the invention. As described herein, TOCA 511 refers to a replication competent retroviral vector encoded in a plasmid designated as pAC3-yCD2 (a.k.a T5.0002). The viral vector is comprised of a replication-competent retrovirus derived from a murine leukemia virus (MLV) encoding all retroviral components (gag, pol and env) required for viral replication, with the original ecotropic envelope replaced with the amphotropic envelope from the 4070A virus.

[0065] The TOCA 511 vector encodes a yeast cytosine deaminase (CD) gene. This gene sequence has been inserted downstream of an

internal ribosome entry site (IRES) derived from the Encephalomyocarditis Virus (EMCV), which is inserted downstream of the viral env gene as shown in Figure 5, below. The gene in the TOCA 511 vector is a modified yeast cytosine deaminase gene. The rationale for using a modified CD gene is to allow for more efficient in vivo conversion of the oral prodrug flucytosine (5-FC) to the active cytotoxic agent fluorouracil (5-FU).

[0066] The methods and compositions of the disclosure are applicable to other vector and recombinant retroviral vectors. The disclosure describes various modification and recombinant vectors that can be produced by the cell lines and methods of the disclosure.

[0067] The methods and cell lines of the disclosure include recombinant constructs comprising one or more of the nucleic acid sequences encoding a heterologous nucleic acid of interest (e.g., a cytosine deaminase such as the polynucleotides and polypeptides provided in SEQ ID NOs:1-13) a gamma Interferon gene or any of a number of therapeutic genes such as those disclosed in the published patent application WO2010036986. In one embodiment, the viral vector is a retroviral vector.

[0068] The terms "vector", "vector construct" and "expression vector" mean the vehicle by which a DNA or RNA sequence (e.g. a foreign gene) can be introduced into a host cell, so as to transform the host and promote expression (e.g. transcription and translation) of the introduced sequence. Vectors typically comprise the DNA of a transmissible agent, into which foreign DNA encoding a protein is inserted by restriction enzyme technology. A common type of vector is a "plasmid", which generally is a self-contained molecule of double-stranded DNA that can readily accept additional (foreign) DNA and which can readily introduced into a suitable host cell. A large number of vectors, including plasmid and fungal vectors, have been described for replication and/or expression in a variety of eukaryotic and prokaryotic hosts. Non-limiting examples include pKK plasmids (Clontech), pUC plasmids, pET plasmids (Novagen, Inc., Madison, Wis.), pRSET or pREP plasmids (Invitrogen, San Diego, Calif.), or pMAL plasmids (New England Biolabs, Beverly, Mass.), and many appropriate host cells, using methods disclosed or cited herein

or otherwise known to those skilled in the relevant art. Recombinant cloning vectors will often include one or more replication systems for cloning or expression, one or more markers for selection in the host, e.g., antibiotic resistance, and one or more expression cassettes.

[0069] The terms "express" and "expression" mean allowing or causing the information in a gene or DNA sequence to become manifest, for example producing a protein by activating the cellular functions involved in transcription and translation of a corresponding gene or DNA sequence. A DNA sequence is expressed in or by a cell to form an "expression product" such as a protein. The expression product itself, e.g. the resulting protein, may also be said to be "expressed" by the cell. A polynucleotide or polypeptide is expressed recombinantly, for example, when it is expressed or produced in a foreign host cell under the control of a foreign or native promoter, or in a native host cell under the control of a foreign promoter.

[0070] In one embodiment, the vector is a viral vector. In a further embodiment, the viral vector is a replication competent retroviral vector capable of infecting only replicating mammalian cells. Retroviruses have been classified in various ways but the nomenclature has been standardized in the last decade (see ICTVdB - The Universal Virus Database, v 4 on the World Wide Web (www.ncbi.nlm.nih.gov/ICTVdb/ICTVdB/) and the text book "Retroviruses," Eds. Coffin, Hughs and Varmus, Cold Spring Harbor Press 1997; the disclosure of which are incorporated herein by reference). The replication competent retroviral vector is derived from the Retroviridae family of viruses and can comprise a member of the Orthoretrovirinae sub-family, or more typically comprises a retrovirus from the gammaretrovirus genus. In one embodiment, a replication competent retroviral vector comprises an internal ribosomal entry site (IRES) 5' to a polynucleotide encoding a cytosine deaminase. In one embodiment, the polynucleotide encoding a cytosine deaminase is 3' to an *env* polynucleotide of a retroviral vector.

[0071] The disclosure provides modified retroviral vectors. The modified retroviral vectors can be derived from members of the

retroviridae family. The classification of this family has changed several times over the last ten to fifteen years. Currently the Retroviridae family consists of two sub-families: the Spumaretrovirinae-which has a single genus, the spumavirus (or foamy viruses) such as the human and simian foamy virus (HFV) and the Orthoretrovirinae sub-family which has 6 genus - betaretrovirus (e.g. MMTV), gammaretrovirus (e.g. MLV), alpharetrovirus (e.g. ALV) deltaretrovirus (e.g. BLV and HTLV-1) lentivirus (e.g. HIV 1) and epsilon retrovirus (e.g. wall eye dermal sarcoma virus). These classifications are made on the basis of common molecular features such as the relative reading frames for *gag*, *pol* and *env*, the processing of the polyproteins, the individual tRNAs used for priming reverse transcription, and the nature of the LTR structures. The original method of classification of retroviruses was into groups A, B, C and D on the basis of particle morphology, as seen under the electron microscope during viral maturation. A-type particles represent the immature particles of the B- and D-type viruses seen in the cytoplasm of infected cells. These particles are not infectious. B-type particles bud as mature virion from the plasma membrane by the enveloping of intracytoplasmic A-type particles. At the membrane they possess a toroidal core of 75 nm, from which long glycoprotein spikes project. After budding, B-type particles contain an eccentrically located, electron-dense core. The betaretrovirus, Mouse mammary tumor virus (MMTV) has a B-type morphology, but betaretroviruses can also have a D-type structure. D-type particles resemble B-type particles in that they show as ring-like structures in the infected cell cytoplasm, which bud from the cell surface, but the virion incorporate short surface glycoprotein spikes. The electron-dense cores are also eccentrically located within the particles. Mason Pfizer monkey virus (MPMV), also a betaretrovirus, is the prototype D-type virus. No intracytoplasmic particles can be observed in cells infected by C-type viruses. Instead, mature particles bud directly from the cell surface via a crescent 'C'-shaped condensation which then closes on itself and is enclosed by the plasma membrane. Envelope glycoprotein spikes may be visible, along with a uniformly electron-dense core. Budding may occur from the surface plasma membrane or directly into

intracellular vacuoles. Alpharetroviruses, gammaretroviruses, deltaretroviruses and epsilonretroviruses all have the C-type structural appearance.

[0072] Retroviruses are defined by the way in which they replicate their genetic material. During replication the RNA is converted into DNA. Following infection of the cell a double-stranded molecule of DNA is generated from the two molecules of RNA which are carried in the viral particle by the molecular process known as reverse transcription. The DNA form becomes covalently integrated in the host cell genome as a provirus, from which viral RNAs are expressed with the aid of cellular and/or viral factors. The expressed viral RNAs are packaged into particles and released as infectious virion.

[0073] The retrovirus particle is composed of two identical RNA molecules. Each wild-type genome has a positive sense, single-stranded RNA molecule, which is capped at the 5' end and polyadenylated at the 3' tail. The diploid virus particle contains the two RNA strands complexed with gag proteins, viral enzymes (pol gene products) and host tRNA molecules within a 'core' structure of gag proteins. Surrounding and protecting this capsid is a lipid bilayer, derived from host cell membranes and containing viral envelope (env) proteins. The env proteins bind to a cellular receptor for the virus and the particle typically enters the host cell via receptor-mediated endocytosis and/or membrane fusion.

[0074] After the outer envelope is shed, the viral RNA is copied into DNA by reverse transcription. This is catalyzed by the reverse transcriptase enzyme encoded by the pol region and uses the host cell tRNA packaged into the virion as a primer for DNA synthesis. In this way the RNA genome is converted into the more complex DNA genome.

[0075] The double-stranded linear DNA produced by reverse transcription may, or may not, have to be circularized in the nucleus. The provirus now has two identical repeats at either end, known as the long terminal repeats (LTR). The termini of the two LTR sequences produces the site recognized by a pol product--the integrase protein--which catalyzes integration, such that the provirus is always joined to host DNA two base pairs (bp) from the

ends of the LTRs. A duplication of cellular sequences is seen at the ends of both LTRs, reminiscent of the integration pattern of transposable genetic elements. Integration is thought to occur essentially at random within the target cell genome. However, by modifying the long-terminal repeats it is possible to control the integration of a retroviral genome.

[0076] Transcription, RNA splicing and translation of the integrated viral DNA is mediated by host cell proteins. Various spliced transcripts are generated. In the case of the human retroviruses HIV-1/2 and HTLV-I/II viral proteins are also used to regulate gene expression. The interplay between cellular and viral factors is a factor in the control of virus latency and the temporal sequence in which viral genes are expressed.

[0077] Retroviruses can be transmitted horizontally and vertically. Efficient infectious transmission of retroviruses requires the expression on the target cell of receptors which specifically recognize the viral envelope proteins, although viruses may use receptor-independent, nonspecific routes of entry at low efficiency. In addition, the target cell type must be able to support all stages of the replication cycle after virus has bound and penetrated. Vertical transmission occurs when the viral genome becomes integrated in the germ line of the host. The provirus will then be passed from generation to generation as though it were a cellular gene. Hence endogenous proviruses become established which frequently lie latent, but which can become activated when the host is exposed to appropriate agents.

[0078] As mentioned above, the integrated DNA intermediate is referred to as a provirus. Prior gene therapy or gene delivery systems use methods and retroviruses that require transcription of the provirus and assembly into infectious virus while in the presence of an appropriate helper virus or in a cell line containing appropriate sequences enabling encapsidation without coincident production of a contaminating helper virus. As described below, a helper virus is not required for the production of the recombinant retrovirus of the disclosure, since the sequences for encapsidation are provided in the genome thus providing a replication competent retroviral vector for gene delivery or therapy.

[0079] The retroviral genome and the proviral DNA of the disclosure have at least three genes: the *gag*, the *pol*, and the *env*, these genes may be flanked by one or two long terminal (LTR) repeat, or in the provirus are flanked by two long terminal repeat (LTR) and sequences containing cis-acting sequences such as *psi*. The *gag* gene encodes the internal structural (matrix, capsid, and nucleocapsid) proteins; the *pol* gene encodes the RNA-directed DNA polymerase (reverse transcriptase), protease and integrase; and the *env* gene encodes viral envelope glycoproteins. The 5' and/or 3' LTRs serve to promote transcription and polyadenylation of the virion RNAs. The LTR contains all other cis-acting sequences necessary for viral replication. Lentiviruses have additional genes including *vif*, *vpr*, *tat*, *rev*, *vpu*, *nef*, and *vpx* (in HIV-1, HIV-2 and/or SIV).

[0080] Adjacent to the 5' LTR are sequences necessary for reverse transcription of the genome (the tRNA primer binding site) and for efficient encapsidation of viral RNA into particles (the *Psi* site). If the sequences necessary for encapsidation (or packaging of retroviral RNA into infectious virion) are missing from the viral genome, the result is a cis defect which prevents encapsidation of genomic viral RNA. This type of modified vector is what has typically been used in prior gene delivery systems (*i.e.*, systems lacking elements which are required for encapsidation of the virion).

[0081] In a first embodiment, the disclosure provides a recombinant retrovirus capable of infecting a non-dividing cell, a dividing cell, or a cell having a cell proliferative disorder. The recombinant replication competent retrovirus of the disclosure comprises a polynucleotide sequence encoding a viral GAG, a viral POL, a viral ENV, and a heterologous polynucleotide that is expressed after the viral vector infects a target cell, encapsulated within a virion.

[0082] In one embodiment the heterologous nucleic acid sequence is preceded by a promoter and is operably linked to the promoter

[0083] In another embodiment the heterologous nucleic acid sequence is preceded by an internal ribosome entry site (IRES) and is operably linked to the IRES.

[0084] An internal ribosome entry sites ("IRES") refers to a segment of nucleic acid that promotes the entry or retention of a ribosome during translation of a coding sequence usually 3' to the IRES. In some embodiments the IRES may comprise a splice acceptor/donor site, however, preferred IRESSs lack a splice acceptor/donor site. Normally, the entry of ribosomes into messenger RNA takes place via the cap located at the 5' end of all eukaryotic mRNAs. However, there are exceptions to this universal rule. The absence of a cap in some viral mRNAs suggests the existence of alternative structures permitting the entry of ribosomes at an internal site of these RNAs. To date, a number of these structures, designated IRES on account of their function, have been identified in the 5' noncoding region of uncapped viral mRNAs, such as that, in particular, of picornaviruses such as the poliomyelitis virus (Pelletier et al., 1988, Mol. Cell. Biol., 8, 1103-1112) and the EMCV virus (encephalo-myocarditis virus (Jang et al., J. Virol., 1988, 62, 2636-2643). The disclosure provides the use of an IRES in the context of a replication-competent retroviral vector.

[0085] Depending upon the intended use of the retroviral vector of the disclosure any number of heterologous polynucleotide or nucleic acid sequences may be inserted into the retroviral vector. Some examples are given in WO2010/036986. For example, for *in vitro* studies commonly used marker genes or reporter genes may be used, including, antibiotic resistance and fluorescent molecules (e.g., GFP). Additional polynucleotide sequences encoding any desired polypeptide sequence may also be inserted into the vector of the disclosure. Where *in vivo* delivery of a heterologous nucleic acid sequence is sought both therapeutic and non-therapeutic sequences may be used. For example, the heterologous sequence can encode a therapeutic molecule including antisense molecules or ribozymes directed to a particular gene associated with a cell proliferative disorder, the heterologous sequence can be a suicide gene (e.g., HSV-tk or PNP or cytosine deaminase), an small interfering RNA or micro-RNA, a growth factor or a therapeutic protein (e.g., Factor IX). Other therapeutic proteins applicable to the disclosure are easily identified in the art.

[0086] In one embodiment, the heterologous polynucleotide within the vector comprises a cytosine deaminase that has been optimized for expression in a human cell. In a further embodiment, the cytosine deaminase comprises a sequence that has been human codon optimized and comprises mutations that increase the cytosine deaminase's stability (e.g., reduced degradation or increased thermo-stability) compared to a wild-type cytosine deaminase. In yet another embodiment, the heterologous polynucleotide encodes a fusion construct comprising a cytosine deaminase (either human codon optimized or non-optimized, either mutated or non-mutated) operably linked to a polynucleotide encoding a polypeptide having UPRT or OPRT activity. In another embodiment, the heterologous polynucleotide comprises a CD polynucleotide of the disclosure (e.g., SEQ ID NO:3, 5, 11, 13, 15, or 17).

[0087] In another embodiment, replication competent retroviral vector can comprise a heterologous polynucleotide encoding a polypeptide comprising a cytosine deaminase (as described herein) and may further comprise a polynucleotide comprising a miRNA or siRNA molecule linked to a cell-type or tissue specific promoter.

[0088] As used herein, the term "RNA interference" (RNAi) refers to the process of sequence-specific post-transcriptional gene silencing mediated by short interfering nucleic acids (siRNAs). The term "agent capable of mediating RNA interference" refers to siRNAs as well as DNA and RNA vectors that encode siRNAs when transcribed within a cell. As used herein, the term "siNA" refers to short interfering nucleic acid. The term is meant to encompass any nucleic acid molecules that are capable of mediating sequence specific RNA interference, for example short interfering RNA (siRNA), double-stranded RNA (dsRNA), micro-RNA (miRNA), short hairpin RNA (shRNA), short interfering oligonucleotide, short interfering nucleic acid, short interfering modified oligonucleotide, chemically-modified siRNA, post-transcriptional gene silencing RNA (ptgsRNA), and others.

[0089] Suitable range for designing stem lengths of a hairpin duplex, includes stem lengths of 20-30 nucleotides, 30-50 nucleotides, 50-100 nucleotides, 100-150 nucleotides, 150-200 nucleotides, 200-300 nucleotides, 300-400 nucleotides, 400-500

nucleotides, 500-600 nucleotides, and 600-700 nucleotides. Suitable range for designing loop lengths of a hairpin duplex, includes loop lengths of 4-25 nucleotides, 25-50 nucleotides, or longer if the stem length of the hair duplex is substantial. In certain context, hairpin structures with duplexed regions that are longer than 21 nucleotides may promote effective siRNA-directed silencing, regardless of the loop sequence and length.

[0090] The replicating retroviruses of the disclosure can also be used to modify disease by expressing engineered siRNA or miRNA (Dennis, Nature, 418: 122 2002) that switches off or lowers expression of key genes that govern the proliferation or survival of diseased cells including tumor cells. Such targets include genes like Rad 51 a central enzyme in DNA repair, and without which cell growth is drastically restricted. Other targets include many of the signaling pathway molecules that control cell growth (Marquez & McCaffrey Hum Gene Ther. 19:27 2008). The vectors will replicate through the tumor and before growth inhibition occurs the virus first integrates into the host genome and continues to make virus after growth of that cell is inhibited. Methods for selecting functional miRNA or siRNA sequences are known in the art. Key feature in general in designing effective siRNA or miRNA sequences is usually avoiding "off-target" effects. However for the use of replicating vectors that are highly specific to tumor cells such as those of the disclosure, these side effects are not very important, as the cells are expected to eventually die. Vector of this disclosure would be made using cells from other species for which the corresponding protein is not significantly targeted. Such cells include dog cell lines or chicken cell line. Alternatively the virus is made by transient transfection on human 293 derived cells or other cell line that allows efficient transient transfection. For this use the virus does not need to express an IRES, and the siRNA or miRNA sequence can simply be inserted at a convenient site on the viral genome. This site includes the region downstream of the envelope and upstream of the 3'LTR of the replicating retrovirus. Alternatively polIII transcription units can be inserted in the viral genome with the appropriate siRNA or miRNA's, preferably downstream of the 3' envelope gene. Several different siRNA or miRNA

sequences can be inserted to ensure efficient down regulation of the target gene or down regulation of more than one gene. Suitable sequences and targets can be obtained from sources known to those skilled in the art. For example:

- The MIT/ICBP siRNA Database <http://web.mit.edu/sirna/> - "The MIT [Massachusetts Institute of Technology]/ICBP [Integrative Cancer Biology Program] siRNA Database is a university-wide effort to catalog these experimentally validated reagents and make that information available to other researchers, both within and outside the MIT community. (Massachusetts Institute of Technology).
- RNAi Central - http://katahdin.cshl.org:9331/RNAi_web/scripts/main2.pl RNAi resources, including siRNA and shRNA design tools. (Hannon Lab, Cold Spring Harbor Laboratory)
- The RNAi Web - <http://www.rnaiweb.com/> General resource.
- siDIRECT - <http://genomics.jp/sidirect/> Online target-specific siRNA design program for mammalian RNA interference. (University of Tokyo, Japan).
- siRNA Database - A comprehensive siRNA database that contains siRNA targets against all known mRNA sequences throughout a variety of organisms. (Part of the Protein Lounge systems biology Web site)
- siRNA Database and Resources for RNA Interference Studies <http://www.rnainterference.org/>
- siRNA Selector - <http://bioinfo.wistar.upenn.edu/siRNA/siRNA.htm>. A set of rules was used for evaluating siRNA functionality based on thermodynamics parameters (Khvorova *et al.*, 2003, Schwarz *et al.*, 2003) and sequence-related determinants developed by Dharmakon (Reynolds *et al.*, 2004). Specificity is determined using BLAST against UniGene databases. (Wistar Institute)
- siRNA Target Finder http://www.ambion.com/techlib/misc/siRNA_finder.html (Ambion)

[0091] The replicating retroviruses of the disclosure can also express targets for naturally occurring siRNA's that are restricted in expression to particular cell types so that replication of the vector is significantly inhibited in those cell types. For anti-tumor purposes some normal cells in the body that are naturally

replicating at some level are hematopoietic cells, cells of the lining of the gut, and some endothelial cells. These are then potential sites where virus that is in the circulation could productively infect. In general this would be undesirable. Any stray infection of cells such as these can be inhibited by including a target for naturally occurring siRNA's or combination of siRNA's in these cell types. Some feasibility of using siRNA targets to suppress immune responses has already been shown. (Brown et al. Nat Biotechnol. 2007 25:1457-67). These targets are small RNA sequences with an homologous match to the siRNA sequences that are naturally occurring. These sequences can be inserted in any convenient site in the vectors of the current invention without, in general significant deleterious consequence for vector viability, other than in a cell of the type desired. Vectors can be made and used as previously described. The siRNA target can be inserted 3' to the transgene but before the 3'LTR or upstream of the IRES but after the 3' end of the envelope. In general the target would not be inserted into protein coding sequences

[0092] In yet further embodiments, the heterologous polynucleotide may comprise a cytokine such as an interleukin, interferon gamma or the like.

[0093] Generally, the recombinant virus of the disclosure is capable of transferring a nucleic acid sequence into a target cell.

[0094] The term "nucleic acid regulatory domain" refers collectively to promoter sequences (e.g., pol II promoter sequences), polyadenylation signals, transcription termination sequences, upstream regulatory domains, origins of replication, enhancers and the like, which collectively provide for the replication, transcription and translation of a coding sequence in a recipient cell. Not all of these control sequences need always be present so long as the selected coding sequence is capable of being replicated, transcribed and translated in an appropriate host cell. One skilled in the art can readily identify regulatory nucleic acid sequence from public databases and materials. Furthermore, one skilled in the art can identify a regulatory sequence that is applicable for the intended use, for example, *in vivo*, *ex vivo*, or *in vitro*.

[0095] The term "promoter region" is used herein in its ordinary sense to refer to a nucleotide region comprising a DNA regulatory sequence, wherein the regulatory sequence is derived from a gene which is capable of binding RNA polymerase and initiating transcription of a downstream (3'-direction) coding sequence. The regulatory sequence may be homologous or heterologous to the desired gene sequence. For example, a wide range of promoters may be utilized, including viral or mammalian promoter as described above.

[0096] The heterologous nucleic acid sequence is typically under control of either the viral LTR promoter-enhancer signals or an internal promoter, and retained signals within the retroviral LTR can still bring about efficient integration of the vector into the host cell genome. Accordingly, the recombinant retroviral vectors of the disclosure, the desired sequences, genes and/or gene fragments can be inserted at several sites and under different regulatory sequences. For example, a site for insertion can be the viral enhancer/promoter proximal site (i.e., 5' LTR-driven gene locus). Alternatively, the desired sequences can be inserted into a regulatory sequence distal site (e.g., the IRES sequence 3' to the env gene) or where two or more heterologous sequences are present one heterologous sequence may be under the control of a first regulatory region and a second heterologous sequence under the control of a second regulatory region. Other distal sites include viral promoter sequences, where the expression of the desired sequence or sequences is through splicing of the promoter proximal cistron, an internal heterologous promoter as SV40 or CMV, or an internal ribosome entry site (IRES) can be used.

[0097] In one embodiment, the retroviral genome of the disclosure contains an IRES comprising a cloning site for insertion of a desired polynucleotide sequence. In one embodiment, the IRES is located 3' to the env gene in the retroviral vector, but 5' to the desired heterologous nucleic acid. Accordingly, a heterologous polynucleotide sequence encoding a desired polypeptide may be operably linked to the IRES.

[0098] In another embodiment a targeting polynucleotide sequence is included as part of the recombinant retroviral vector of the disclosure. The targeting polynucleotide sequence is a targeting

ligand (e.g., peptide hormones such as heregulin, a single-chain antibodies, a receptor or a ligand for a receptor), a tissue-specific or cell-type specific regulatory element (e.g., a tissue-specific or cell-type specific promoter or enhancer), or a combination of a targeting ligand and a tissue-specific/cell-type specific regulatory element. Preferably, the targeting ligand is operably linked to the env protein of the retrovirus, creating a chimeric retroviral env protein. The viral GAG, viral POL and viral ENV proteins can be derived from any suitable retrovirus (e.g., MLV or lentivirus-derived). In another embodiment, the viral ENV protein is non-retrovirus-derived (e.g., alphavirus, CMV or VSV).

[0099] The recombinant retrovirus of the disclosure is therefore genetically modified in such a way that the virus is targeted to a particular cell type (e.g., smooth muscle cells, hepatic cells, renal cells, fibroblasts, keratinocytes, mesenchymal stem cells, bone marrow cells, chondrocyte, epithelial cells, intestinal cells, neoplastic cells, glioma cells, neuronal cells and others known in the art) such that the nucleic acid genome is delivered to a target non-dividing, a target dividing cell, or a target cell having a cell proliferative disorder. Targeting can be achieved in two ways. The first way directs the retrovirus to a target cell by binding to cells having a molecule on the external surface of the cell. This method of targeting the retrovirus utilizes expression of a targeting ligand on the coat of the retrovirus to assist in targeting the virus to cells or tissues that have a receptor or binding molecule which interacts with the targeting ligand on the surface of the retrovirus. After infection of a cell by the virus, the virus injects its nucleic acid into the cell and the retrovirus genetic material can integrate into the host cell genome. The second method for targeting uses cell- or tissue-specific regulatory elements to promote expression and transcription of the viral genome in a targeted cell which actively utilizes the regulatory elements, as described more fully below. The transferred retrovirus genetic material is then transcribed and translated into proteins within the host cell. The targeting regulatory element is typically linked to the 5' and/or 3' LTR, creating a chimeric LTR.

[00100] By inserting a heterologous nucleic acid sequence of interest into the viral vector of the disclosure, along with another gene which encodes, for example, the ligand for a receptor on a specific target cell, the vector is now target specific. Viral vectors can be made target specific by attaching, for example, a sugar, a glycolipid, or a protein. Targeting can be accomplished by using an antibody to target the viral vector. Those of skill in the art will know of, or can readily ascertain, specific polynucleotide sequences which can be inserted into the viral genome or proteins which can be attached to a viral envelope to allow target specific delivery of the viral vector containing the nucleic acid sequence of interest.

[00101] Thus, the disclosure includes, in one embodiment, a chimeric env protein comprising a retroviral env protein operably linked to a targeting polypeptide. The targeting polypeptide can be a cell specific receptor molecule, a ligand for a cell specific receptor, an antibody or antibody fragment to a cell specific antigenic epitope or any other ligand easily identified in the art which is capable of binding or interacting with a target cell. Examples of targeting polypeptides or molecules include bivalent antibodies using biotin-streptavidin as linkers (Etienne-Julan *et al.*, *J. Of General Viro.*, 73, 3251-3255 (1992); Roux *et al.*, *Proc. Natl. Acad. Sci USA* 86, 9079-9083 (1989)), recombinant virus containing in its envelope a sequence encoding a single-chain antibody variable region against a hapten (Russell *et al.*, *Nucleic Acids Research*, 21, 1081-1085 (1993)), cloning of peptide hormone ligands into the retrovirus envelope (Kasahara *et al.*, *Science*, 266, 1373-1376 (1994)), chimeric EPO/env constructs (Kasahara *et al.*, 1994), single-chain antibody against the low density lipoprotein (LDL) receptor in the ecotropic MLV envelope, resulting in specific infection of HeLa cells expressing LDL receptor (Somia *et al.*, *Proc. Natl. Acad. Sci USA*, 92, 7570-7574 (1995)), similarly the host range of ALV can be altered by incorporation of an integrin ligand, enabling the virus to now cross species to specifically infect rat glioblastoma cells (Valsesia-Wittmann *et al.*, *J. Virol.* 68, 4609-4619 (1994)), and Dornberg and co-workers (Chu and Dornburg, *J. Virol* 69, 2659-2663 (1995)) have reported tissue-specific targeting

of spleen necrosis virus (SNV), an avian retrovirus, using envelopes containing single-chain antibodies directed against tumor markers.

[00102] The disclosure provides a method of producing a recombinant retrovirus capable of infecting a target cell comprising transfecting a suitable host cell with the following: a vector comprising a polynucleotide sequence encoding a viral gag, a viral pol and a viral env, wherein the vector contains a cloning site for introduction of a heterologous gene, operably linked to a regulatory nucleic acid sequence, and recovering the recombinant virus.

[00103] The retrovirus and methods of the disclosure provide a replication competent retrovirus that does not require helper virus or additional nucleic acid sequence or proteins in order to propagate and produce virion. For example, the nucleic acid sequences of the retrovirus of the disclosure encode, for example, a group specific antigen and reverse transcriptase, (and integrase and protease-enzymes necessary for maturation and reverse transcription), respectively, as discussed above. The viral gag and pol can be derived from a lentivirus, such as HIV or a gammaretrovirus such as MoMLV. In addition, the nucleic acid genome of the retrovirus of the disclosure includes a sequence encoding a viral envelope (ENV) protein. The env gene can be derived from any retroviruses. The env may be an amphotropic envelope protein which allows transduction of cells of human and other species, an ecotropic envelope protein, which is able to transduce only mouse and rat cells, a xenotropic envelope, a GALV envelope, an RD114 envelope, an FeLV envelope or other retroviral envelope. The envelope may also be an envelope from a heterologous source such as an alphavirus, CMV or VSV. Further, it may be desirable to target the recombinant virus by linkage of the envelope protein with an antibody or a particular ligand for targeting to a receptor of a particular cell-type. As mentioned above, retroviral vectors can be made target specific by inserting, for example, a glycolipid, or a protein. Targeting is often accomplished by using an antibody to target the retroviral vector to an antigen on a particular cell-type (e.g., a cell type found in a certain tissue, or a cancer cell type). Those of skill in the art will know of, or can readily ascertain without undue experimentation, specific methods to achieve

delivery of a retroviral vector to a specific target. In one embodiment, the *env* gene is derived from a non-retrovirus (e.g., alphavirus, CMV or VSV). Examples of retroviral-derived *env* genes include, but are not limited to: Moloney murine leukemia virus (MoMuLV), Harvey murine sarcoma virus (HaMuSV), murine mammary tumor virus (MuMTV), gibbon ape leukemia virus (GaLV), human immunodeficiency virus (HIV) and Rous Sarcoma Virus (RSV). Other *env* genes such as Vesicular stomatitis virus (VSV) (Protein G), cytomegalovirus envelope (CMV), or influenza virus hemagglutinin (HA) can also be used.

[00104] In one embodiment, the retroviral genome is derived from a gammaretrovirus, and more particularly a mammalian gammaretrovirus. By "derived" is meant that the parent polynucleotide sequence is an wild-type gammaretrovirus that has been modified by insertion or removal of naturally occurring sequences (e.g., insertion of an IRES, insertion of a heterologous polynucleotide encoding a polypeptide or inhibitory nucleic acid of interest, shuffling of a more effective promoter from a different retrovirus or virus in place of the wild-type promoter and the like).

[00105] Unlike recombinant retroviruses produced by standard methods in the art that are defective and require assistance in order to produce infectious vector particles, the disclosure provides a retrovirus that is replication-competent.

[00106] In another embodiment, the disclosure provides retroviral vectors that are targeted using regulatory sequences. Cell- or tissue-specific regulatory sequences (e.g., promoters) can be utilized to target expression of gene sequences in specific cell populations. Suitable mammalian and viral promoters for the disclosure are described elsewhere herein. Accordingly, in one embodiment, the disclosure provides a retrovirus having tissue-specific promoter elements at the 5' end of the retroviral genome. Preferably, the tissue-specific regulatory elements/sequences are in the U3 region of the LTR of the retroviral genome, including for example cell- or tissue-specific promoters and enhancers to neoplastic cells (e.g., tumor cell-specific enhancers and promoters), and inducible promoters (e.g., tetracycline).

[00107] Transcription control sequences of the disclosure can also include naturally occurring transcription control sequences naturally associated with a gene encoding a superantigen, a cytokine or a chemokine.

[00108] In some circumstances, it may be desirable to regulate expression. For example, different viral promoters with varying strengths of activity may be utilized depending on the level of expression desired. In mammalian cells, the CMV immediate early promoter is often used to provide strong transcriptional activation. Modified versions of the CMV promoter that are less potent have also been used when reduced levels of expression of the transgene are desired. When expression of a transgene in hematopoietic cells is desired, retroviral promoters such as the LTRs from MLV or MMTV can be used. Other viral promoters that can be used include SV40, RSV LTR, HIV-1 and HIV-2 LTR, adenovirus promoters such as from the E1A, E2A, or MLP region, AAV LTR, cauliflower mosaic virus, HSV-TK, and avian sarcoma virus.

[00109] Similarly tissue specific or selective promoters may be used to effect transcription in specific tissues or cells so as to reduce potential toxicity or undesirable effects to non-targeted tissues. For example, promoters such as the PSA, probasin, prostatic acid phosphatase or prostate-specific glandular kallikrein (hK2) may be used to target gene expression in the prostate. Other promoters/regulatory domains that can be used are set forth in Table 1.

[00110] In certain indications, it may be desirable to activate transcription at specific times after administration of the gene therapy vector. This may be done with such promoters as those that are hormone or cytokine regulatable. For example in therapeutic applications where the indication is a gonadal tissue where specific steroids are produced or routed to, use of androgen or estrogen regulated promoters may be advantageous. Such promoters that are hormone regulatable include MMTV, MT-1, ecdysone and RuBisco. Other hormone regulated promoters such as those responsive to thyroid, pituitary and adrenal hormones may be used. Cytokine and inflammatory protein responsive promoters that could be used include K and T Kininogen (Kageyama et al., 1987), c-fos, TNF-alpha, C-

reactive protein (Arcone et al., 1988), haptoglobin (Oliviero et al., 1987), serum amyloid A2, C/EBP alpha, IL-1, IL-6 (Poli and Cortese, 1989), Complement C3 (Wilson et al., 1990), IL-8, alpha-1 acid glycoprotein (Prowse and Baumann, 1988), alpha-1 antitrypsin, lipoprotein lipase (Zechner et al., 1988), angiotensinogen (Ron et al., 1990), fibrinogen, c-jun (inducible by phorbol esters, TNF-alpha, UV radiation, retinoic acid, and hydrogen peroxide), collagenase (induced by phorbol esters and retinoic acid), metallothionein (heavy metal and glucocorticoid inducible), Stromelysin (inducible by phorbol ester, interleukin-1 and EGF), alpha-2 macroglobulin and alpha-1 antichymotrypsin. Tumor specific promoters such as osteocalcin, hypoxia-responsive element (HRE), MAGE-4, CEA, alpha-fetoprotein, GRP78/BiP and tyrosinase may also be used to regulate gene expression in tumor cells.

[00111] In addition, this list of promoters should not be construed to be exhaustive or limiting, those of skill in the art will know of other promoters that may be used in conjunction with the promoters and methods disclosed herein.

TABLE 1 TISSUE SPECIFIC PROMOTERS

Tissue	Promoter
Pancreas	Insulin Elastin Amylase pdr-1 pdx-1 glucokinase
Liver	Albumin PEPCK HBV enhancer α fetoprotein apolipoprotein C α -1 antitrypsin vitellogenin, NF-AB Transthyretin
Skeletal muscle	Myosin H chain Muscle creatine kinase Dystrophin Calpain p94 Skeletal alpha-actin fast troponin 1
Skin	Keratin K6 Keratin K1
Lung	CFTR Human cytokeratin 18 (K18) Pulmonary surfactant proteins A, B and C CC-10 P1
Smooth muscle	sm22 α SM-alpha-actin
Endothelium	Endothelin-1 E-selectin von Willebrand factor TIE (Korhonen et al., 1995) KDR/flk-1 Melanocytes Tyrosinase
Adipose tissue	Lipoprotein lipase (Zechner et al., 1988) Adipsin (Spiegelman et al., 1989) acetyl- CoA carboxylase (Pape and Kim, 1989) glycerophosphate dehydrogenase (Dani et al., 1989) adipocyte P2 (Hunt et al., 1986)
Blood	β -globin

Glioma

GFAP, nestin, Msi 1 (J. Huang et al. Acta Biochim Biophys Sin 2010, 42: 274-280)

[00112] "Tissue-specific regulatory elements" are regulatory elements (e.g., promoters) that are capable of driving transcription of a gene in one tissue while remaining largely "silent" in other tissue types. It will be understood, however, that tissue-specific promoters may have a detectable amount of "background" or "base" activity in those tissues where they are silent. The degree to which a promoter is selectively activated in a target tissue can be expressed as a selectivity ratio (activity in a target tissue/activity in a control tissue). In this regard, a tissue specific promoter useful in the practice of the disclosure typically has a selectivity ratio of greater than about 5. Preferably, the selectivity ratio is greater than about 15.

[00113] It will be further understood that certain promoters, while not restricted in activity to a single tissue type, may nevertheless show selectivity in that they may be active in one group of tissues, and less active or silent in another group. Such promoters are also termed "tissue specific", and are contemplated for use with the disclosure. For example, promoters that are active in a variety of central nervous system (CNS) neurons may be therapeutically useful in protecting against damage due to stroke, which may effect any of a number of different regions of the brain. Accordingly, the tissue-specific regulatory elements used in the disclosure, have applicability to regulation of the heterologous proteins as well as a applicability as a targeting polynucleotide sequence in the present retroviral vectors.

[00114] The retroviral vectors and CD polynucleotide and polypeptide of the disclosure can be used to treat a wide range of disease and disorders including a number of cell proliferative diseases and disorders (see, e.g., U.S. Pat. Nos. 4,405,712 and 4,650,764; Friedmann, 1989, Science, 244:1275-1281; Mulligan, 1993, Science, 260:926-932, R. Crystal, 1995, Science 270:404-410, each of which are incorporated herein by reference in their entirety, see also, The Development of Human Gene Therapy, Theodore Friedmann, Ed., Cold Spring Harbor Laboratory Press, Cold Spring Harbor, N.Y.,

1999. ISBN 0-87969-528-5, which is incorporated herein by reference in its entirety).

[00115] The phrase "non-dividing" cell refers to a cell that does not go through mitosis. Non-dividing cells may be blocked at any point in the cell cycle, (e.g., G_0/G_1 , $G_{1/S}$, $G_{2/M}$), as long as the cell is not actively dividing. For ex vivo infection, a dividing cell can be treated to block cell division by standard techniques used by those of skill in the art, including, irradiation, aphidocolin treatment, serum starvation, and contact inhibition. However, it should be understood that ex vivo infection is often performed without blocking the cells since many cells are already arrested (e.g., stem cells). For example, a recombinant lentivirus vector is capable of infecting many non-dividing cells, regardless of the mechanism used to block cell division or the point in the cell cycle at which the cell is blocked. Examples of pre-existing non-dividing cells in the body include neuronal, muscle, liver, skin, heart, lung, and bone marrow cells, and their derivatives. For dividing cells gamma-retroviral vectors can be used, as they are only capable of infecting cells that are dividing.

[00116] By "dividing" cell is meant a cell that undergoes active mitosis, or meiosis. Such dividing cells include stem cells, skin cells (e.g., fibroblasts and keratinocytes), gametes, and other dividing cells known in the art. Of particular interest and encompassed by the term dividing cell are cells having cell proliferative disorders, such as neoplastic cells. The term "cell proliferative disorder" refers to a condition characterized by an abnormal number of cells. The condition can include both hypertrophic (the continual multiplication of cells resulting in an overgrowth of a cell population within a tissue) and hypotrophic (a lack or deficiency of cells within a tissue) cell growth or an excessive influx or migration of cells into an area of a body. The cell populations are not necessarily transformed, tumorigenic or malignant cells, but can include normal cells as well. Cell proliferative disorders include disorders associated with an overgrowth of connective tissues, such as various fibrotic conditions, including scleroderma, arthritis and liver cirrhosis. Cell proliferative disorders include neoplastic disorders such as

head and neck carcinomas. Head and neck carcinomas would include, for example, carcinoma of the mouth, esophagus, throat, larynx, thyroid gland, tongue, lips, salivary glands, nose, paranasal sinuses, nasopharynx, superior nasal vault and sinus tumors, esthesioneuroblastoma, squamous cell cancer, malignant melanoma, sinonasal undifferentiated carcinoma (SNUC), brain (including glioblastomas) or blood neoplasia. Also included are carcinoma's of the regional lymph nodes including cervical lymph nodes, prelaryngeal lymph nodes, pulmonary juxtaesophageal lymph nodes and submandibular lymph nodes (Harrison's Principles of Internal Medicine (eds., Isselbacher, et al., McGraw-Hill, Inc., 13th Edition, ppl850-1853, 1994). Other cancer types, include, but are not limited to, lung cancer, colon-rectum cancer, breast cancer, prostate cancer, urinary tract cancer, uterine cancer lymphoma, oral cancer, pancreatic cancer, leukemia, melanoma, stomach cancer, skin cancer and ovarian cancer.

[00117] The disclosure also provides gene therapy for the treatment of cell proliferative disorders. Such therapy would achieve its therapeutic effect by introduction of an appropriate therapeutic polynucleotide sequence (e.g., antisense, ribozymes, suicide genes, siRNA), into cells of subject having the proliferative disorder. Delivery of polynucleotide constructs can be achieved using the recombinant retroviral vector of the disclosure, particularly if it is based on MLV, which will is capable of infecting only dividing cells, and which continues to be made in infected cells, even after the cells stop dividing.

[00118] In addition, the therapeutic methods (e.g., the gene therapy or gene delivery methods) as described herein can be performed *in vivo* or *ex vivo*. It may be preferable to remove the majority of a tumor prior to gene therapy, for example surgically or by radiation. Surgery or radiation can also be used after gene therapy. In some aspects, the retroviral therapy may be preceded or followed by chemotherapy.

[00119] Thus, the disclosure provides a recombinant retrovirus capable of infecting a non-dividing cell, a dividing cell or a neoplastic cell, therein the recombinant retrovirus comprises a viral GAG; a viral POL; a viral ENV; a heterologous nucleic acid

operably linked to an IRES or an internal promoter; and cis-acting nucleic acid sequences necessary for packaging, reverse transcription and integration. The recombinant retrovirus can be a lentivirus, such as HIV, or can be a gammaretrovirus. As described above for the method of producing a recombinant retrovirus, the recombinant retrovirus of the disclosure may further include at least one of VPR, VIF, NEF, VPX, TAT, REV, and VPU protein. While not wanting to be bound by a particular theory, it is believed that one or more of these genes/protein products are important for increasing the viral titer of the recombinant retrovirus produced (e.g., NEF) or may be advantageous for infection and packaging of virion in cells with high levels of viral restriction elements (e.g. VIF for cells with active APOBEC3G or equivalent).

[00120] The disclosure also provides a method of nucleic acid transfer to a target cell to provide expression of a particular nucleic acid (e.g., a heterologous sequence). Therefore, in another embodiment, the disclosure provides a method for introduction and expression of a heterologous nucleic acid in a target cell comprising infecting the target cell with the recombinant virus of the disclosure and expressing the heterologous nucleic acid in the target cell. As mentioned above, the target cell can be any cell type including dividing, non-dividing, neoplastic, immortalized, modified and other cell types recognized by those of skill in the art, so long as they are capable of infection by a retrovirus.

[00121] It may be desirable to modulate the expression of a gene in a cell by the introduction of a nucleic acid sequence (e.g., the heterologous nucleic acid sequence) by the method of the disclosure, wherein the nucleic acid sequence give rise, for example, to an antisense or ribozyme molecule. The term "modulate" envisions the suppression of expression of a gene when it is over-expressed, or augmentation of expression when it is under-expressed. Where a cell proliferative disorder is associated with the expression of a gene, nucleic acid sequences that interfere with the gene's expression at the translational level can be used. This approach utilizes, for example, antisense nucleic acid, ribozymes, or triplex agents to block transcription or translation of a specific mRNA, either by

masking that mRNA with an antisense nucleic acid or triplex agent, or by cleaving it with a ribozyme.

[00122] Antisense nucleic acids are DNA or RNA molecules that are complementary to at least a portion of a specific mRNA molecule (Weintraub, Scientific American, 262:40, 1990). In the cell, the antisense nucleic acids hybridize to the corresponding mRNA, forming a double-stranded molecule. The antisense nucleic acids interfere with the translation of the mRNA, since the cell will not translate a mRNA that is double-stranded. Antisense oligomers of about 15 nucleotides are preferred, since they are easily synthesized and are less likely to cause problems than larger molecules when introduced into the target cell. The use of antisense methods to inhibit the *in vitro* translation of genes is well known in the art (Marcus-Sakura, Anal. Biochem., 172:289, 1988).

[00123] The antisense nucleic acid can be used to block expression of a mutant protein or a dominantly active gene product, such as amyloid precursor protein that accumulates in Alzheimer's disease. Such methods are also useful for the treatment of Huntington's disease, hereditary Parkinsonism, and other diseases. Of particular interest are the blocking of genes associated with cell-proliferative disorders. Antisense nucleic acids are also useful for the inhibition of expression of proteins associated with toxicity.

[00124] Use of an oligonucleotide to stall transcription is known as the triplex strategy since the oligomer winds around double-helical DNA, forming a three-strand helix. Therefore, these triplex compounds can be designed to recognize a unique site on a chosen gene (Maher, *et al.*, Antisense Res. and Dev., 1(3):227, 1991; Helene, C., Anticancer Drug Design, 6(6):569, 1991).

[00125] Ribozymes are RNA molecules possessing the ability to specifically cleave other single-stranded RNA in a manner analogous to DNA restriction endonucleases. Through the modification of nucleotide sequences which encode these RNAs, it is possible to engineer molecules that recognize specific nucleotide sequences in an RNA molecule and cleave it (Cech, J. Amer. Med. Assn., 260:3030, 1988). A major advantage of this approach is that, because they are

sequence-specific, only mRNAs with particular sequences are inactivated.

[00126] It may be desirable to transfer a nucleic acid encoding a biological response modifier (e.g., a cytokine). Included in this category are immunopotentiating agents including nucleic acids encoding a number of the cytokines classified as "interleukins". These include, for example, interleukins 1 through 15. Also included in this category, although not necessarily working according to the same mechanisms, are interferons, and in particular gamma interferon, tumor necrosis factor (TNF) and granulocyte-macrophage-colony stimulating factor (GM-CSF). Other polypeptides include, for example, angiogenic factors and anti-angiogenic factors. It may be desirable to deliver such nucleic acids to bone marrow cells or macrophages to treat enzymatic deficiencies or immune defects. Nucleic acids encoding growth factors, toxic peptides, ligands, receptors, or other physiologically important proteins can also be introduced into specific target cells.

[00127] For example, HER2 (see, e.g., SEQ ID NO:23 and 24), a member of the EGF receptor family, is the target for binding of the drug trastuzumab (Herceptin™, Genentech). Trastuzumab is a mediator of antibody-dependent cellular cytotoxicity (ADCC). Activity is preferentially targeted to HER2-expressing cells with 2+ and 3+ levels of overexpression by immunohistochemistry rather than 1+ and non-expressing cells (Herceptin prescribing information, Crommelin 2002). Enhancement of expression of HER2 by introduction of vector expressing HER2 or truncated HER2 (expressing only the extracellular and transmembrane domains) in HER2 low tumors may facilitate optimal triggering of ADCC and overcome the rapidly developing resistance to HER2 that is observed in clinical use.

[00128] The substitution of yCD2 for the intracellular domain of HER2 allows for cell surface expression of HER2 and cytosolic localization of yCD2. The HER2 extracellular domain (ECD) and transmembrane domain (TM) (approximately 2026 bp from about position 175 to 2200) can be amplified by PCR (Yamamoto *et al.*, Nature 319:230-234, 1986; Chen *et al.*, Canc. Res., 58:1965-1971, 1998) or chemically synthesized (BioBasic Inc., Markham, Ontario, Canada) and inserted between the IRES and yCD2 gene in the vector pAC3-yCD2

SEQ ID NO: 19. Alternatively, the yCD gene can be excised and replaced with a polynucleotide encoding a HER2 polypeptide or fragment thereof. A further truncated HER2 with only the Herceptin binding domain IV of the ECD and TM domains (approximately 290 bp from position 1910 to 2200) can be amplified or chemically synthesized and used as above (Landgraf 2007; Garrett et al., J. of Immunol., 178:7120-7131, 2007). A further modification of this truncated form with the native signal peptide (approximately 69 bp from position 175-237) fused to domain IV and the TM can be chemically synthesized and used as above. The resulting viruses can be used to treat a cell proliferative disorder in a subject in combination with trastuzumab or trastuzumab and 5-FC.

[00129] Alternatively, HER2 and the modifications described above can be expressed in a separate vector containing a different ENV gene or other appropriate surface protein. This vector can be replication competent (Logg et al. J.Mol Biol. 369:1214 2007) or non-replicative "first generation" retroviral vector that encodes the envelope and the gene of interest (Emi et al. J.Virol 65:1202 1991). In the latter case the pre-existing viral infection will provide complementary gag and pol to allow infective spread of the "non-replicative" vector from any previously infected cell. Alternate ENV and glycoproteins include xenotropic and polytropic ENV and glycoproteins capable of infecting human cells, for example ENV sequences from the NZB strain of MLV and glycoproteins from MCF, VSV, GALV and other viruses (Palu 2000, Baum et al., Mol. Therapy, 13(6):1050-1063, 2006). For example, a polynucleotide can comprise a sequence wherein the GAG and POL and yCD2 genes of SEQ ID NO: 19 are deleted, the ENV corresponds to a xenotropic ENV domain of NZB MLV or VSV-g, and the IRES or a promoter such as RSV is operatively linked directly to HER2, HER2 ECDTM, HER2 ECDIVTM, or HER2 SECIVTM.

[00130] Mixed infection of cells by VSVG pseudotyped virus and amphotropic retrovirus results in the production of progeny virions bearing the genome of one virus encapsidated by the envelope proteins of the other [Emi 1991]. The same is true for other envelopes that pseudotype retroviral particles. For example, infection by retroviruses derived as above results in production of progeny virions capable of encoding yCD2 and HER2 (or variant) in

infected cells. The resulting viruses can be used to treat a cell proliferative disorder in a subject in combination with trastuzumab or trastuzumab and 5-FC.

[00131] Another aspect of the development of resistance to trastuzumab relates to the interference with intracellular signaling required for the activity of trastuzumab. Resistant cells show loss of PTEN and lower expression of p27kipl [Fujita, Brit J. Cancer, 94:247, 2006; Lu et al., Journal of the National Cancer Institute, 93(24): 1852-1857, 2001; Kute et al., Cytometry Part A 57A:86-93, 2004).

[00132] For example, a polynucleotide encoding PTEN (SEQ ID NO:25) can be chemically synthesized (BioBasic Inc., Markham, Canada) and operably inserted directly after the yCD2 gene in the vector pAC3-yCD2 SEQ ID NO: 19 or 22, or with a linker sequence as previously described, or as a replacement for yCD2. In a further example, the PTEN encoding polynucleotide can be synthesized as above and inserted between the IRES and yCD2 sequences or with a linker as previously described.

[00133] Alternatively, PTEN can be expressed in a separate vector containing a different ENV gene or other appropriate surface protein. This vector can be replication competent (Logg et al. J.Mol Biol. 369:1214 2007) or non replicative "first generation" retroviral vector that encodes the envelope and the gene of interest (Emi et al., J.Virol 65:1202 1991). In the latter case the pre-existing viral infection will provide complementary gag and pol to allow infective spread of the "non-replicative" vector from any previously infected cell. Alternate ENV and glycoproteins include xenotropic and polytropic ENV and glycoproteins capable of infecting human cells, for example ENV sequences from the NZB strain of MLV and glycoproteins from MCF, VSV, GALV and other viruses (Palu, Rev Med Virol. 2000, Baum, Mol. Ther. 13(6):1050-1063, 2006). For example, a polynucleotide can comprise a sequence wherein the gag and pol and yCD2 genes of SEQ ID NO: 19 are deleted, the ENV corresponds to a xenotropic ENV domain of NZB MLV or VSV-g, and the IRES or a promoter such as RSV is operatively linked directly to PTEN.

[00134] Mixed infection of cells by VSVG pseudotyped virus and amphotropic retrovirus results in the production of progeny virions bearing the genome of one virus encapsidated by the envelope proteins of the other [Emi 1991]. The same is true for other envelopes that pseudotype retroviral particles. For example, infection by retroviruses derived as above results in production of progeny virions capable of encoding yCD2 and PTEN (or variant) or PTEN alone in infected cells. The resulting viruses can be used to treat a cell proliferative disorder in a subject in combination with trastuzumab or trastuzumab and 5-FC.

[00135] Similarly, a polynucleotide encoding p27kip1 (SEQ ID NO:27 and 28) can be chemically synthesized (BioBasic Inc., Markham, Canada) and operably inserted directly after the yCD2 gene in the vector pAC3-yCD2 SEQ ID NO: 19 or with a linker sequence. In a further example, the p27kip1 encoding polynucleotide can be synthesized as above and inserted between the IRES and yCD2 sequences or with a linker as previously described or in place of the yCD2 gene.

[00136] Alternatively, p27kip1 can be expressed in a separate vector containing a different env gene or other appropriate surface protein. This vector can be replication competent or non-replicative "first generation" retroviral vector that encodes the envelope and the gene of interest (Emi et al. J.Virol 65:1202 1991). In the latter case the pre-existing viral infection will provide complementary gag and pol to allow infective spread of the "non-replicative" vector from any previously infected cell. Alternate ENV and glycoproteins include xenotropic and polytropic ENV and glycoproteins capable of infecting human cells, for example, ENV sequences from the NZB strain of MLV and glycoproteins from MCF, VSV, GALV and other viruses (Palu 2000, Baum 2006, supra). For example, a polynucleotide can comprise a sequence wherein the gag and pol and yCD2 genes of SEQ ID NO: 19 are deleted, the ENV corresponds to a xenotropic ENV domain of NZB MLV or VSV-g, and the IRES or a promoter such as RSV is operatively linked directly to p27kip1.

[00137] Mixed infection of cells by VSVG pseudotyped virus and amphotropic retrovirus results in the production of progeny virions

bearing the genome of one virus encapsidated by the envelope proteins of the other [Emi 1991]. The same is true for other envelopes that pseudotype retroviral particles. For example, infection by retroviruses derived as above from both SEQ ID NO: 19 and TT results in production of progeny virions capable of encoding yCD2 and p27kip1 (or variant) in infected cells. The resulting viruses can be used to treat a cell proliferative disorder in a subject in combination with trastuzumab or trastuzumab and 5-FC.

[00138] In another example, CD20 is the target for binding of the drug rituximab (Rituxan™, Genentech). Rituximab is a mediator of complement-dependent cytotoxicity (CDC) and ADCC. Cells with higher mean fluorescence intensity by flow cytometry show enhanced sensitivity to rituximab (van Meerten *et al.*, Clin Cancer Res 2006; 12(13):4027-4035, 2006). Enhancement of expression of CD20 by introduction of vector expressing CD20 in CD20 low B cells may facilitate optimal triggering of ADCC.

[00139] For example, a polynucleotide encoding CD20 (SEQ ID NO:29 and 30) can be chemically synthesized (BioBasic Inc., Markham, Canada) and operably inserted directly after the yCD2 gene in the vector pAC3-yCD2(-2) SEQ ID NO: 19 or 22 with a linker sequence as previously described, or as a replacement for the yCD2 gene. In a further example, the CD20 encoding polynucleotide can be synthesized as above and inserted between the IRES and yCD2 sequences or with a linker as previously described. As a further alternative the CD20 sequence can be inserted into the pAC3-yCD2 vector after excision of the CD gene by PstI and NotI digestion.

[00140] In still a further example, a polynucleotide encoding CD20 (SEQ ID NO:29 and 30) can be chemically synthesized (BioBasic Inc., Markham, Canada) and inserted into a vector containing a non amphotropic env gene or other appropriate surface protein (Tedder *et al.*, PNAS, 85:208-212, 1988). Alternate ENV and glycoproteins include xenotropic and polytropic ENV and glycoproteins capable of infecting human cells, for example ENV sequences from the NZB strain of MLV and glycoproteins from MCF, VSV, GALV and other viruses [Palu 2000, Baum 2006]. For example, a polynucleotide can comprise a sequence wherein the gag and pol and yCD2 genes of SEQ ID NO: 19 are deleted, the ENV corresponds to a xenotropic ENV domain of NZB MLV

or VSV-g, and the IRES or a promoter such as RSV is operatively linked directly to CD20.

[00141] Mixed infection of cells by VSVG pseudotyped virus and amphotropic retrovirus results in the production of progeny virions bearing the genome of one virus encapsidated by the envelope proteins of the other [Emi 1991]. The same is true for other envelopes that pseudotype retroviral particles. For example, infection by retroviruses derived as above from both SEQ ID NO: 19 or 22 results in production of progeny virions capable of encoding yCD2 and CD20 in infected cells. The resulting viruses can be used to treat a cell proliferative disorder in a subject in combination with Rituxan and/or 5-FC. Similarly, infection of a tumor with a vector encoding only the CD20 marker can make the tumor treatable by the use of Rituxan.

[00142] Levels of the enzymes and cofactors involved in pyrimidine anabolism can be limiting. OPRT, thymidine kinase (TK), Uridine monophosphate kinase, and pyrimidine nucleoside phosphorylase expression is low in 5-FU resistant cancer cells compared to sensitive lines (Wang et al., Cancer Res., 64:8167-8176, 2004). Large population analyses show correlation of enzyme levels with disease outcome (Fukui et al., Int'l. J. OF Mol. Med., 22:709-716, 2008). Coexpression of CD and other pyrimidine anabolism enzymes (PAE) can be exploited to increase the activity and therefore therapeutic index of fluoropyrimidine drugs.

[00143] To further increase the genetic stability (see, e.g., Fig. 5) of yCD2/PAE containing vectors, the enzyme encoding gene can be chemically synthesized with random mutations throughout the sequence. These mutations can be essentially random or can consist of only mutations at the wobble position for each amino acids. The library of mutated sequences is inserted downstream of the yCD2 gene as was previously described for SEQ ID NO: 11 and 13 to create a library of plasmids that can then be used to generate a library of infectious particles by transient transfection of 293T cells or equivalent. Sensitive cells can be infected with retrovirus encoding the fusion polypeptide and subjected to selection with appropriate chemicals. For example, randomly mutagenized Herpes Thymidine Kinase (TK) is chemically synthesized (Bio Basic Inc,

Markham, Canada). The synthetic sequence is inserted 3' of the yCD2 sequence in SEQ ID NO:19, or by itself in the pAC3-yCD2 vector backbone after excision of the CD2 gene. The retroviral vector mixture is packaged as previously described. Mouse fibroblast LMTK- cells are infected with vector and selected for TK activity in HAT media (Hiller et al., Mol. Cell Biol. 8(8):3298-3302, 1988). Serial passage of supernatants of resistant cells to fresh LMTK- cells again selected in HAT media results in selection of stable vectors expressing TK. TK⁺ resistant cells can be isolated and TK sequences rescued by standard PCR based techniques for mutation analysis (Cowell et al., CDNA Library Protocols, Published by Humana Press, 1996). In this manner, sequences are selected for both expression of functional protein and genomic stability of retroviral vector construct. Similar strategies can be employed for UPRT (SEQ ID NO: 11, 13), OPRT (SEQ ID NO: 15, 17) (Olah et al., Cancer Res. 40:2869-2875, 1980; and Suttle, Somatic Cell & Mol. Genet., 15(5):435-443, 1989) and other genes of interest.

[00144] Alternatively, OPRT, UPRT, TK or other PAE can be expressed in a separate vector containing a different ENV gene or other appropriate surface glycoprotein. This vector can be replication competent (Logg et al. J.Mol Biol. 369:1214 2007) or non-replicative "first generation" retroviral vector that encodes the envelope and the gene of interest (Emi et al. J.Virol 65:1202 1991). In the latter case the pre-existing viral infection will provide complementary gag and pol to allow infective spread of the "non-replicative" vector from any previously infected cell. Alternate ENV and glycoproteins include xenotropic and polytropic ENV and glycoproteins capable of infecting human cells, for example ENV sequences from the NZB strain of MLV and glycoproteins from MCF, VSV, GALV and other viruses [Palu 2000, Baum 2006, *supra*]. For example, a polynucleotide can comprise a sequence wherein the GAG and POL genes are deleted, the ENV corresponds to a xenotropic ENV domain from NZB MLV or VSV-g, and the IRES or a promoter such as RSV is operatively linked directly to OPRT, UPRT, TK, or other PAE gene.

[00145] Mixed infection of cells by VSV-g pseudotyped virus and amphotropic retrovirus results in the production of progeny virions bearing the genome of one virus encapsidated by the envelope

proteins of the other (Emi et al., J. Virol. 65:1202, 1991). The same is true for other envelopes that pseudotype retroviral particles. For example, infection by retroviruses derived as above from both SEQ ID NOs: 19 and 20 results in production of progeny virions capable of encoding YCD2 and OPRT in infected cells. The resulting viruses can be used to treat a cell proliferative disorder in a subject in combination with 5-FC.

[00146] The recombinant retrovirus of the disclosure can be used for the treatment of a neuronal disorder for example, may optionally contain an exogenous gene, for example, a gene which encodes a receptor or a gene which encodes a ligand. Such receptors include receptors which respond to dopamine, GABA, adrenaline, noradrenaline, serotonin, glutamate, acetylcholine and other neuropeptides, as described above. Examples of ligands which may provide a therapeutic effect in a neuronal disorder include dopamine, adrenaline, noradrenaline, acetylcholine, gamma-aminobutyric acid and serotonin. The diffusion and uptake of a required ligand after secretion by an infected donor cell would be beneficial in a disorder where the subject's neural cell is defective in the production of such a gene product. A cell genetically modified to secrete a neurotrophic factor, such as nerve growth factor, (NGF), might be used to prevent degeneration of cholinergic neurons that might otherwise die without treatment.

[00147] Alternatively, cells be grafted into a subject with a disorder of the basal ganglia, such as Parkinson's disease, can be modified to contain an exogenous gene encoding L-DOPA, the precursor to dopamine. Parkinson's disease is characterized by a loss of dopamine neurons in the substantia-nigra of the midbrain, which have the basal ganglia as their major target organ.

[00148] Other neuronal disorders that can be treated similarly by the method of the disclosure include Alzheimer's disease, Huntington's disease, neuronal damage due to stroke, and damage in the spinal cord. Alzheimer's disease is characterized by degeneration of the cholinergic neurons of the basal forebrain. The neurotransmitter for these neurons is acetylcholine, which is necessary for their survival. Engraftment of cholinergic cells infected with a recombinant retrovirus of the disclosure containing

an exogenous gene for a factor which would promote survival of these neurons can be accomplished by the method of the disclosure, as described. Following a stroke, there is selective loss of cells in the CA1 of the hippocampus as well as cortical cell loss which may underlie cognitive function and memory loss in these patients. Once identified, molecules responsible for CA1 cell death can be inhibited by the methods of this disclosure. For example, antisense sequences, or a gene encoding an antagonist can be transferred to a neuronal cell and implanted into the hippocampal region of the brain.

[00149] For diseases due to deficiency of a protein product, gene transfer could introduce a normal gene into the affected tissues for replacement therapy, as well as to create animal models for the disease using antisense mutations. For example, it may be desirable to insert a Factor IX encoding nucleic acid into a retrovirus for infection of a muscle or liver cell.

[00150] The disclosure also provides gene therapy for the treatment of cell proliferative or immunologic disorders. Such therapy would achieve its therapeutic effect by introduction of an antisense, an siRNA or dominant negative encoding polynucleotide into cells having the proliferative disorder, wherein the polynucleotide binds to and prevents translation or expression of a gene associated with a cell-proliferative disorder. Delivery of heterologous nucleic acids useful in treating or modulating a cell proliferative disorder (e.g., antisense or siRNA polynucleotides) can be achieved using a recombinant retroviral vector of the disclosure. In another embodiment, a cell proliferative disorder is treated by introducing a CD polynucleotide of the disclosure, expressing the polynucleotide to produce a polypeptide comprising cytosine deaminase activity and contacting the cell with 5-fluorocytosine in an amount and for a period of time to produce a cytotoxic amount of 5-FU.

[00151] In addition, the disclosure provides polynucleotide sequence encoding a recombinant retroviral vector of the disclosure. The polynucleotide sequence can be incorporated into various viral particles. For example, various viral vectors which can be utilized for gene therapy include adenovirus, herpes virus, vaccinia, or,

preferably, an RNA virus such as a retrovirus and more particularly a mammalian gamma retrovirus. The retroviral vector can be a derivative of a murine, simian or human retrovirus. Examples of retroviral vectors in which a foreign gene (e.g., a heterologous polynucleotide sequence) can be inserted include, but are not limited to: derivatives of Murine Leukemia virus (MLV), Moloney murine leukemia virus (MoMuLV), murine mammary tumor virus (MuMTV), Rous Sarcoma Virus (RSV), Gibbon ape leukemia virus (GALV), baboon endogenous virus (BEV), and the feline virus RD114. All of these vectors can transfer or incorporate a gene for a selectable marker so that transduced cells can be identified and generated. By inserting a heterologous sequence of interest into the viral vector, along with another gene which encodes the ligand for a receptor on a specific target cell, for example, the vector is now target specific. Retroviral vectors can be made target specific by attaching, for example, a sugar, a glycolipid, or a protein. Targeting is accomplished by using an antibody or ligand to target the retroviral vector. Those of skill in the art will know of, or can readily ascertain without undue experimentation, specific polynucleotide sequences which can be inserted into the retroviral genome or attached to a viral envelope to allow target specific delivery of the retroviral vector containing the heterologous polynucleotide. In addition, the retroviral vector can be targeted to a cell by utilizing a cell- or tissue-specific regulatory element contained in the LTR of the retroviral genome. Preferably the cell- or tissue-specific regulatory element is in the U3 region of the LTRs. In this way, after integration into a cell, the retroviral genome will only be expressed in cells where the cell- or tissue-specific promoter is active.

[00152] In yet another embodiment, the disclosure provides plasmids comprising a recombinant retroviral derived construct. The plasmid can be directly introduced into a target cell or a cell culture such as NIH 3T3 or other tissue culture cells. The resulting cells release the retroviral vector into the culture medium.

[00153] The disclosure provides a polynucleotide construct comprising from 5' to 3': a promoter or regulatory region useful for initiating transcription; a psi packaging signal; a gag encoding

nucleic acid sequence, a *pol* encoding nucleic acid sequence; an *env* encoding nucleic acid sequence; an internal ribosome entry site nucleic acid sequence; a heterologous polynucleotide encoding a marker, therapeutic or diagnostic polypeptide; and a LTR nucleic acid sequence. As described elsewhere herein and as follows the various segment of the polynucleotide construct of the disclosure (e.g., a recombinant replication competent retroviral polynucleotide) are engineered depending in part upon the desired host cell, expression timing or amount, and the heterologous polynucleotide. A replication competent retroviral construct of the disclosure can be divided up into a number of domains that may be individually modified by those of skill in the art.

[00154] For example, the promoter can comprise a CMV promoter having a sequence as set forth in SEQ ID NO:19, 20 or 22 from nucleotide 1 to about nucleotide 582 and may include modification to one or more (e.g., 2-5, 5-10, 10-20, 20-30, 30-50, 50-100 or more nucleic acid bases) so long as the modified promoter is capable of directing and initiating transcription. In one embodiment, the promoter or regulatory region comprises a CMV-R-U5 domain polynucleotide. The CMV-R-U5 domain comprises the immediately early promoter from human cytomegalovirus to the MLV R-U5 region. In one embodiment, the CMV-R-U5 domain polynucleotide comprises a sequence as set forth in SEQ ID NO:19, 20 or 22 from about nucleotide 1 to about nucleotide 1202 or sequences that are at least 95% identical to a sequence as set forth in SEQ ID NO:19, 20, or 22 wherein the polynucleotide promotes transcription of a nucleic acid molecule operably linked thereto. The gag domain of the polynucleotide may be derived from any number of retroviruses, but will typically be derived from a gamma-retrovirus and more particularly from a mammalian gamma-retrovirus. In one embodiment the gag domain comprises a sequence from about nucleotide number 1203 to about nucleotide 2819 or a sequence having at least 95%, 98%, 99% or 99.8% (rounded to the nearest 10th) identity thereto. The pol domain of the polynucleotide may be derived from any number of retroviruses, but will typically be derived from an gamma-retrovirus and more particularly from a mammalian gammaretrovirus. In one embodiment the pol domain comprises a sequence from about nucleotide number

2820 to about nucleotide 6358 or a sequence having at least 95%, 98%, 99% or 99.9% (roundest to the nearest 10th) identity thereto. The env domain of the polynucleotide may be derived from any number of retroviruses, but will typically be derived from an gammaretrovirus or gamma-retrovirus and more particularly from a mammalian gammaretrovirus or gamma-retrovirus. In some embodiments the env coding domain comprises an amphotropic env domain. In one embodiment the env domain comprises a sequence from about nucleotide number 6359 to about nucleotide 8323 or a sequence having at least 95%, 98%, 99% or 99.8% (roundest to the nearest 10th) identity thereto. The IRES domain of the polynucleotide may be obtained from any number of internal ribosome entry sites. In one embodiment, IRES is derived from an encephalomyocarditis virus. In one embodiment the IRES domain comprises a sequence from about nucleotide number 8327 to about nucleotide 8876 or a sequence having at least 95%, 98%, or 99% (roundest to the nearest 10th) identity thereto so long as the domain allows for entry of a ribosome. The heterologous domain can comprise a cytosine deaminase of the disclosure. In one embodiment, the CD polynucleotide comprises a human codon optimized sequence. In yet another embodiment, the CD polynucleotide encodes a mutant polypeptide having cytosine deaminase, wherein the mutations confer increased thermal stabilization that increase the melting temperature (T_m) by 10⁰C allowing sustained kinetic activity over a broader temperature range and increased accumulated levels of protein. In one embodiment, the cytosine deaminase comprises a sequence as set forth in SEQ ID NO:19 or 22 from about nucleotide number 8877 to about 9353. The heterologous domain may be followed by a polypurine rich domain. The 3' LTR can be derived from any number of retroviruses, typically an gammaretrovirus and preferably a mammalian gammaretrovirus. In one embodiment, the 3' LTR comprises a U3-R-U5 domain. In yet another embodiment the LTR comprises a sequence as set forth in SEQ ID NO:19 or 22 from about nucleotide 9405 to about 9998 or a sequence that is at least 95%, 98% or 99.5% (rounded to the nearest 10th) identical thereto.

[00155] The disclosure also provides a recombinant retroviral vector comprising from 5' to 3' a CMV-R-U5, fusion of the immediate

early promoter from human cytomegalovirus to the MLV R-U5 region; a PBS, primer binding site for reverse transcriptase; a 5' splice site; a ψ packaging signal; a gag, ORF for MLV group specific antigen; a pol, ORF for MLV polymerase polyprotein; a 3' splice site; a 4070A env, ORF for envelope protein of MLV strain 4070A; an IRES, internal ribosome entry site of encephalomyocarditis virus; a modified cytosine deaminase (thermostabilized and codon optimized); a PPT, polypurine tract; and a U3-R-U5, MLV long terminal repeat. This structure is further depicted in Figure 3.

[00156] The disclosure also provides a retroviral vector comprising a sequence as set forth in SEQ ID NO:19, 20 or 22.

[00157] A number of chemotherapeutic agents are currently on the market having varying degrees of success from full remission to temporary remission and prolonged life with expected recurrence. Some of the cancer therapeutic agents on the market target the vascular angiogenic properties of tumor. The composition target the angiogenesis of tumors seeking to reduces blood supply and nutrients to the tumor or cancer and thereby reduce the tumor and prolong a subject's life. VEGF is an angiogenic factor known to play a role in tumor growth. Thus, antagonists of VEGF have been developed as anti-cancer agents.

[00158] Human VEGF mediates neoangiogenesis in normal and malignant vasculature; it is overexpressed in most malignancies and high levels have correlated with a greater risk of metastases and poor prognosis in many. When VEGF interacts with its receptor in *in vitro* models of angiogenesis, endothelial cell proliferation and new blood vessel formation occur. In animal models, VEGF has been demonstrated to induce vascular endothelial-cell proliferation/migration, sustain survival of newly-formed blood vessels, and enhance vascular permeability.

[00159] A VEGF antagonist agent is one that targets or negatively regulates the VEGF signaling pathway. Examples include VEGF inhibitors (e.g., agents that directly inhibit VEGF (e.g., VEGF-A, -B, -C, or -D), such as by binding VEGF (e.g., anti-VEGF antibodies such as bevacizumab (AVASTIN®) or ranibizumab (LUCENTIS®), or other inhibitors such as pegaptanib, NEOVASTAT®, AE-941, VEGF Trap, and PI-88)), modulators of VEGF expression (e.g., INGN-241, oral

tetrathiomolybdate, 2-methoxyestradiol, 2-methoxyestradiol nanocrystal dispersion, bevasiranib sodium, PTC-299, Veglin), inhibitors of a VEGF receptor (e.g., KDR or VEGF receptor III (Flt4), for example anti-KDR antibodies, VEGFR2 antibodies such as CDP-791, IMC-1121B, VEGFR2 blockers such as CT-322), modulators of VEGFR expression (e.g., VEGFR1 expression modulator Sirna-027) or inhibitors of VEGF receptor downstream signaling. In some aspects described herein, the VEGF antagonist agent is bevacizumab, pegaptanib, ranibizumab, sorafenib, sunitinib, AE-941, VEGF Trap, pazopanib, vandetanib, vatalanib, cediranib, fenretinide, squalamine, INGN-241, oral tetrathiomolybdate, tetrathiomolybdate, Panzem NCD, 2-methoxyestradiol, AEE-788, AG-013958, bevasiranib sodium, AMG-706, axitinib, BIBF-1120, CDP-791, CP-547632, PI-88, SU-14813, SU-6668, XL-647, XL-999, IMC-1121B, ABT-869, BAY-57-9352, BAY-73-4506, BMS-582664, CEP-7055, CHIR-265, CT-322, CX-3542, E-7080, ENMD-1198, OSI-930, PTC-299, Sirna-027, TKI-258, Veglin, XL-184, or ZK-304709.

[00160] Bevacizumab (AVASTATIN®) (rhuMAb-VEGF) (Anti-VEGF monoclonal antibody) is a recombinant human/murine chimeric monoclonal antibody directed against vascular endothelial growth factor (VEGF)). It is prepared by engineering VEGF-binding residues of a murine anti-VEGF monoclonal antibody into framework regions of human immunoglobulin-1 (IgG1) (Prod Info Avastin, 2004). Only 7% of the amino acid sequence is derived from the murine antibody, with 93% from IgG1. Bevacizumab binds and neutralizes all human VEGF forms via recognition of binding sites for the two human VEGF receptor types (flt-1 and flk-1). In animal models, the antibody has been shown to stabilize established tumors or suppress tumor growth by inhibiting angiogenesis induced by VEGF.

[00161] The pharmacokinetics of bevacizumab are linear after doses of 0.3 mg/kg or greater (Anon, 2002). Following 90-minute intravenous infusions of 0.3, 1, 3, and 10 mg/kg in advanced cancer patients (n=25), peak serum concentrations of bevacizumab ranged from 5 to 9 mcg/mL, 21 to 39 mcg/mL, 52 to 92 mcg/mL, and 186 to 294 mcg/mL, respectively; slight accumulation was observed with repeat doses (weekly), but this was not significant and pharmacokinetics

remained linear. Steady-state levels of bevacizumab were obtained in 100 days after 1 to 20 mg/kg weekly, every 2 weeks, or every 3 week.

[00162] The recommended dose of bevacizumab is 5 milligrams/kilogram infused intravenously over 30 minutes every 2 weeks until disease progression diminishes. Bevacizumab should follow chemotherapy. Efficacy of single-agent bevacizumab has not been established. Bevacizumab (which may be coadministered with the gemcitabine and docetaxel, or within a week before or after chemotherapy), is administered intravenously, at about 1 mg/kg to about 15 mg/kg, preferably about 5 mg/kg.

[00163] The methods and compositions of the disclosure are useful in combination therapies including therapies with bevacizumab. As described herein a replication competent retrovirus (RCR) of the disclosure comprising a therapeutic (e.g., a cytotoxic gene) is useful in treating cell proliferative disorders. An advantage of the RCR of the disclosure includes its ability to infect replicating cells cancer cells. Where the transgene of the vector comprises a cytotoxic gene (e.g., a gene that encodes a polypeptide that converts a non-cytotoxic agent to a cytotoxic agent) provides the ability to kill cancer cells.

[00164] The disclosure provides methods for treating cell proliferative disorders such as cancer and neoplasms comprising administering an RCR vector of the disclosure produced by the HT1080+T5.0002 cells or similar HT1080 derived cells producing vectors encoding other heterologous genes, followed by treatment with a chemotherapeutic agent or anti-cancer agent. In one embodiment, the RCR vector is administered to a subject for a period of time prior to administration of the chemotherapeutic or anti-cancer agent that allows the RCR to infect and replicate. The subject is then treated with a chemotherapeutic agent or anti-cancer agent for a period of time and dosage to reduce proliferation or kill the cancer cells. In one aspect, if the treatment with the chemotherapeutic or anti-cancer agent reduces, but does not kill the cancer/tumor (e.g., partial remission or temporary remission), the subject may then be treated with a non-toxic therapeutic agent (e.g., 5-FC) that is converted to a toxic therapeutic agent in cells expression a cytotoxic gene (e.g., cytosine deaminase) from the RCR.

Using such methods the RCXR vectors of the disclosure are spread during a replication process of the tumor cells, such cells can then be killed by treatment with an anti-cancer or chemotherapeutic agent and further killing can occur using the RCR treatment process described herein.

[00165] In yet another embodiment of the disclosure, the heterologous gene can comprise a coding sequence for a target antigen (e.g., a cancer antigen). In this embodiment, cells comprising a cell proliferative disorder are infected with an RCR comprising a heterologous polynucleotide encoding the target antigen to provide expression of the target antigen (e.g., overexpression of a cancer antigen). An anticancer agent comprising a targeting cognate moiety that specifically interacts with the target antigen is then administered to the subject. The targeting cognate moiety can be operably linked to a cytotoxic agent or can itself be an anticancer agent. Thus, a cancer cell infected by the RCR comprising the targeting antigen coding sequences increases the expression of target on the cancer cell resulting in increased efficiency/efficacy of cytotoxic targeting.

[00166] Blocking of interactions between cells of the immune system has been shown to have significant immunological effects, either activating or suppressing (Waldmann *Annu Rev Med.* 57:65 2006). For example, blockade of the interaction of CTLA-4 (CD 152) and B7.1 (CD80) which modulates the activation of T cells has been shown to cause immune stimulation, presumably by blocking this suppressive interaction (Peggs *et al.* *Curr. Opin. Immunol.* 18:206, 2006). This blockade can potentially be achieved either by antibodies against CTLA-4 or by soluble B7.1. Systemic administration of these types of molecules can have undesirable global effects which can at a minimum lead to deleterious side effects or even death in the case of one C28 agonist (Suntharalingam *et al.* *NEJM* 355 1018 2006). Pfizer has been developing one such anti-CTLA-4 blockading antibody (CP-675,206) as an anticancer reagent but has recently stopped development because of significant side effects. Local delivery of blockading molecules that are released into the local environment, from the tumor after infection with a replication competent vector encoding such molecules that are

released into the extracellular space, provides the immune modulation locally and avoid these serious side effects. The blocking molecules are antibodies, single chain antibodies, soluble versions of the natural ligand or other peptides that bind such receptors.

[00167] Thus in yet another embodiment, an RCR of the disclosure can comprise a coding sequence comprising a binding domain (e.g., an antibody, antibody fragment, antibody domain or receptor ligand) that specifically interacts with a cognate antigen or ligand. The RCR comprising the coding sequence for the binding domain can then be used to infect cells in a subject comprising a cell proliferative disorder such as a cancer cell or neoplastic cell. The infected cell will then express the binding domain or antibody. An antigen or cognate operably linked to a cytotoxic agent or which is cytotoxic itself can then be administered to a subject. The cytotoxic cognate will then selectively kill infected cells expressing the binding domain. Alternatively the binding domain itself can be an anti-cancer agent.

[00168] As used herein, the term "antibody" refers to a protein that includes at least one immunoglobulin variable domain or immunoglobulin variable domain sequence. For example, an antibody can include a heavy (H) chain variable region (abbreviated herein as VH), and a light (L) chain variable region (abbreviated herein as VL). In another example, an antibody includes two heavy (H) chain variable regions and two light (L) chain variable regions. The term "antibody" encompasses antigen-binding fragments of antibodies (e.g., single chain antibodies, Fab fragments, F(ab')₂, a Fd fragment, a Fv fragments, and dAb fragments) as well as complete antibodies.

[00169] The VH and VL regions can be further subdivided into regions of hypervariability, termed "complementarity determining regions" (CDR), interspersed with regions that are more conserved, termed "framework regions" (FR). The extent of the framework region and CDRs has been precisely defined (see, Kabat, E. A., *et al.* (1991) Sequences of Proteins of Immunological Interest, Fifth Edition, U.S. Department of Health and Human Services, NIH Publication No. 91-3242, and Chothia, C. *et al.* (1987) J. Mol. Biol.

196:901-917). Kabat definitions are used herein. Each VH and VL is typically composed of three CDRs and four FRs, arranged from amino-terminus to carboxy-terminus in the following order: FR1, CDR1, FR2, CDR2, FR3, CDR3, FR4.

[00170] An "immunoglobulin domain" refers to a domain from the variable or constant domain of immunoglobulin molecules.

Immunoglobulin domains typically contain two .beta.-sheets formed of about seven .beta.-strands, and a conserved disulphide bond (see, e.g., A. F. Williams and A. N. Barclay 1988 *Ann. Rev. Immunol.* 6:381-405). The canonical structures of hypervariable loops of an immunoglobulin variable can be inferred from its sequence, as described in Chothia *et al.* (1992) *J. Mol. Biol.* 227:799-817; Tomlinson *et al.* (1992) *J. Mol. Biol.* 227:776-798); and Tomlinson *et al.* (1995) *EMBO J.* 14(18):4628-38.

[00171] As used herein, an "immunoglobulin variable domain sequence" refers to an amino acid sequence which can form the structure of an immunoglobulin variable domain. For example, the sequence may include all or part of the amino acid sequence of a naturally-occurring variable domain. For example, the sequence may omit one, two or more N- or C-terminal amino acids, internal amino acids, may include one or more insertions or additional terminal amino acids, or may include other alterations. In one embodiment, a polypeptide that includes immunoglobulin variable domain sequence can associate with another immunoglobulin variable domain sequence to form a target binding structure (or "antigen binding site"), e.g., a structure that interacts with Tiel, e.g., binds to or inhibits Tiel.

[00172] The VH or VL chain of the antibody can further include all or part of a heavy or light chain constant region, to thereby form a heavy or light immunoglobulin chain, respectively. In one embodiment, the antibody is a tetramer of two heavy immunoglobulin chains and two light immunoglobulin chains, wherein the heavy and light immunoglobulin chains are inter-connected by, e.g., disulfide bonds. The heavy chain constant region includes three domains, CH1, CH2 and CH3. The light chain constant region includes a CL domain. The variable region of the heavy and light chains contains a binding domain that interacts with an antigen. The constant regions of the

antibodies typically mediate the binding of the antibody to host tissues or factors, including various cells of the immune system (e.g., effector cells) and the first component (C1q) of the classical complement system. The term "antibody" includes intact immunoglobulins of types IgA, IgG, IgE, IgD, IgM (as well as subtypes thereof). The light chains of the immunoglobulin may be of types kappa or lambda. In one embodiment, the antibody is glycosylated. An antibody can be functional for antibody-dependent cytotoxicity and/or complement-mediated cytotoxicity.

[00173] The term "monospecific antibody" refers to an antibody that displays a single binding specificity and affinity for a particular target, e.g., epitope. This term includes a "monoclonal antibody" which refers to an antibody that is produced as a single molecular species, e.g., from a population of homogenous isolated cells. A "monoclonal antibody composition" refers to a preparation of antibodies or fragments thereof of in a composition that includes a single molecular species of antibody. In one embodiment, a monoclonal antibody is produced by a mammalian cell. One or more monoclonal antibody species may be combined.

[00174] One or more regions of an antibody can be human or effectively human. For example, one or more of the variable regions can be human or effectively human. For example, one or more of the CDRs can be human, e.g., HC CDR1, HC CDR2, HC CDR3, LC CDR1, LC CDR2, and LC CDR3. Each of the light chain CDRs can be human. HC CDR3 can be human. One or more of the framework regions can be human, e.g., FR1, FR2, FR3, and FR4 of the HC or LC. In one embodiment, all the framework regions are human, e.g., derived from a human somatic cell, e.g., a hematopoietic cell that produces immunoglobulins or a non-hematopoietic cell. In one embodiment, the human sequences are germline sequences, e.g., encoded by a germline nucleic acid. One or more of the constant regions can be human or effectively human. In another embodiment, at least 70, 75, 80, 85, 90, 92, 95, or 98% of the framework regions (e.g., FR1, FR2, and FR3, collectively, or FR1, FR2, FR3, and FR4, collectively) or the entire antibody can be human or effectively human. For example, FR1, FR2, and FR3 collectively can be at least 70, 75, 80, 85, 90, 92, 95, 98, or 99% identical to a human sequence encoded by a human

germline V segment of a locus encoding a light or heavy chain sequence.

[00175] All or part of an antibody can be encoded by an immunoglobulin gene or a segment thereof. Exemplary human immunoglobulin genes include the kappa, lambda, alpha (IgA1 and IgA2), gamma (IgG1, IgG2, IgG3, IgG4), delta, epsilon and mu constant region genes, as well as the myriad immunoglobulin variable region genes. Full-length immunoglobulin light chains (about 25 Kd or 214 amino acids) are encoded by a variable region gene at the NH2-terminus (about 110 amino acids) and a kappa or lambda constant region gene at the COOH-- terminus. Full-length immunoglobulin heavy chains (about 50 Kd or 446 amino acids), are similarly encoded by a variable region gene (about 116 amino acids) and one of the other aforementioned constant region genes, e.g., gamma (encoding about 330 amino acids). A light chain refers to any polypeptide that includes a light chain variable domain. A heavy chain refers to any polypeptide that a heavy chain variable domain.

[00176] The disclosure provides a method of treating a subject having a cell proliferative disorder. The subject can be any mammal, and is preferably a human. The subject is contacted with a recombinant replication competent retroviral vector of the disclosure. The contacting can be *in vivo* or *ex vivo*. Methods of administering the retroviral vector of the disclosure are known in the art and include, for example, systemic administration, topical administration, intraperitoneal administration, intra-muscular administration, intracranial, cerebrospinal, as well as administration directly at the site of a tumor or cell-proliferative disorder. Other routes of administration known in the art.

[00177] Thus, the disclosure includes various pharmaceutical compositions useful for treating a cell proliferative disorder. The pharmaceutical compositions according to the disclosure are prepared by bringing a retroviral vector containing a heterologous polynucleotide sequence useful in treating or modulating a cell proliferative disorder according to the disclosure into a form suitable for administration to a subject using carriers, excipients and additives or auxiliaries. Frequently used carriers or auxiliaries include magnesium carbonate, titanium dioxide, lactose,

mannitol and other sugars, talc, milk protein, gelatin, starch, vitamins, cellulose and its derivatives, animal and vegetable oils, polyethylene glycols and solvents, such as sterile water, alcohols, glycerol and polyhydric alcohols. Intravenous vehicles include fluid and nutrient replenishers. Preservatives include antimicrobial, anti-oxidants, chelating agents and inert gases. Other pharmaceutically acceptable carriers include aqueous solutions, non-toxic excipients, including salts, preservatives, buffers and the like, as described, for instance, in Remington's Pharmaceutical Sciences, 15th ed. Easton: Mack Publishing Co., 1405-1412, 1461-1487 (1975) and The National Formulary XIV., 14th ed. Washington: American Pharmaceutical Association (1975), the contents of which are hereby incorporated by reference. The pH and exact concentration of the various components of the pharmaceutical composition are adjusted according to routine skills in the art. See Goodman and Gilman's The Pharmacological Basis for Therapeutics (7th ed.).

[00178] For example, and not by way of limitation, a retroviral vector useful in treating a cell proliferative disorder will include an amphotropic ENV protein, GAG, and POL proteins, a promoter sequence in the U3 region retroviral genome, and all cis-acting sequence necessary for replication, packaging and integration of the retroviral genome into the target cell.

[00179] As described above, the disclosure provides a host cells (e.g., a 293 cells or HT1080 cells) that are transduced (transformed or transfected) with a vector provided herein. The vector may be, for example, a plasmid (e.g., as used with 293T cells), a viral particle (as used with HT1080 cells), a phage, etc. The host cells can be cultured in conventional nutrient media modified as appropriate for activating promoters, selecting transformants, or amplifying a coding polynucleotide. Culture conditions, such as temperature, pH and the like, are those previously used with the host cell selected for expression, and will be apparent to those skilled in the art and in the references cited herein, including, e.g., Sambrook, Ausubel and Berger, as well as e.g., Freshney (1994) Culture of Animal Cells: A Manual of Basic Technique, 3rd ed. (Wiley-Liss, New York) and the references cited therein.

[00180] In one embodiment of the disclosure, a producer cell produces replication competent retroviral vectors having increased stability relative to retroviral vectors made by conventional transient transfection techniques. Such increased stability during production, infection and replication is important for the treatment of cell proliferative disorders. The combination of transduction efficiency, transgene stability and target selectivity is provided by the replication competent retrovirus. The compositions and methods provide insert stability and maintains transcription activity of the transgene and the translational viability of the encoded polypeptide.

[00181] The following examples are meant to further illustrate the invention and are not meant to limit the broader disclosure above.

EXAMPLES

[00182] AC3-yCD2 ("V" viral particle) was produced from a HT1080+T5.0002 producer line derived from the HT1080 human fibrosarcoma cell line (ATCC, Catalog# CCL-121) obtained directly from the American Type Culture Collection (P.O. Box 1549, Manassas, VA).

[00183] The cell line HT1080+T5.0002 was expanded to create a pre-bank and a subsequent master cell bank (MCB). The MCB was used to produce clinical lots. The flow diagram for generating the pre-bank and the master cell bank is shown in Figure 1.

[00184] The Toca511 viral vector is encoded by a plasmid (pAC3-yCD2; a.k.a. T5.0002) consisting of 11,893 base pairs of nucleotides. Diagram 1 below provides a restriction enzyme map of the total construct of the pAC3-yCD2 plasmid along with the sequence location of the certain genetic elements.

[00185] **General scheme for making stable expression producer cell lines making replication competent vector AC3-yCD2(V).** The vector producer cell line "HT1080+T5.0002", was produced by transducing naïve HT1080 cells with AC3-yCD2 virus produced transiently in 293T cells by transfection (See Figure 1). The transient transfection used to produce AC3-yCD2 (viral particles) was performed using the GLP sequenced "qualified plasmid stock". More specifically, transiently produced AC3-yCD2 vector was harvested after 48 hours post transfection and filtered through a 0.45 um filter with 0.8 mL

of filtered supernatant used to transduce a 75% confluent culture of HT1080 cells containing 15 mL of media. This infection volume converted to an approximate transduction dose of about 0.1 transduction unit (TU) per cell. The transduction was allowed to spread throughout the culture for 9 days with cells refed or passaged every 2-4 days prior to freezing down the initial Pre-Bank stock consisting of 12 vials with each vial containing approximately 5×10^6 cells per vial. The freezing media included 10% DMSO, USP (Cryoserv, Bioniche Pharma USA, LLC, Lake Forest, IL) and 90% gamma-irradiated fetal bovine serum (Hyclone Laboratories, Inc, Logan Utah). Cells were frozen in a -80°C freezer and then transferred to a liquid nitrogen freezer under vapor phase conditions the following day. The media used for growing HT1080+T5.0002 cells to produce the vector comprises a defined DMEM media, GlutaMax (L-glutamine substitute), non-essential amino acids (NEAA), and Defined Fetal Bovine Serum (FBS).

[00186] The 293T cell line was developed from HEK (Human Embryonic Kidney) 293 cells and was originally described in 1987 (Dubridge 1987). The cell line was developed by transfecting a temperature sensitive SV40 T-antigen mutant, tsA1609 (Dubridge 1987), into HEK 293 cells (Graham 1977). The 293T cells are more susceptible to transfection than the original HEK 293 cell line. Because of their higher transfectability, 293T cells have commonly been used to produce high titer vectors by transient transfection (Yang et al. Hum. Gene Ther.10:123-132 1999).

[00187] **Example 2: Preparation of vector from HT1080+T5.0002 stable expression producer line as an adherent line with fetal calf serum.** HT1080+T5.0002 cells are grown in disposable multilayered cell culture vessels (Cell Stack, Corning). Production of the crude Toca 511 retroviral vector is performed by harvesting the conditioned media from confluent cultures of HT1080+T5.0002 cells harvested every 10-24 hour period over 2-4 harvest cycles using a manual fed batch process using multiple Cell Stacks containing approximately 1.2 L of conditioned media each. Crude TOCA 511 retroviral vector is harvested directly into 10 - 20L process bags and stored at $2-8^{\circ}\text{C}$ until approximately 40L of material is collected. Sample of the combined crude pool harvest used for PTC

mycoplasma, in vitro viral testing, bioburden, informational PCR titering and retentions.

[00188] The crude vector material is clarified by passing through a 0.45 micron filter cartridge and treated with Benzonase to digest host cell genomic DNA. The clarified and DNA digested TOCA 511 vector is then captured and concentrated using anion exchange (AEX) chromatography. The eluted concentrated bulk product then undergoes a buffer exchange and purification step using size exclusion (SEC) chromatography. The formulation buffer comprises Tris-based formulation buffer containing sodium chloride, sucrose, mannitol, ascorbate, ascorbic acid and human serum albumin. The formulated bulk is 0.2 um filtered to insure sterility, sampled for testing and then divided in multiple containers as bulk material stored frozen below (<) -65°C.

[00189] The vector produced from HT1080+T5.0002 cells was tested on naïve PC3 (human prostate adenocarcinoma) or U-87 cells (human glioblastoma-astrocytoma), depending on the test. These tests included; (1) transfer of CD (cytosine deaminase) protein expression by Western analysis, (2) functional CD activity of the CD protein to convert 5-FC to 5-FU by HPLC analysis, as well as, (3) measuring the ability for 5-FC to kill U-87 cells (MTS assay) transduced with AC3-yCD2 (V).

[00190] **Example 3: Construction of vectors encoding cytosine deaminase, Green fluorescent protein (GFP), mouse gamma Interferon (IFN) and other proteins or nucleic acids.** These replicating retroviral vectors were constructed as previously described in WO 2010/036986. Table 1 describing the nature of some of these vectors is included below.

Table 1: Vector constructs and names

Ref. Code	Reference name	Original Name	5'LTR Prom	Envelope	Vector	IRES	Trans-gene	3'LTR
T5.0000	pACE-yCD	pACE-CD (Tai et al. 2005)	CMV	Ampho (4070A)	pACE	EMCV	Wt yeast CD	MLV U3
T5.0001	pAC3-yCD1	CDopt sequence	CMV	Ampho (4070A)	pAC3	EMCV	modified CD	MLV U3
T5.0002	pAC3-yCD2	CDopt+3pt	CMV	Ampho (4070A)	pAC3	EMCV	Modif-ied CD	MLV U3
T5.0006	pAC3-eGFP	pAC3-emd, pAC3GFP	CMV	Ampho (4070A)	pAC3	EMCV	Emerald GFP	MLV U3

T5.0007	pAC3-yCD	pAC3-yCD	CMV	Ampho (4070A)	pAC3	EMCV	Wt yeast CD	MLV U3
	pAC3-mIFNg	pAC3-mIFNg	CMV	Ampho (4070A)	pAC3	EMCV	Mouse Gamma IFN	MLV U3
	pAC3-hIFNg	pAC3-hIFNg	CMV	Ampho (4070A)	pAC3	EMCV	Human Gamma IFN	MLV U3

[00191] Other vectors that can be produced using the cell lines and methods described in this application, are also described in WO 2010/036986. These include vectors encoding single chain antibodies, IL-2, miRNA's and siRNA's under the control of a pol III promoter, and siRNA target sequences.

[00192] **Example 4: Quantitative PCR titering assay.** The functional vector concentration, or titer, is determined using a quantitative PCR-based (qPCR) method. In this method, vector is titered by infecting a transducible host cell line (e.g. PC-3 human prostatic carcinoma cells, ATCC Cat# CRL-1435) with a standard volume of vector and measuring the resulting amount of provirus present within the host cells after transduction. The cells and vector are incubated under standard culturing condition (37 °C, 5% CO₂) for 24 hr to allow for complete infection prior to the addition of the anti-retroviral AZT to stop vector replication. Next, the cells are harvested from the culture dish and the genomic DNA (gDNA) is purified using an Invitrogen Purelink gDNA purification kit and eluted from the purification column with sterile RNase-/DNase-free water. The A₂₆₀/A₂₈₀ absorbance ratio is measured on a spectrophotometer to determine the concentration and relative purity of the sample. The gDNA concentrations are normalized with additional RNase-/DNase-free water to the lowest concentration of any given set of gDNA preparations such that the input DNA for the qPCR is constant for all samples analyzed. Genomic DNA purity is further assessed by electrophoresis of an aliquot of each sample on an ethidium bromide stained 0.8% agarose gel. If the sample passes an A₂₆₀/A₂₈₀ absorbance range of 1.8-2.0 and shows a single band of gDNA, then the sample is ready for qPCR analysis of provirus copy number of the vector. Using primers that interrogate the LTR region of the provirus (reverse-transcribed vector DNA and vector DNA that is integrated into the host gDNA), qPCR is performed to estimate the total number of transduction events that occurred when the known

volume of vector was used to transduce the known number of cells. The number of transduction events per reaction is calculated from a standard curve that utilizes a target-carrying plasmid of known copy-number that is serially diluted from 10^7 to 10 copies and measured under identical qPCR conditions as the samples. Knowing how many genomic equivalents were used for each qPCR reaction (from the concentration previously determined) and how many transduction events that occurred per reaction, we determine the total number of transduction events that occurred based on the total number of cells that were present at the time of transduction. This value is the titer of the vector after dilution into the medium containing the cells during the initial transduction. To calculate the corrected titer value, the dilution is corrected for by multiplying through by the volume of culture and the volume of titer divided by the volume of titer. These experiments are performed in replicate cultures and analyzed by qPCR using triplicate measurements for each condition to determine an average titer and with its associated standard deviation and coefficient of variance.

[00193] **Example 5: Potency assay for vectors encoding cytosine deaminase.** This assay assesses cell samples for cytosine deaminase activity 4 days post-transduction and measures both the replicative capacity of the vector and the corresponding cytosine deaminase activity. U-87 cells were grown in 96 well plates and transduced with a dilution series of virus (up to 12 dilutions at half log intervals). 5-Fluorocytosine was added to cells for one hour, the reaction was stopped by addition of 10% trichloroacetic acid and the resulting filtered mixture analyzed by HPLC for cytosine deaminase activity by measuring the 5-fluorouracil produced. The HPLC assay was performed on a Shimadzu LC20AT unit connected in series with a photoarray detector and autoinjector. The HPLC method used a Hypersil BDS C18 column run isocratically at 1 mL/min with 95% Buffer A: 50mM ammonium phosphate containing 0.1% tetra-n-butylammonium perchlorate with pH adjustment of the buffer to 2.1 with phosphoric acid and 5% Solvent B: 100% methanol. The run time was 6 minutes. The photodiode detector array scans from 190 to 350nm with chromatograms selected to display absorbance at 264 nm for 5-fluorouracil. The Browser function is used to transfer data in a

bulk report with the 5-fluorouracil retention time and area at 264 nm and the 5-fluorocytosine retention time and area at 285 nm reported. Peak area is then plotted against inputted dilution to generate a 4-parameter curve fit and the EC50 values of the test sample is compared to an in-house Reference Vector (See Figure 10 and Figure 11 for examples of these plots).

[00194] **Example 6: Vector Purification and concentration.** Vectors of the disclosure were manufactured by transient transfection on 293T cells, or from a producer cell pool, or from a cloned producer cell line. The medium can be with serum or serum free, and the cells can be grown as adherent cells or in suspension, normally in perfusion mode. The medium was harvested, and when made from the stable producer cell lines, stored for up to 2 weeks at 2-8 degrees centigrade. Vector from the stable cell lines had a half life at 2-8 degrees C that is greater than 7 days, while this is not true for material made from transient transfection. This bulk harvest was then filtered through a 0.45 micron filter cartridge, treated with benzonase (L.Shastry et al Hum Gene Ther 15:221 2004) and further chromatography column steps.. (see, e.g., US5792643; T. Rodriguez et al. J Gene Med 9:233 2007; P.Sheridan et al Mol.Ther. 2:262-275 2000). The vector preparations were loaded on an anion exchange column and the vector eluted in a NaCl gradient. The fraction containing vector was initially identified using the PCR assay (example 4), and subsequently by A260, and positive fractions collected and pooled. The preparation was then loaded on a size exclusion column (SEC) to remove salt and other remaining contaminants. The SEC is eluted with formulation buffer and the vector fraction on the SEC column was collected from the void volume, and tested as bulk material for titer. It was then filtered through 0.2 micron filters and 0.8 to 3ml aliquoted into vials. Clinical material is released based on standard testing such as sterility, mycoplasma and endotoxins, plus product specific potency (example 5, Figs 10 & 11), strength (example 4), and identity testing. Titer is determined as Transducing Units (TU) by PCR quantitation of integrated viral vector DNA in target cells (Example 4). The final product is targeted to have a titer of up to 10^9 TU/ml

formulated in isotonic Tris-buffered sucrose solution, as a sterile injectable.

[00195] In general, to accurately and precisely determine the strength of vector lots, a quantitative PCR-based titer assay has been developed (described in general terms in example 4). The details of the assay procedure consist of the following steps:

[00196] **Transduction.** Transductions are performed in a 12-well plate format using the stable human prostate adenocarcinoma derived PC-3 cell line. For each test sample, three dilutions of un-titered vector preparation are used to transduce PC-3 cells in triplicate wells. Viral replication is stopped 24 hours post-transduction with azidothymidine (AZT). Cells are maintained for an additional 24 -64 hours prior to harvesting and genomic DNA purification.

[00197] **Example 8: Cloning of a Non-Clonal Pool of Infected HT1080 Cells.** *Dilution Seeding.* Pre-warm media and Multiple 96 well cell culture plates were labelled in order to identify the clone based on the plate and well position and the wells were filled with prewarmed media containing single cell suspension of the HT1080. An early passage of 100% infected HT1080 cells was harvested by trypsinizing and creating a single cell suspension consisting of 1 cell per 600 microL. 200 microL was delivered into each well of a 96 well plate in order to seed approximately 0.3 cells per well. In performing this procedure, a majority of the wells received either 0, 1 or 2 cells per well. Cells were allowed to attach for approximately 4 hours and each well examined to eliminate wells that have received more than 1 cell per well or are empty.

[00198] *Clone Propagation.* The wells that initially contained 1 cell per well were cultured by replacing $\frac{1}{2}$ of the media (approximately 100 μ L) with fresh 100 microL every 3-4 days for every well. Accidental transfer of cells from one well to another was avoided by replacing the tip used to feed each well during media replacement. Full media replacement was required as cells started to approach confluence in the well. Once the cells reached confluence, each clonal candidate was pasaged to a well of a 48 well plate to continue expansion. Each clone was propagated and passed to a well of a 6 well plate, followed by a T-25 flask, followed by T-75 flask each time the cells reached confluence. Once the clonal

cells reached confluence in a T-75 flask, at least 2-3 vials of cryopreserved cells containing $1-2 \times 10^6$ cells per vial were prepared.

[00199] *Clone Selection Based on Performance.* Once the clone candidates were frozen down, cell culture experiments were performed to identify the best performing clone and back up clones based on titer production performance and ideal cell culture attributes. The best clone was chosen based on (1) the ability of the clone to provide the highest sustained titers over 2-4 subsequent days with daily media replacement [See Figure 12 and Table 2, below]; (2) the ability of the virus produced to transfer expression of the desired gene of interest to a naïve cell (See Figures 10 and 11); (3) the ability of the clone to divide reasonably having a doubling time between 18 - 30 hours and ability to reach 100% confluence as a uniform lawn of cells with minimal cell detachment upon reaching confluence.

[00200] **Example 9: Infection of D-17 and Cf2-Th Cell Lines to Make a Non-Clonal Pool and Subsequent Clonal Vector Producer Cell Line Candidates.** To produce D-17 (canine osteosarcoma; ATCC # CCL-183) and Cf2-Th (canine thymus; ATCC # CRL-1430) cell line vector producer pools and dilution clones that express MLV replication competent retroviral vector, the exact same methods described above for HT-1080 cells were used to create D-17 and Cf2-Th cell lines. Results are shown in Table 2 below

Table 2: Data to Support Creation of Producer Pools and Subsequent Dilution Clones of HT-1080, D-17 and Cf2-Th Replication Competent Retroviral Vectors

Cell Line Vector Producing Cell Line	MLV Replication Competent Vector Expressed	Parental Cell Line	Titer Sample	Titers Observed (TU/mL)*
HT1080+T5.0002 (Non-Clonal Pool)	AC3-yCD2	HT-1080	HT+T5.0002, Day 2 HT+T5.0002, Day 3 HT+T5.0002, Day 4 HT+T5.0002, Day 5.5	1.56E+06 2.23E+06 1.90E+07 2.57E+07
HT5.yCD2.128A (Dilution Clone)	AC3-yCD2	HT-1080	Clone 12-8, Day 0 Clone 12-8, Day 1 Clone 12-8, Day 2 Clone 12-8, Day 3	5.26E+06 7.94E+06 1.00E+07 1.02E+07
D17+T5.0002 (Non-Clonal Pool)	AC3-yCD2	D-17	D17+T5.0002, Day 2 D17+T5.0002, Day 3 D17+T5.0002, Day 4 D17+T5.0002, Day 5.5	4.20E+06 3.83E+06 4.87E+06 1.39E+06
D5.yCD2.1G7A (Dilution Clone)	AC3-yCD2	D-17	D5.yCD2.1G7A , Day 1 D5.yCD2.1G7A , Day 2 D5.yCD2.1G7A , Day 3	1.78E+06 2.54E+06 4.24E+06
CF2+T5.0002 (Non-Clonal Pool)	AC3-yCD2	Cf2-Th	CF2+T5.0002, Day 2 CF2+T5.0002, Day 3 CF2+T5.0002, Day 4 CF2+T5.0002, Day 5.5	4.17E+04 6.97E+03 4.97E+06 3.14E+06
CF5.yCD2.3A12A (Dilution Clone)	AC3-yCD2	Cf2-Th	CF5.yCD2.3A12A , Day 1 CF5.yCD2.3A12A, Day 2 CF5.yCD2.3A12A, Day 3	1.81E+07 2.68E+07 3.78E+06

*TU/mL indicates transduction units per mL as determined by quantitative qPCR methods to determine copy number of integrated proviral MLV genomes post transduction into a titrating naïve U-87 cell line.

[00201] **Example 10: Testing Infectivity and transfer of express of Replication Competent Retroviral Vector Produced from Infected Cf2-Th cells with T5.0006 (GFP expressing replication competent vector).** An evaluation was performed with the replication competent retroviral vector, T5.0006(V), encoding the gene for green fluorescent protein (GFP) to evaluate the vector's ability to infect and propagate in canine derived tumor cell lines. For this study, three canine glioblastoma cell lines , J3T-bg, SDT-3G and G06-A were received from the laboratory of Dr. Peter Dickinson (University of California, Davis; Vet Med Surgery and Radiological Sciences). All three of these cell lines were originally derived from spontaneous glioma explants and were within 8-14 passages of the original

isolates. To test viral infectivity, 0.1 mL of 0.45micron filtered T5.0006(V) viral supernatants were placed into triplicate 2 mL cultures containing 4.4×10^5 cells of each tumor type in 6-well culture plates with the exception of SDT-3G which was at 1.9×10^4 cells. Triplicate plates were prepared, one plate for each time point. To track infectivity, one plate with triplicate infections, and non-infected control wells, was harvested at days 1, 3 and 6 to perform FACs analysis for the presence of GFP fluorescence to determine the percentage of infected cells at each day post infection. The inoculating T5.0006 viral supernatant was derived from internal infected cultures of Cf2-Th stable producer cells made as described above and characterized for titer of virus produced.

[00202] *Cf2-Th+T5.0006 producer line and T5.0006(V) Virus:* A culture of Cf2-Th cells, was previously infected with transiently produced T5.0006(V) virus generated by transfecting the plasmid pAC3-emd (aka pT5.0006) into 293T cells using standard calcium phosphate transfection procedures. After several passages and on the day of infection of the three canine glioma tumor cells lines, fresh viral supernatants were collected from a confluent infected Cf2-Th culture and passed through a 0.45 micron syringe filter to remove any viable infected Cf2-Th cells.

[00203] *Infection of the three canine glioblastoma cell lines and the positive control HT-1080 cell line:* The three canine glioblastoma cell lines: J3Tbg, SDT-3G and G06-A, were received as cryopreserved cells on Nov. 20, 2008 from the laboratory of Dr. Peter Dickinson, University of California, Davis; Vet Med Surgery and Radiological Sciences. All three of these cell lines were originally derived from spontaneous gliomas and were within 8-14 passages of the original isolates as indicated in the documentation attached with the receipt of the frozen vials. The HT1080 positive control cell line was derived from in-house frozen stocks originally sourced from ATCC (CCL-121; Lot 6805248).

[00204] One vial was thawed of each cell line and cultured for several passages in DMEM media supplemented with 10% fetal bovine serum and 200 mM Glutamax and incubated at 37 C under 5% CO₂ conditions. One day prior to infecting the cells, one 6 well plate was seeded with 5×10^4 cells/cm² (4.4×10^5 cells/well) for each tumor cell

line in 2 mL of fresh complete DMEM media with the exception of the SDT-3G plates which were prepared at 1.9×10^4 cells/well. The positive control HT1080 cultures were seeded 3.5 hours before the addition of virus on the same day of the tumor cell line viral infections. Viral infections were performed by adding 0.1 mL of filtered T5.0006(V) to three wells out of each 6 well plate leaving three uninfected wells to serve as negative controls for FACS analysis. After infection, the plates were returned to the 37 C incubator. Triplicate plates were prepared for each cell line.

[00205] At 1, 3 and 6 days post infection, triplicate wells from each infected and non-infected cell line were harvested using trypzean reagent (Sigma-Aldrich), were washed in complete media and then fixed with 1% paraformaldehyde in PBS with 2% FBS and 0.09% sodium azide and stored refrigerated in the dark or on ice until subjected to FACS analysis. Note that the remaining cultures after the day 3 harvest point were passaged on day 3.

[00206] *FACS Analysis:* All paraformaldehyde fixed cells were analyzed on a BD LSRII FACS machine located at Sidney Kimmel Cancer Center (SN H47200068) with analysis using BD FACS Diva Software Version 5.0.1. HT1080 and HT1080 100% GFP infected cells from a previous infection were used to set the gating. Each sample was read once.

[00207] Table 3 demonstrates the average results of the triplicate readings of the percent infected cells after 1, 3 and 6 days post infection. Figure 13 shows the graphical representation of the data. The data suggests that each canine tumor line infected with T5.0006(V) demonstrated some level of GFP expression above background negative controls however differences in viral spread kinetics were observed between the different tumor cell lines. The G06-A tumor line demonstrated 94.5% GFP positivity 6 days post infection followed by J3T-bg and SDT-3G demonstrating 81.2% and 30.9% GFP positivity at the same harvest point respectively. All controls were valid with uninfected controls showing insignificant background levels of GFP expression and the HT1080 permissive positive control cell line demonstrating 73.4% GFP positivity by day 3 post infection (Day 6 samples were lost). In similar past

experiments, using the same conditions, the human U87 glioma line becomes 80-90% GFP positive.

Table 3. Summary of Percent Positive Cells for GFP Expression on Three Canine Glioma Cell Lines after Infection with T5.0006 (GFP) Vector

Days Post Infection	J3T-bg uninfected (% GFP Positive)	J3T-bg +T5.0006 (% GFP Positive)	G06-A uninfected (% GFP Positive)	G06-A +T5.0006 (% GFP Positive)	SDT-3G uninfected (% GFP Positive)	SDT-3G+T5.0006 (% GFP Positive)	HT1080 uninfected (% GFP Positive)	HT1080 +T5.0006 (% GFP Positive)
1 Day	0.8	0.7	0.0	13.8	0.3	1.6	0.3	2.5
3 Day	0.5	13.4	0.1	61.8	0.3	8.1	0.0	73.4
6 Day	0.3	81.2	6.2	94.5	2.2	30.9	lost	lost

lost = test sample lost

[00208] **Example 11: Adaptation of HT-1080 Replication Competent**

MLV Viral Vector Producer Cell Line from Serum and Adherence

Dependence to a Serum Free Suspension Culture. The serum free adaptation process was performed after screening and identification of suitable dilution clone of HT-1080 replication competent vector producing cell line. The serum free adaptation process can also be performed with a non-clonal vector producing HT1080 cell line. The adaptation process was initiated by seeding approximately 2×10^7 cells into a 125 mL shaker flask containing 10 mL of 5% serum containing conditioned media and 10 mL of a selected serum free media of choice, resulting into a reduced serum concentration of 2.5%. In this case the serum free media was FreeStyle 293 Expression Media distributed through Invitrogen Corp, Carlsbad, CA, The culture was placed on a shaking platform located in a tissue culture incubator with both temperature and CO₂ gas control. The shaking platform was set to a preferred 80 RPM and the incubator is set to a preferred 37°C and a preferred 5% CO₂ conditions. Every 3-7 days, the culture was re-fed by collecting cells that are in suspension and reseeded into a new shaker flask containing 10 mL of the same initial conditioned media and 10 mL of fresh serum free media maintaining a level of serum of approximately 2.5%. The culture was examined at each re-feeding event with viable cell counts performed as needed to check for cell propagation. When the cells showed evidence of growth based on cell doubling or glucose consumption, a serum concentration of 1.67% was then targeted by adjusting the volume amount of condition media and fresh serum free media. The culture again was examined and refed every 3- 7 days.

When the cells show evidence of growth, a serum concentration of 1.25% was targeted by again adjusting the volume of conditioned media and fresh serum free media. This process was continued targeting subsequent serum conditions of 1.0%, 0.9%, 0.83% serum conditions until the cells were in 100% serum free conditions. During this adaptation process the cell culture was expanded to approximately 200 mL volume in a 1,000 mL shaking flask targeting a minimal viable culture of approximately 0.5 to 1.0×10^6 cell/mL. Once the cells reached 100% serum free conditions, the cells were continuously passaged under serum free conditions isolating single suspended cells by allowing heavier clumping cells to settle for short periods of time without agitation. Once the culture consists of approximately 95% population of the single cell suspension consistently, the culture could be frozen in cryopreservation media consisting of 10% DMSO and 90% serum free media using standard mammalian cell freezing conditions.

[00209] **Example 12: Vector made from stable producer cell lines is more stable than vector made by transient transfection in long term storage.** *Vector production by transient transfection.* Crude supernatant containing replication competent MLV virus encoding either the gene for cytosine deaminase or the gene for green fluorescent protein were produced by two transient transfection methods. The first method used the standard calcium phosphate transfection procedure described by Graham and van der Eb using 293T cells which have commonly been used to produce high titer vectors as originally described by Yang 1999. The second transfection method used the commercially available proprietary transfecting reagent (Fugene) distributed by Promega (Madison, WI). Forty-eight hours after transfection, viral supernatants were filtered using a 0.2 or 0.45 micron filter, with aliquots frozen and stored at temperatures $\leq -65^{\circ}\text{C}$. The frozen clarified supernatants were titered by the quantitative qPCR method to establish an initial concentration of infectious titer. Subsequent testing of the titer on various dates revealed that the viral preparations were not stable and lost at least one log of titer as rapidly as 14 days as tested by the same quantitative qPCR method (See Table 4).

[00210] Vector production from stable lines. To compare this stability profile against replication competent MLV virus produced from stably infected HT-1080 cells, T5.0002 viral preparations were produced as described in the previous example and subsequently purified and formulated in a Tris sodium chloride isotonic buffer containing 10 mg/mL of sucrose and 1 mg/mL of human serum albumin. The specific T5.0002 lots used in this stability study are lots T003-002-40L, M100-09, M101-09 and M102-09 with the last three lots produced under good manufacturing practices (GMP). To evaluate stability of the virus, procedures used to address (1) infectious titer; and (2) transfer of expression in naïve cells.

[00211] Storage. Both undiluted and 1/100 diluted doses of T5.0002 from lot T003-002-40L were pulled from $\leq -65^{\circ}\text{C}$ long term storage conditions with vials subsequently thawed at 3, 6 and 12 months post-vialing and tested within the following assays: Strength, Potency, and TCID50.

Table 4. Various Replication Competent MLV Virus Produced by Transient Transfection

<i>Replication MLVirus Description</i>	<i>Parental Cell Line (Transfection Method)</i>	<i>Sample ID</i>	<i>qPCR Titer (TU/mL)</i>
T5.0002	293T (Calcium Phosphate)	051508-RCR-2	3.2×10^7
T5.0002	293T (Calcium Phosphate)	051508-RCR-2	1.4×10^6
T5.0002	293T (Calcium Phosphate)	CS003 (2-D3-IN-080108-CS)	1.3×10^6
T5.0002	293T (Calcium Phosphate)	CS003 (2-D3-IN-080108-CS)	2.4×10^4
T5.0006 ⁽²⁾	HT-1080 (Fugene)	HT1080-D4-102508	2.3×10^6
T5.0006	HT-1080 (Fugene)	HT1080-D4-102508	2.8×10^3
T5.0006	293T (Fugene)	293T-D2-102308	2.6×10^6
T5.0006	293T (Fugene)	293T-D2-102308	2.3×10^3

[00212] GMP produced lots M100-09, M101-09 and M102-09 were prepared from the HT1080+T5.0002 stable producer cell line purified and stored at $\leq -65^{\circ}\text{C}$ since preparation. Vials were pulled and thawed at 3, and 6 months post-vialing and tested within the

following assays: Strength, Potency, TCID₅₀, pH, osmolality and appearance.

[00213] *Infectious titer by Quantitative qPCR.* No decrease in titer is observed for purified viral vector produced from the stably infected HT-1080 cell line when stored at $\leq -65^{\circ}\text{C}$ for up to 12 months for all lots tested. Tables 5 and 6 show the measured titers for Lot T003-002-40L (Table 5) and GMP lots (Table 6). Figure 14 shows the generated titer trend over 12 months for all lots tested.

Table 5. Measured titers of the development lots T003-002-40L (Undiluted and 1/100) at Release, and 3, 6 and 12 months stored $\leq -65^{\circ}\text{C}$.

T003-002-40L	Release	3M	6M	12M
	TU/mL			
Undiluted	1.14E+08	1.73E+08	1.09E+08	2.71E+08
1/100	1.08E+06	2.79E+06	1.66E+06	3.82E+06

Table 6. Measured titers of Clinical lots M100-09 (High Dose), M101-09 (Mid Dose) and M102-09 (Low Dose) at Release, and 3 and 6 months stored at $\leq -65^{\circ}\text{C}$.

	Release	3M	6M	1X F/T*
	TU/mL			
M100-09	1.90E+08	1.00E+08	2.49E+08	2.38E+08
M101-09	2.00E+07	1.08E+07	3.52E+07	3.56E+07
M102-09	2.70E+06	1.22E+06	4.15E+06	4.01E+06

* Vials were thawed at the 3M timepoint, re-frozen at $\leq -65^{\circ}\text{C}$ and tested with the 6M samples.

[00214] *Transfer of Biological Expression Assay using Cell Culture and HPLC Analysis to Evaluate Stability of Viral Vector Stored $\leq -65^{\circ}\text{C}$.* Vector stability was assessed by measuring the vector's ability to infect a naïve cell type under various dilutions and test the ability to convert 5-fluorocytosine (5-FC) to 5-fluorouracil (5-FU) from the transfer of the cytosine deaminase gene from the viral vector to the naïve infected cell. The conversion of 5-FC to 5-FU is quantitated by HPLC with the raw data processed utilizing a non-linear regression of the transformed dilution values. Both doses (undiluted and 1/100 diluted samples) from Lot T003-002-40L show no decrease in transfer of expression capability when stored at $\leq -65^{\circ}\text{C}$ for up to 12 months. Both T003-002-40L (undiluted) and M100-09 generated a dose curve comparable to the

current reference Vector. M101-09 generated the expected curve at 1/10 of the undiluted vector (M100-09). T003-002-40L (1/100) and M102-09 generated the expected curve at 1/100 of their undiluted vector, respectively. Figures 10 and 11 show the 5-FC conversion dose response for lot s T003-002-40L (Figure 10) and GMP lots (Figure 11) at the last time point tested.

[00215] *TCID₅₀ assay on vector lots.* Vector stability was assessed by measuring the vector's ability to infect a naïve cell type by calculating the infectious dose at which 50% of the cells would be infected under tissue culture conditions (TCID₅₀). The method used to determine if a cell was infected was determined by PCR detection. In this evaluation, no observed decrease in infectivity was observed based on the TCID₅₀ when stored at ≤-65°C for up to 12 months for all lots tested within the current variability of the assay (%CV of Reference Vector over 8 assays was 45%). Tables 13 and 14 show the measured TCID₅₀/mL value for the lot T003-002-40L (Table 7) and GMP lots (Table 8).

Table 7. TCID₅₀ of Lot T003-002-40L (Undiluted and 1/100) at Release, 3 and 12 months at ≤-65°C

T003-002-40L	Release	3M	12M
	TCID ₅₀ /mL		
Undiluted	2.0E+08	9.0E+07	2.00E+08
1/100	1.3E+06	6.5E+05	7.95E+05

Table 8. TCID₅₀ of GMP Lots M100-09 (High Dose), M101-09 (Mid Dose) and M102-09 (Low Dose) at Release, 3 and 6 months at ≤-65°C

	Release	3M	6M	1X F/T*
	TCID ₅₀ /mL			
M100-09	5.0E+07	5.0E+07	7.9E+07	5.01E+07
M101-09	7.9E+06	1.3E+06	1.3E+07	1.26E+07
M102-09	5.0E+05	5.0E+05	7.9E+05	5.01E+05

* Vials were thawed at the 3M timepoint, re-frozen at ≤-65°C and tested with the 6M samples.

[00216] Based on the above stability data, purified replication competent MLV viral vector produced from a stably infected HT-1080 cells are more stable than the identical vector produced by transient transfection when stored at temperatures of ≤-65°C.

[00217] **Example 13: T5.0002 vector made from an HT1080 clone and produced from suspension serum free cultures is as potent as vector made from the adherent HT1080+T5.0002 line in medium with fetal calf serum, in a mouse tumor model.** Vector was prepared from one of the serum free suspension clones and from the HT1080+T5.0002 cell line, and purified and processed as described in example 6.

[00218] In separate experiments these vector preparations were used to treat a mouse glioma tumor model - Tu2449 in B6C3F1 mice (H M. Smilowitz J Neurosurg 106:652-659, 2007), Mice were implanted intracranially with the tumor and four days later ascending doses of vector (10^4 , 10^5 Tu/g brain) were administered to cohorts of 10 animals for both vector preparations. At day 13 5-FC dosing was carried by twice daily ip injections (500mg/kg BID) for four days, and the 5-FC treatment then carried out non a schedule of 10 days off 4 days on. Kaplan-Meyer plots showed that the survival with the material from the cloned line was at least as good as that from the HT1080+T5.0002 line. Both showed 80-90 survival in the 10^5 Tu groups past day 100 while controls had a median survival of around 30 days.

[00219] **Example 14: Use of purified vector encoding mouse gamma interferon as a therapy in a syngeneic mouse cancer model.** The objective of this study was to assess the effectiveness Toca 511 (encoding yCD2) and Toca 621 (encoding mouse gamma interferon) in the S91/BALB/c model by evaluating the spread of novel MLV based retroviral vectors in mouse S91 subcutaneous (subQ) tumors in immunocompetent BALB/c mice. Vector was prepared from: 1) HT108+T5.0002 (Toca 511) and is a preparation of a replication-competent retroviral vector carrying the optimized cytosine deaminase gene; 2) HT1080+mIFN a stable producer line of Toca 621, a replication-competent retroviral vector carrying the interferon gamma gene; and 3) HT1080+T5.0006 (GFP Vector) m, were each delivered via intra-tumoral injection (IT).

[00220] **Mice.** Female BALB/c mice (age ~8 weeks) were purchased from Jackson Laboratories. Mice were acclimated for 7 days after arrival.

[00221] **Tumor cells.** S91 Cloudman cells (ATCC, Manassas VA) derived from Clone M-3, a melanin-producing cell line was adapted to cell culture by Y. Yasumura, A.H. Tashjian and G. Sato from a

Cloudman S91 melanoma in a (C X DBA) F1 male mouse. Cells were cultured in Dulbecco's modified Eagles medium with 10% fetal bovine serum, sodium pyruvate, and Glutamax (Hyclone, Logan UT, and Invitrogen, San Diego CA). Cells were resuspended in PBS (Hyclone, Logan UT) for implantation. S91 were injected 1E5 in 200 μ L IV and 1E5 in 100 μ L SQ.

[00222] Four groups of female BALB/c mice (65 mice, ~8 weeks of age) were implanted subQ at their right flank with S91 tumor cells. After the tumors were allowed to grow until they reached approximately 50-125mm³, 3 mice were dosed IT with PBS (Group 1), 10 mice were injected IT with Toca 511 4.7E8/ml (Group 2), 5 mice were injected IT with Toca 621 2.8E8/ml (Group 3), and 6 mice were injected IT with GFP (Group 4) within days 15-19.

Group Assignments

Group	Treatment	N
1	Control: PBS	2
2	Toca 511	10
3	Toca 621	5
4	GFP Vector	6
Total Number of Animals		23

[00223] Vector. Toca 511 and Toca 621 (50 μ L) was injected slowly intratumorally using an insulin syringe.

[00224] Toca 511(encoding the yCD2 cytosine deaminase gene) lot number T511019-FNL was used for all Group 2 animals, and Toca 621 (encoding mouse Interferon Gamma) lot number T621006 SEC was used for all Group 3 animals. This material was produced using the same process used for clinical trial material but it was not made in accordance with cGMP.

[00225] Toca 511 lot number T511019-FNL has a titer of 4.7E8 TU/mL.

[00226] Toca 621 lot number T621006 SEC has a titer of 2.8E8 TU/mL.

[00227] MLV-GFP (T5.0006) is lot number TGFP004-FNL with a titer of 9.0E7 TU/mL.

[00228] Tumors injected with Toca 621 showed a ($p=0.0016$) decrease in tumor growth compared to tumors injected with Toca 511 (Figure 15). One animal from Toca 621 injection cleared the tumor. Further analysis showed that genomes could be detected in some of the Toca 511 and Toca 621 tumors up to 24 days after injection. One of two explants from Toca 621 injected tumors had detectable secretion of IFN γ (18.8pg/mL) by ELISA.

[00229] **Example 15 Rate of GFP viral spread in a U-87 subcutaneous Xenograft model in nude mice, using GFP vector from a stable producer line.** To determine the rate of viral spread based on a single administration of vector $3e5/100\mu\text{L}$ into established U-87 xenografts, by determining the percentage of GFP expressing cells at various time points, in a subcutaneous model of a tumor in nude mice.

[00230] *Study description:* a total of 5 mice (ID# 71 to #75) underwent right and left dorsal flank implantation of $2e6$ U-87 cells administered S.Q on day 0. At day 13 the right dorsal tumor of each mouse was injected with purified T50006 (GFP vector) 3×10^5 TU/ $100\mu\text{L}$ made from an HT1080 producer pool constructed as described above, and purified as described in example YYY. At the same day the animal ID# 71 was sacrificed; animals ID#72, ID#73, ID# 74 and ID# 75 were sacrificed at days 5, 9, 12 and 26 after vector inoculation, respectively. Tumors were removed and processed for FACS analysis of GFP. Results are shown in figure 16 and show a steady increase in the % GFP positive cells over time, indicatring vector spread in this model.

What is claimed is:

1. A retrovirus producing HT1080 cell line that produces a replication competent retrovirus particle, said HT1080 cell line stably expresses a recombinant retroviral genome comprising a *gag* gene, *pol* gene, *env* gene, a heterologous polynucleotide, and retroviral *psi* (Ψ) factor for the assembly of the recombinant retroviral genome, wherein the HT1080 cell line been adapted to being grown and continuously passaged in serum free media and in suspension.

2. The retrovirus producing cell line of claim 1, wherein the replication competent retrovirus comprises:

a retroviral GAG protein;

a retroviral POL protein;

a retroviral envelope;

a retroviral polynucleotide comprising Long-Terminal Repeat (LTR) sequences at the 3' end of the retroviral polynucleotide sequence, a promoter sequence at the 5' end of the retroviral polynucleotide, said promoter being suitable for expression in a mammalian cell, a *gag* nucleic acid domain, a *pol* nucleic acid domain and an *env* nucleic acid domain;

a cassette comprising an internal ribosome entry site (IRES) or regulatory nucleic acid domain operably linked to a heterologous polynucleotide, wherein the cassette is positioned 5' to the 3' LTR and 3' to the *env* nucleic acid domain encoding the retroviral envelope; and

cis-acting sequences necessary for reverse transcription, packaging and integration in a target cell, wherein the RCR maintains higher replication competency after 6 passages compared to a pACE vector.

3. The retrovirus producing cell line of claim 2, wherein the retroviral polynucleotide sequence is derived from murine leukemia virus (MLV), Moloney murine leukemia virus (MoMLV), or Gibbon ape leukemia virus (GALV), murine mammary tumor virus (MuMTV), Rous

Sarcoma Virus (RSV), Gibbon ape leukemia virus (GALV), baboon endogenous virus (BEV), and the feline virus RD114.

4. The retrovirus producing cell line of claim 2 or 3, wherein the MLV is an amphotropic MLV.

5. The retrovirus producing cell line of claim 1, wherein the retrovirus is a gammaretrovirus.

6. The retrovirus producing cell line of claim 2, wherein the promoter sequence is associated with a growth regulatory gene.

7. The retrovirus producing cell line of claim 2, wherein the promoter sequence comprises a tissue-specific promoter sequence.

8. The retrovirus producing cell line of claim 7, wherein the tissue-specific promoter sequence comprises at least one androgen response element (ARE).

9. The retrovirus producing cell line of claim 8, wherein the androgen response element is derived from the probasin promoter.

10. The retrovirus producing cell line of claim 7, wherein the tissue-specific promoter sequence comprises a probasin promoter.

11. The retrovirus producing cell line of claim 2, wherein the promoter comprises a CMV promoter having a sequence as set forth in SEQ ID NO:19, 20 or 22 from nucleotide 1 to nucleotide 582 and may include modification to one or more nucleic acid bases and which is capable of directing and initiating transcription.

12. The retrovirus producing cell line of claim 2, wherein the promoter comprises a sequence as set forth in SEQ ID NO:19, 20 or 22 from nucleotide 1 to nucleotide 582.

13. The retrovirus producing cell line of claim 2, wherein the promoter comprises a CMV-R-U5 domain polynucleotide.

14. The retrovirus producing cell line of claim 13, wherein the CMV-R-U5 domain comprise the immediately early promoter from human cytomegalovirus linked to an MLV R-U5 region.

15. The retrovirus producing cell line of claim 14, wherein the CMV-R-U5 domain polynucleotide comprises a sequence as set forth in SEQ ID NO:19, 20 or 22 from nucleotide 1 to nucleotide 1202 or sequences that are at least 95% identical to a sequence as set forth in SEQ ID NO:19, 20 or 22, wherein the polynucleotide promotes transcription of a nucleic acid molecule operably linked thereto.

16. The retrovirus producing cell line of claim 2, wherein the gag of the polynucleotide is derived from a gammaretrovirus.

17. The retrovirus producing cell line of claim 16, wherein the gag nucleic acid domain comprises a sequence from nucleotide number 1203 to nucleotide 2819 of SEQ ID NO: 19 or 22 or a sequence having at least 95%, 98%, 99% or 99.8% identity thereto.

18. The retrovirus producing cell line of claim 2, wherein the pol domain of the polynucleotide is derived from a gammaretrovirus.

19. The retrovirus producing cell line of claim 18, wherein the pol domain comprises a sequence from nucleotide number 2820 to nucleotide 6358 of SEQ ID NO:19 or 22 or a sequence having at least 95%, 98%, 99% or 99.9% identity thereto.

20. The retrovirus producing cell line of claim 2, wherein the env domain comprises a sequence from nucleotide number 6359 to nucleotide 8323 of SEQ ID NO:19 or 22 or a sequence having at least 95%, 98%, 99% or 99.8% identity thereto.

21. The retrovirus producing cell line of claim 2, wherein the IRES is derived from an encephalomyocarditis virus.

22. The retrovirus producing cell line of claim 21, wherein the IRES comprises a sequence from nucleotide number 8327 to nucleotide 8876 of SEQ ID NO:19 or 22 or a sequence having at least 95%, 98%, or 99% identity thereto.
23. The retrovirus producing cell line of claim 2, wherein the heterologous nucleic acid comprises a polynucleotide having a sequence as set forth in SEQ ID NO:3, 5, 11, 13, 15 or 17.
24. The retrovirus producing cell line of claim 2, wherein the heterologous nucleic acid encodes a polypeptide comprising a sequence as set forth in SEQ ID NO:4.
25. The retrovirus producing cell line of claim 2, wherein the heterologous nucleic acid is human codon optimized and encodes a polypeptide as set forth in SEQ ID NO:4.
26. The retrovirus producing cell line of claim 2, wherein the heterologous nucleic acid comprises a sequence as set forth in SEQ ID NO: 19 or 22 from nucleotide number 8877 to 9353.
27. The retrovirus producing cell line of claim 26, wherein the 3' LTR is derived from an gammaretrovirus.
28. The retrovirus producing cell line of claim 27, wherein the 3' LTR comprises a U3-R-U5 domain.
29. The retrovirus producing cell line of claim 28, wherein the 3' LTR comprises a sequence as set forth in SEQ ID NO:19 or 22 from nucleotide 9405 to 9998 or a sequence that is at least 95%, 98% or 99.5% identical thereto.
30. The retrovirus producing cell line of claim 2, wherein the retroviral polynucleotide comprises a sequence as set forth in SEQ ID NO:19, 20 or 22.

31. The retrovirus producing cell line of claim 2, wherein the heterologous nucleic acid sequence encodes a biological response modifier.

32. The retrovirus producing cell line of claim 31, wherein the biological response modifier comprises an immunopotentiating cytokine.

33. The retrovirus producing cell line of claim 32, wherein the immunopotentiating cytokine is selected from the group consisting of interleukins 1 through 15, interferon, tumor necrosis factor (TNF), and granulocyte-macrophage-colony stimulating factor (GM-CSF).

34. The retrovirus producing cell line of claim 32, wherein the immunopotentiating cytokine is interferon.

35. The retrovirus producing cell line of claim 34, wherein the interferon is gamma interferon.

36. The retrovirus producing cell line of claim 2, wherein the heterologous nucleic acid encodes a polypeptide that converts a nontoxic prodrug in to a toxic drug.

37. The retrovirus producing cell line of claim 36, wherein the polypeptide that converts a nontoxic prodrug in to a toxic drug is thymidine kinase, purine nucleoside phosphorylase (PNP), or cytosine deaminase.

38. The retrovirus producing cell line of claim 2, wherein the heterologous nucleic acid sequence encodes targeting moiety.

39. The retrovirus producing cell line of claim 38, wherein the targeting moiety comprises a cancer antigen.

40. The retrovirus producing cell line of claim 2, wherein the heterologous nucleic acid sequence encodes a binding domain.

41. The retrovirus producing cell line of claim 40, wherein the binding domain comprises a receptor domain, an antibody, or antibody fragment.

42. The retrovirus producing cell line of claim 2, wherein the heterologous nucleic acid sequence comprises an inhibitory polynucleotide.

43. The retrovirus producing cell line of claim 42, wherein the inhibitory polynucleotide comprises an RNAi or siRNA sequence and wherein the regulatory nucleic acid domain is a promoter.

44. A method of producing the retrovirus producing HT1080 cell line of claim 1 comprising:

- transforming a 293 cell line with a plasmid encoding a retroviral vector comprising from 5' to 3':

- a CMV-R-U5 fusion of the immediate early promoter from human cytomegalovirus to an MLV R-U5 region;

- a PBS, primer binding site for reverse transcriptase;

- a 5' splice site;

- ψ packaging signal;

- a gag coding sequence for MLV group specific antigen;

- a pol coding sequence for MLV polymerase polyprotein;

- a 3' splice site;

- a 4070A env coding sequence for envelope protein of MLV strain 4070A;

- an internal ribosome entry site (IRES) from encephalomyocarditis virus or a nucleic acid regulatory domain;

- a modified cytosine deaminase coding sequence;

- a polypurine tract; and

- a U3-R-U5 MLV long terminal repeat;

- culturing the 293 cell to produce viral particles;

- isolating the viral particles;

- infecting an HT1080 cell line with the viral particles thereby affording a retrovirus producing HT1080 cell line that produces replication competent retrovirus particles, wherein the retrovirus

producing HT1080 cell line is grown in serum free media and in suspension.

45. The cell line produced by the method of claim 44.

46. A method for producing a composition for gene therapy comprising culturing the cell line of claim 44 to produce viral particles and substantially purifying the viral particles.