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 (71) Demandeur/Applicant:  
 GENELUX CORPORATION, US  
 (72) Inventeurs/Inventors:  
 YU, YONG A., US;  
 CHEN, NANHAI, US  
 (74) Agent: SMART & BIGGAR

(54) Titre : UTILISATION D'UN AGENT CHIMIOThERAPEUTIQUE DANS LA PREPARATION D'UN MEDICAMENT  
 POUR TRAITER OU AMELIORER UN EFFET SECONDAIRE INDESIRABLE ASSOCIE A UNE THERAPIE VIRALE  
 ONCOLYTIQUE.  
 (54) Title: USE OF A CHEMOTHERAPEUTIC AGENT IN THE PREPARATION OF A MEDICAMENT FOR TREATING OR  
 AMELIORATING AN ADVERSE SIDE EFFECT ASSOCIATED WITH ONCOLYTIC VIRAL THERAPY

(57) **Abrégé/Abstract:**

Gemcitabine, irinotecan, doxorubicin and cisplatin are chemotherapeutic agents shown to inhibit the growth of an oncolytic vaccinia virus. As such, they can control viral titer- in a subject. These compounds i can be used for the treatment or amelioration of side affects associated with oncolytic virus therapy, or for controlling the oncolytic virus load in a subject.

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**GENELUX CORPORATION** [US/US]; 3030 Bunker  
Hill Street, Suite 310, San Diego, CA 92109 (US).(71) Applicant (for US only): **CHEN, Nanhai** [CN/US]; 9167  
Buckwheat Street, San Diego, CA 92129 (US).

## (72) Inventor; and

(75) Inventor/Applicant (for US only): **YU, Yong, A.**  
[CN/US]; 3830 Elijah Ct. Unit 422, San Diego, CA 92130  
(US).(74) Agents: **SEIDMAN, Stephanie, L.** et al.; Bell Boyd &  
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(54) Title: USE OF A CHEMOTHERAPEUTIC AGENT IN THE PREPARATION OF A MEDICAMENT FOR TREATING OR  
AMELIORATING AN ADVERSE SIDE EFFECT ASSOCIATED WITH ONCOLYTIC VIRAL THERAPY(57) Abstract: Gemcitabine, irinotecan, doxorubicin and cisplatin are chemotherapeutic agents shown to inhibit the growth of an  
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USE OF A CHEMOTHERAPEUTIC AGENT IN THE PREPARATION OF A MEDICAMENT FOR  
TREATING OR AMELIORATING AN ADVERSE SIDE EFFECT ASSOCIATED WITH ONCOLYTIC  
VIRAL THERAPY

## **RELATED APPLICATIONS**

5           Benefit of priority is claimed to U.S. Provisional Application Serial No.  
60/950,587, to Nanhai Chen and Yong A. Yu, filed on July 18, 2007, entitled "USE  
OF MODIFIED VACCINIA VIRUS STRAINS IN COMBINATION WITH A  
CHEMOTHERAPEUTIC AGENT FOR USE IN THERAPEUTIC METHODS" and  
to U.S. Provisional Application Serial No. 60/981,748, to Nanhai Chen and Yong A.  
10   Yu, filed on October 22, 2007, entitled "USE OF MODIFIED VACCINIA VIRUS  
STRAINS IN COMBINATION WITH A CHEMOTHERAPEUTIC AGENT FOR  
USE IN THERAPEUTIC METHODS" Where permitted, the subject matter of each  
of these applications is incorporated by reference in its entirety.

          This application is related to U.S. Application Serial No. 12/218,953 to  
15   Nanhai Chen and Yong A. Yu, filed on July 18, 2008, entitled "USE OF MODIFIED  
VACCINIA VIRUS STRAINS IN COMBINATION WITH A  
CHEMOTHERAPEUTIC AGENT FOR USE IN THERAPEUTIC METHODS,"  
which also claims priority to U.S. Provisional Application Serial Nos. 60/950,587 and  
60/981,748. Where permitted, the subject matter of this application is incorporated by  
20   reference in its entirety.

          This application is related to U.S. Application Serial No. 11/975,088, filed on  
October 16, 2007, entitled "METHODS FOR ATTENUATING VIRUS STRAINS  
FOR DIAGNOSTIC AND THERAPEUTIC USES," to U.S. Application Serial No.  
11/975,090, filed on October 16, 2007, entitled "MODIFIED VACCINIA VIRUS  
25   STRAINS FOR USE IN DIAGNOSTIC AND THERAPEUTIC METHODS," to U.S.  
Application Serial No. 12/080,766, filed on April 4, 2008, entitled "METHODS FOR  
ATTENUATING VIRUS STRAINS FOR DIAGNOSTIC AND THERAPEUTIC  
USES," and to International Application No. PCT/US2007/022172, filed on October  
16, 2007, entitled "MODIFIED VACCINIA VIRUS STRAINS FOR USE IN  
30   DIAGNOSTIC AND THERAPEUTIC METHODS."

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This application also is related to U.S. Application Serial No. 12/157,960 to Nanhai Chen, Yuman Fong, Aladar A. Szalay, Yong A. Yu and Qian Zhang, filed on June 13, 2008, entitled "MICROORGANISMS FOR IMAGING AND/OR TREATMENT OF TUMORS" and to International Application No.

5 PCT/US2008/007377 to Nanhai Chen, Yuman Fong, Aladar A. Szalay, Yong A. Yu and Qian Zhang, filed on June 13, 2008, entitled "MICROORGANISMS FOR IMAGING AND/OR TREATMENT OF TUMORS."

This application is related to U.S. Application Serial No. 10/872,156, to Aladar A. Szalay, Tatyana Timiryasova, Yong A. Yu and Qian Zhang, filed on June  
10 18, 2004, entitled "MICROORGANISMS FOR THERAPY," which claims the benefit of priority under 35 U.S.C. §119(a) to each of EP Application No. 03 013 826.7, filed 18 June 2003, entitled "Recombinant vaccinia viruses useful as tumor-specific delivery vehicle for cancer gene therapy and vaccination," EP Application No. 03 018 478.2, filed 14 August 2003, entitled "Method for the production of a  
15 polypeptide, RNA or other compound in tumor tissue," and EP Application No. 03 024 283.8, filed 22 October 2003, entitled "Use of a Microorganism or Cell to Induce Autoimmunization of an Organism Against a Tumor." This application also is related to International Application No. PCT/US04/19866, filed on June 18, 2004, entitled  
"MICROORGANISMS FOR THERAPY."

20 This application also is related to U.S. Application Serial No. 10/866,606, filed June 10, 2004, entitled "Light emitting microorganisms and cells for diagnosis and therapy of tumors," which is a continuation of U.S. Application Serial No. 10/189,918, filed July 3, 2002, entitled "Light emitting microorganisms and cells for diagnosis and therapy of tumors." This application also is related to International  
25 PCT Application PCT/IB02/04767, filed July 31, 2002, entitled "Microorganisms and Cells for Diagnosis and Therapy of Tumors," EP Application No. 01 118 417.3, filed July 31, 2001, entitled "Light-emitting microorganisms and cells for tumor diagnosis/therapy," EP Application No. 01 125 911.6, filed October 30, 2001, entitled "Light emitting microorganisms and cells for diagnosis and therapy of tumors" and  
30 EP Application No. 02 0794 632.6, filed July 31, 2002, entitled "Microorganisms and Cells for Diagnosis and Therapy of Tumors."

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Where permitted, the subject matter of each of the above applications is incorporated by reference in its entirety.

### **FIELD OF THE INVENTION**

5 Compositions containing modified and/or attenuated viruses in combination with chemotherapeutic agents, and methods for preparing and using the compositions are provided. Methods for using compositions containing modified and/or attenuated viruses that are administered with chemotherapeutic agents are also provided. Diagnostic and therapeutic methods also are provided.

### **BACKGROUND**

10 Chemotherapeutic agents are commonly used in the treatment of cancer. Examples of chemotherapeutic agents include, for example, 5-fluorouracil (5-FU), gemcitabine, cisplatin, irinotecan and doxorubicin. Chemotherapeutic agents often are involved in interference with DNA replication and transcription; they act upon cancerous cells and tumors by inhibiting the ability of cells to divide and grow. 5-FU  
15 is a pyrimidine analogue that exhibits anti-tumor activity. Its mode of action is principally through inhibition of an enzyme, thymidylate synthase, that is involved in pyrimidine synthesis for DNA replication. Gemcitabine, also known as 4-amino-1-[3,3-difluoro-4-hydroxy-5-(hydroxymethyl) tetrahydrofuran-2-yl]-1H-pyrimidine-2-one, is a nucleoside analogue that also exhibits antitumor activity. The mechanism of  
20 therapy is related to the ability of gemcitabine to inhibit DNA synthesis through competition with deoxycytosinetriphosphate (dCTP) for incorporation into DNA. Cisplatin (also known as cisplatinum and CDDP) is a platinum-based chemotherapy that acts by crosslinking DNA, which inhibits DNA replication. Irinotecan is a chemotherapeutic agent that is a topoisomerase 1 inhibitor; thus, it acts to inhibit the  
25 relaxation of DNA during winding/unwinding of the double helix during DNA replication, leading to inhibition of both DNA replication and transcription. Doxorubicin is a DNA-interacting drug that can intercalate DNA and interfere with the action of topoisomerase II, thereby leading to inhibition of DNA replication and transcription.

30 Modified and attenuated viruses are used for treatment and therapy of diseases such as, for example, cancer. Mutation of non-essential genes is a method of

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attenuation that preserves the ability of the virus to propagate without the need of a packaging cell lines. In viruses such as vaccinia virus, mutations in non-essential genes, such as the thymidine kinase (*TK*) gene or hemagglutinin (*HA*) gene have been employed to attenuate the virus (e.g., Buller et al. (1985) *Nature* 317, 813-815, Shida et al. (1988) *J. Virol.* 62(12):4474-80, Taylor et al. (1991) *J. Gen. Virol.* 72 (Pt 1):125-30, U.S. Patent Nos. 5,364,773, 6,265,189, 7,045,313). The inactivation of these genes decreases the overall pathogenicity of the virus without affecting the ability of the viruses to replicate in certain cell types. The viruses selectively infect, replicate within, and lyse cancer cells, and can be used in treatment of a wide variety of cancers. The treatment of disease by these agents can be accompanied unpleasant side effects that can result in patient non-compliance or cessation of treatment. Accordingly, it is among the objects herein to provide compositions and methods for treatment of disease in patients while minimizing the side effects of the therapies.

#### SUMMARY

Provided are methods and compositions for treatment of diseases, such as cancer, that minimize or reduce undesired side effects. Among the compositions and methods are those for clearance of a virus administered to a subject for treatment of disease. Provided are methods for the use of chemotherapeutic agents in conjunction with modified vaccinia viruses, or viral vectors, for use in therapeutic methods. The methods permit the control of viral titer or viral load such that the patient from experiences minimal or reduced side effects and/or reduced toxicity associated with the administered virus. In particular examples, the adverse side effects are one or more of pock formation, weight loss, fever, abdominal pain, aches or pains in muscles, cough, diarrhea, and feeling of discomfort or illness.

Provided herein are methods for treating one or more adverse side effects associated with viral treatment, where a chemotherapeutic agent is administered to a subject being treated with a therapeutic virus and the amount of chemotherapeutic agent administered is sufficient to control or reduce viral titer in the subject. In such methods, the subject is identified as one who exhibits one or more adverse effects following administration of the virus.

Provided herein are methods for controlling viral load in a subject, comprising administering a chemotherapeutic agent to a subject treated with a therapeutic virus,

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where the subject exhibits a viral titer that is equal to or exceeds an amount that causes one or more adverse side effects in the subject during treatment with the virus. In such methods, the amount of chemotherapeutic agent administered is sufficient to control or reduce viral titer in the subject.

5            Provided herein are methods of for treating one or more adverse side effects associated with viral treatment or controlling viral load in a subject, where the chemotherapeutic agents employed the methods can be administered systemically, intravenously, intraarterially, intratumorally, endoscopically, intralesionally, intramuscularly, intradermally, intraperitoneally, intravesicularly, intraarticularly, 10 intrapleurally, percutaneously, subcutaneously, orally, parenterally, intranasally, intratracheally, by inhalation, intracranially, intraprostatically, intravitreally, topically, ocularly, vaginally, or rectally. Typically, the chemotherapeutic agent is administered systemically.

          Methods to maintain or control numbers of a modified vaccinia virus delivered 15 to a patient for treatment of cancer are contemplated such that the patient suffers minimal side effects or systemic toxicity associated with the administered virus, the methods comprising co-administration of the virus with a regimen of a chemotherapeutic agent that inhibits the replication of the virus. In some 20 embodiments, the co-administration of virus and the chemotherapeutic agent allows the sustained release of virally-expressed antigens and the chemotherapeutic agent in a patient. In some embodiments, the co-administration of virus and the chemotherapeutic agent allows the sustained delivery of virally-expressed antigens and the chemotherapeutic agent in a patient.

          Methods to maintain or control numbers of a modified vaccinia virus delivered 25 to a patient for treatment of cancer such that the patient suffers minimal side effects or systemic toxicity associated with the virus are provided, comprising: initial administration of a chemotherapeutic agent that inhibits the replication of the virus to the patient; administration of the virus; and subsequent co-administration of virus and the chemotherapeutic agent.

30            Methods are also provided herein to maintain or control numbers of a modified vaccinia virus delivered to a patient for treatment of cancer such that the patient suffers minimal side effects or systemic toxicity associated with the virus

comprising: initial administration of a chemotherapeutic agent that inhibits the replication of the virus to the patient; administration of the virus; and subsequent administration of the chemotherapeutic agent alone or in combination with one or more antiviral agents.

5           Also provided herein are methods to effectively clear a modified vaccinia virus administered to a patient for treatment of a disease, comprising: administration of a chemotherapeutic agent that inhibits the replication of the virus in an amount effective to clear the virus in the patient, such that symptoms associated with the virus are reduced or eliminated in the patient.

10           Methods to maintain or control numbers of a modified vaccinia virus delivered to a patient for treatment of cancer are contemplated such that the patient suffers minimal side effects or systemic toxicity associated with the administered virus, the methods comprising co-administration of the virus with a regimen of gemcitabine. In some embodiments, the co-administration of virus and gemcitabine allows the  
15           sustained release of virally-expressed antigens and gemcitabine in a patient. In some embodiments, the co-administration of virus and gemcitabine allows the sustained delivery of virally-expressed antigens and gemcitabine in a patient.

            Methods to maintain or control numbers of a modified vaccinia virus delivered to a patient for treatment of cancer such that the patient suffers minimal side effects or  
20           systemic toxicity associated with the virus are provided, comprising: initial administration of gemcitabine to the patient; administration of the virus; and subsequent co-administration of virus and gemcitabine.

            Methods are also provided herein to maintain or control numbers of a modified vaccinia virus delivered to a patient for treatment of cancer such that the  
25           patient suffers minimal side effects or systemic toxicity associated with the virus comprising: initial administration of gemcitabine to the patient; administration of the virus; and subsequent administration of gemcitabine alone or in combination with one or more antiviral agents.

            Also provided herein are methods to effectively clear a modified vaccinia  
30           virus administered to a patient for treatment of a disease, comprising: administration of gemcitabine in an amount effective to clear the virus in the patient, such that symptoms associated with the virus are reduced or eliminated in the patient.



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Also provided herein are methods to maintain or control numbers of a modified vaccinia virus delivered to a patient for treatment of cancer such that the patient suffers minimal side effects or systemic toxicity associated with the virus comprising co-administration of the virus with a regimen of irinotecan. In some  
5 embodiments, the co-administration of virus and irinotecan allows the sustained release of virally-expressed antigens and irinotecan in a patient. In some embodiments, the co-administration of virus and irinotecan allows the sustained delivery of virally-expressed antigens and irinotecan in a patient.

Methods to maintain or control numbers of a modified vaccinia virus delivered  
10 to a patient for treatment of cancer such that the patient suffers minimal side effects or systemic toxicity associated with the virus are provided, comprising: initial administration of irinotecan to the patient; administration of the virus; and subsequent co-administration of virus and irinotecan.

Methods are also provided herein to maintain or control numbers of a  
15 modified vaccinia virus delivered to a patient for treatment of cancer such that the patient suffers minimal side effects or systemic toxicity associated with the virus comprising: initial administration of irinotecan to the patient; administration of the virus; and subsequent administration of irinotecan alone or in combination with one or more antiviral agents.

20 Also provided herein are methods to effectively clear a modified vaccinia virus administered to a patient for treatment of a disease, comprising: administration of irinotecan in an amount effective to clear the virus in the patient, such that symptoms associated with the virus are reduced or eliminated in the patient.

In addition, methods to maintain or control numbers of a modified vaccinia  
25 virus delivered to a patient for treatment of cancer are contemplated such that the patient suffers minimal side effects or systemic toxicity associated with the virus, the methods comprising co-administration of the virus with a regimen of doxorubicin. In some embodiments, the co-administration of virus and doxorubicin allows the sustained release of virally-expressed antigens and doxorubicin in a patient. In some  
30 embodiments, the co-administration of virus and doxorubicin allows the sustained delivery of virally-expressed antigens and doxorubicin in a patient.

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Methods to maintain or control numbers of a modified vaccinia virus delivered to a patient for treatment of cancer such that the patient suffers minimal side effects or systemic toxicity associated with the virus are provided, comprising: initial administration of doxorubicin to the patient; administration of the virus; and  
5 subsequent co-administration of virus and doxorubicin.

Methods are also provided herein to maintain or control numbers of a modified vaccinia virus delivered to a patient for treatment of cancer such that the patient suffers minimal side effects or systemic toxicity associated with the virus comprising: initial administration of doxorubicin to the patient; administration of the  
10 virus; and subsequent administration of doxorubicin alone or in combination with one or more antiviral agents.

Also provided herein are methods to effectively clear a modified vaccinia virus administered to a patient for treatment of a disease, comprising: administration of doxorubicin in an amount effective to clear the virus in the patient, such that  
15 symptoms associated with the virus are reduced or eliminated in the patient.

Furthermore, provided herein are methods to maintain or control numbers of a modified vaccinia virus delivered to a patient for treatment of cancer such that the patient suffers minimal side effects or systemic toxicity associated with the virus comprising co-administration of the virus with a regimen of cisplatin. In some  
20 embodiments, the co-administration of virus and cisplatin allows the sustained release of virally-expressed antigens and cisplatin in a patient. In some embodiments, the co-administration of virus and cisplatin allows the sustained delivery of virally-expressed antigens and cisplatin in a patient.

Methods to maintain or control numbers of a modified vaccinia virus delivered to a patient for treatment of cancer such that the patient suffers minimal side effects or systemic toxicity associated with the virus comprising: initial administration of  
25 cisplatin to the patient; administration of the virus; and subsequent co-administration of virus and cisplatin.

Methods are provided herein to maintain or control numbers of a modified vaccinia virus delivered to a patient for treatment of cancer such that the patient suffers minimal side effects or systemic toxicity associated with the virus comprising:  
30 initial administration of cisplatin to the patient; administration of the virus; and

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subsequent administration of cisplatin alone or in combination with one or more antiviral agents.

Also provided herein are methods to effectively clear a modified vaccinia virus administered to a patient for treatment of a disease, comprising: administration  
5 of cisplatin in an amount effective to clear the virus in the patient, such that symptoms associated with the virus are reduced or eliminated in the patient.

The viruses for use in the methods provided can be any virus that is employed for therapy. In particular methods the virus is one that is administered for the treatment of a tumor or a metastasis. Exemplary viruses include, but are not limited  
10 to, is a poxvirus, adenovirus, adeno-associated virus, herpes simplex virus, Newcastle disease virus, vesicular stomatitis virus, mumps virus, influenza virus, measles virus, reovirus, human immunodeficiency virus (HIV), hanta virus, myxoma virus, cytomegalovirus (CMV), lentivirus or Sindbis virus. In particular examples, the virus is a vaccinia virus, such as a Lister strain vaccinia virus (*e.g.*, an LIVP virus).

Exemplary LIVP viruses includes but are not limited to GLV-1h68, GLV-1h70, GLV-  
15 1h71, GLV-1h72, GLV-1h73, GLV-1h74, GLV-1h81, GLV-1h82, GLV-1h83, GLV-1h84, GLV-1h85, GLV-1h86, GLV-1h90, GLV-1h91, GLV-1h92, GLV-1h96, GLV-1h97, GLV-1h98, GLV-1h99, GLV-1h100, GLV-1h101, GLV-1h104, GLV-1h105, GLV-1h106, GLV-1h107, GLV-1h108, GLV-1h109, GLV-1h139, GLV-1h146,  
20 GLV-1h150 GLV-1h151, GLV-1h152 or GLV-1h153.

Also provided herein are combinations, including a composition containing a therapeutic virus, wherein the virus is effective for treatment of cancer and a composition containing a chemotherapeutic agent in an amount effective for clearing the virus from a subject.

25 Provided herein are containing a combination of a therapeutic virus and a chemotherapeutic agent in an amount effective for clearing the virus from a subject, and optionally, instructions for administration of the combination.

Provided herein is a chemotherapeutic agent for use in ameliorating an adverse side effect associated with viral treatment of cancer, where the chemotherapeutic  
30 agent is selected from among gemcitabine, irinotecan, doxorubicin and cisplatin. Also provided herein are uses of a chemotherapeutic agent in the preparation of a medicament for the treating an adverse side effect associated with viral treatment of

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cancer, wherein the chemotherapeutic agent is selected from among gemcitabine, irinotecan, doxorubicin and cisplatin.

## DETAILED DESCRIPTION

### Outline

- 5           **A.     Definitions**
- B.     Methods for Treatment and Diagnosis**
- 1.     Administration**
- a.     Virus Administration and Dosages**
- b.     Chemotherapeutic Agent Administration Dosage**
- 10                    **i.     Gemcitabine Dosage Regimens**
- ii.    Irinotecan Dosage Regimens**
- iii.   Doxorubicin Dosage Regimens**
- iv.   Cisplatin Dosage Regimens**
- 2.     Number of administrations**
- 15                    **3.     Co-administrations**
- 4.     State of the Subject**
- C.     Viruses and Chemotherapeutic Agents for Treatment and**
- Diagnosis**
- 1.     Viruses, vectors**
- 20                    **2.     Modifications of viruses**
- 3.     Exemplary viruses**
- a.     Poxviruses**
- i.     Vaccinia viruses**
- ii.    Modification of Vaccinia Viruses**
- 25                    **iii.   Exemplary Modified Vaccinia Viruses**
- b.     Other cytoplasmic viruses**
- c.     Adenovirus, Herpes, Retroviruses**
- 4.     Chemotherapeutic agents for virus inhibition**
- D.     Monitoring**
- 30                    **1.     Monitoring viral gene expression**
- 2.     Monitoring tumor size**
- 3.     Monitoring antibody titer**
- 4.     Monitoring general health diagnostics**
- 5.     Monitoring coordinated with treatment**
- 35            **E.     Pharmaceutical compositions, combinations and kits**
- F.     Examples**

### A.     DEFINITIONS

40           Unless defined otherwise, all technical and scientific terms used herein have the same meaning as is commonly understood by one of skill in the art to which the invention(s) belong. All patents, patent applications, published applications and publications, websites and other published materials referred to throughout the entire disclosure herein, unless noted otherwise, are incorporated by reference in their

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entirety. In the event that there are pluralities of definitions for terms herein, those in this section prevail. Where reference is made to a URL or other such identifier or address, it is understood that such identifiers can change and particular information on the internet can come and go, but equivalent information is known and can be readily  
5 accessed, such as by searching the internet and/or appropriate databases. Reference thereto evidences the availability and public dissemination of such information.

As used herein, "virus" refers to any of a large group of entities referred to as viruses. Viruses typically contain a protein coat surrounding an RNA or DNA core of genetic material, and are capable of growth and multiplication only in living cells.  
10 Viruses for use in the methods provided herein include, but are not limited, to a poxvirus, including a vaccinia virus. Other exemplary viruses include, but are not limited to, adenovirus, adeno-associated virus, herpes simplex virus, Newcastle disease virus, vesicular stomatitis virus, mumps virus, influenza virus, measles virus, reovirus, human immunodeficiency virus (HIV), hanta virus, myxoma virus,  
15 cytomegalovirus (CMV), lentivirus, Sindbis virus, and any plant or insect virus.

As used herein, the term "viral vector" is used according to its art-recognized meaning. It refers to a nucleic acid vector construct that includes at least one element of viral origin and can be packaged into a viral vector particle. The viral vector particles can be used for the purpose of transferring DNA, RNA or other nucleic acids  
20 into cells either *in vitro* or *in vivo*. Viral vectors include, but are not limited to, retroviral vectors, vaccinia vectors, lentiviral vectors, herpes virus vectors (e.g., HSV), baculoviral vectors, cytomegalovirus (CMV) vectors, papillomavirus vectors, simian virus (SV40) vectors, semliki forest virus vectors, phage vectors, adenoviral vectors, and adeno-associated viral (AAV) vectors.

25 As used herein, the term "modified" with reference to a gene refers to a deleted gene, a gene encoding a gene product having one or more truncations, mutations, insertions or deletions, or a gene that is inserted (into the chromosome or on a plasmid, phagemid, cosmid, and phage) encoding a gene product, typically accompanied by at least a change in function of the modified gene product or virus.

30 As used herein, the term "modified virus" refers to a virus that is altered with respect to a parental strain of the virus. Typically modified viruses have one or more truncations, mutations, insertions or deletions in the genome of virus. A modified

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virus can have one or more endogenous viral genes modified and/or one or more intergenic regions modified. Exemplary modified viruses can have one or more heterologous nucleic acid sequences inserted into the genome of the virus. Modified viruses can contain one more heterologous nucleic acid sequences in the form of a gene expression cassette for the expression of a heterologous gene. As used herein, modification of a heterologous nucleic acid molecule with respect to a virus containing a heterologous nucleic acid molecule refers to any alteration of the heterologous nucleic acid molecule including truncations, mutations, insertions, or deletions of the nucleic acid molecule. Modification of a heterologous nucleic acid molecule can also include alteration of the viral genome, which can be, for example, a deletion of all or a portion heterologous nucleic from the viral genome or insertion of an additional heterologous nucleic acid molecule into the viral genome.

As used herein, the term “therapeutic virus” refers to a virus that is administered for the treatment of a disease or disorder. A therapeutic virus is typically a modified virus. Such modifications include one or more insertions, deletions, or mutations in the genome of the virus. Therapeutic viruses typically possess modifications in one or more endogenous viral genes or one or more intergenic regions, which attenuate the toxicity of the virus, and can optionally express a heterologous therapeutic gene product and/or detectable protein. Therapeutic viruses can contain heterologous nucleic acid molecules, including one or more gene expression cassettes for the expression of the therapeutic gene product and/or detectable protein. Therapeutic viruses can be replication competent viruses (e.g., oncolytic viruses) including conditional replicating viruses, or replication-defective viruses. As used herein, the term, “therapeutic gene product” refers to any heterologous protein expressed by the therapeutic virus that ameliorates the symptoms of a disease or disorder or ameliorates the disease or disorder.

As used herein, attenuation of a virus means to a reduction or elimination of deleterious or toxic effects to a host upon administration of the virus compared to an un-attenuated virus. As used herein, a virus with low toxicity means that upon administration a virus does not accumulate in organs and tissues in the host to an extent that results in damage or harm to organs, or that impacts survival of the host to a greater extent than the disease being treated does. For the purposes herein,

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attenuation of toxicity is used interchangeably with attenuation of virulence and attenuation of pathogenicity.

As used herein, the term "viral load" is the amount of virus present in the blood of a patient. Viral load is also referred to as viral titer or viremia. Viral load can  
5 be measured in variety of standard ways, including immunochemistry methods or by plaque assay.

As used herein, the term "toxicity" with reference to a virus refers to the ability of the virus to cause harm to the subject to which the virus has been administered.

10 As used herein virulence and pathogenicity with reference to a virus refers to the ability of the virus to cause disease or harm in the subject to which the virus has been administered. Hence, for the purposes herein the terms toxicity, virulence, and pathogenicity with reference to a virus are used interchangeably.

As used herein, a delivery vehicle for administration refers to a lipid-based or  
15 other polymer-based composition, such as liposome, micelle, or reverse micelle, which associates with an agent, such as a virus provided herein, for delivery into a host animal.

As used herein, a disease or disorder refers to a pathological condition in an organism resulting from, for example, infection or genetic defect, and characterized  
20 by identifiable symptoms.

As used herein, treatment means any manner in which the symptoms of a condition, disorder or disease are ameliorated or otherwise beneficially altered. Treatment also encompasses any pharmaceutical use of the viruses described and provided herein.

25 As used herein, amelioration or alleviation of symptoms associated with a disease refers to any lessening, whether permanent or temporary, lasting or transient of symptoms that can be attributed to or associated with a disease. Similarly, amelioration or alleviation of symptoms associated with administration of a virus refers to any lessening, whether permanent or temporary, lasting or transient of  
30 symptoms that can be attributed to or associated with an administration of the virus for treatment of a disease.

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As used herein, an effective amount of a virus or compound for treating a particular disease is an amount that is sufficient to ameliorate, or in some manner reduce the symptoms associated with the disease. Such an amount can be administered as a single dosage or can be administered according to a regimen, whereby it is effective. The amount can cure the disease but, typically, is administered in order to ameliorate the symptoms of the disease. Repeated administration can be required to achieve the desired amelioration of symptoms.

As used herein, an effective amount of a therapeutic agent for control of viral unit numbers or viral titer in a patient is an amount that is sufficient to prevent a virus introduced to a patient for treatment of a disease from overwhelming the patient's immune system such that the patient suffers adverse side effects due to virus toxicity or pathogenicity. Such side effects can include, but are not limited to fever, abdominal pain, aches or pains in muscles, cough, diarrhea, or general feeling of discomfort or illness that are associated with virus toxicity and are related to the subject's immune and inflammatory responses to the virus. Side effects or symptoms can also include escalation of symptoms due to a systemic inflammatory response to the virus, such as, but not limited to, jaundice, blood-clotting disorders and multiple-organ system failure. Such an amount can be administered as a single dosage or can be administered according to a regimen, whereby it is effective. The amount can prevent the appearance of side effects but, typically, is administered in order to ameliorate the symptoms of the side effects associated with the virus and virus toxicity. Repeated administration can be required to achieve the desired amelioration of symptoms.

As used herein, an *in vivo* method refers to a method performed within the living body of a subject.

As used herein, a subject includes any animal for whom diagnosis, screening, monitoring or treatment is contemplated. Animals include mammals such as primates and domesticated animals. An exemplary primate is human. A patient refers to a subject such as a mammal, primate, human, or livestock subject afflicted with a disease condition or for which a disease condition is to be determined or risk of a disease condition is to be determined.



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As used herein, the term “neoplasm” or “neoplasia” refers to abnormal new cell growth, and thus means the same as tumor, which can be benign or malignant. Unlike hyperplasia, neoplastic proliferation persists even in the absence of the original stimulus.

5 As used herein, neoplastic disease refers to any disorder involving cancer, including tumor development, growth, metastasis and progression.

As used herein, cancer is a term for diseases caused by or characterized by any type of malignant tumor, including metastatic cancers, lymphatic tumors, and blood cancers. Exemplary cancers include, but are not limited to: leukemia, lymphoma, 10 pancreatic cancer, lung cancer, ovarian cancer, breast cancer, cervical cancer, bladder cancer, prostate cancer, glioma tumors, adenocarcinomas, liver cancer and skin cancer. Exemplary cancers in humans include a bladder tumor, breast tumor, prostate tumor, basal cell carcinoma, biliary tract cancer, bladder cancer, bone cancer, brain and CNS cancer (e.g., glioma tumor), cervical cancer, choriocarcinoma, colon and 15 rectum cancer, connective tissue cancer, cancer of the digestive system; endometrial cancer, esophageal cancer; eye cancer; cancer of the head and neck; gastric cancer; intra-epithelial neoplasm; kidney cancer; larynx cancer; leukemia; liver cancer; lung cancer (e.g. small cell and non-small cell); lymphoma including Hodgkin's and Non-Hodgkin's lymphoma; melanoma; myeloma, neuroblastoma, oral cavity cancer (e.g., 20 lip, tongue, mouth, and pharynx); ovarian cancer; pancreatic cancer, retinoblastoma; rhabdomyosarcoma; rectal cancer, renal cancer, cancer of the respiratory system; sarcoma, skin cancer; stomach cancer, testicular cancer, thyroid cancer; uterine cancer, cancer of the urinary system, as well as other carcinomas and sarcomas. Malignant disorders commonly diagnosed in dogs, cats, and other pets include, but 25 are not limited to, lymphosarcoma, osteosarcoma, mammary tumors, mastocytoma, brain tumor, melanoma, adenosquamous carcinoma, carcinoid lung tumor, bronchial gland tumor, bronchiolar adenocarcinoma, fibroma, myxochondroma, pulmonary sarcoma, neurosarcoma, osteoma, papilloma, retinoblastoma, Ewing's sarcoma, Wilm's tumor, Burkitt's lymphoma, microglioma, neuroblastoma, osteoclastoma, oral 30 neoplasia, fibrosarcoma, osteosarcoma and rhabdomyosarcoma, genital squamous cell carcinoma, transmissible venereal tumor, testicular tumor, seminoma, Sertoli cell tumor, hemangiopericytoma, histiocytoma, chloroma (e.g., granulocytic sarcoma),

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corneal papilloma, corneal squamous cell carcinoma, hemangiosarcoma, pleural mesothelioma, basal cell tumor, thymoma, stomach tumor, adrenal gland carcinoma, oral papillomatosis, hemangioendothelioma and cystadenoma, follicular lymphoma, intestinal lymphosarcoma, fibrosarcoma and pulmonary squamous cell carcinoma. In rodents, such as a ferret, exemplary cancers include insulinoma, lymphoma, sarcoma, neuroma, pancreatic islet cell tumor, gastric MALT lymphoma and gastric adenocarcinoma. Neoplasias affecting agricultural livestock include leukemia, hemangiopericytoma and bovine ocular neoplasia (in cattle); preputial fibrosarcoma, ulcerative squamous cell carcinoma, preputial carcinoma, connective tissue neoplasia and mastocytoma (in horses); hepatocellular carcinoma (in swine); lymphoma and pulmonary adenomatosis (in sheep); pulmonary sarcoma, lymphoma, Rous sarcoma, reticulo-endotheliosis, fibrosarcoma, nephroblastoma, B-cell lymphoma and lymphoid leukosis (in avian species); retinoblastoma, hepatic neoplasia, lymphosarcoma (lymphoblastic lymphoma), plasmacytoid leukemia and swimbladder sarcoma (in fish), caseous lymphadenitis (CLA): chronic, infectious, contagious disease of sheep and goats caused by the bacterium *Corynebacterium pseudotuberculosis*, and contagious lung tumor of sheep caused by jaagsiekte.

As used herein, the term "malignant," as it applies to tumors, refers to primary tumors that have the capacity of metastasis with loss of growth control and positional control.

As used herein, metastasis refers to a growth of abnormal or neoplastic cells distant from the site primarily involved by the morbid process.

As used herein, proliferative disorders include any disorders involving abnormal proliferation of cells, such as, but not limited to, neoplastic diseases.

As used herein, a method for treating or preventing neoplastic disease means that any of the symptoms, such as the tumor, metastasis thereof, the vascularization of the tumors or other parameters by which the disease is characterized are reduced, ameliorated, prevented, placed in a state of remission, or maintained in a state of remission. It also means that the indications of neoplastic disease and metastasis can be eliminated, reduced or prevented by the treatment. Non-limiting examples of the indications include uncontrolled degradation of the basement membrane and proximal

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extracellular matrix, migration, division, and organization of the endothelial cells into new functioning capillaries, and the persistence of such functioning capillaries.

As used herein, a prodrug is a compound that, upon *in vivo* administration, is metabolized or otherwise converted to the biologically, pharmaceutically or therapeutically active form of the compound. To produce a prodrug, the pharmaceutically active compound is modified such that the active compound is regenerated by metabolic processes. The prodrug can be designed to alter the metabolic stability or the transport characteristics of a drug, to mask side effects or toxicity, to improve the flavor of a drug or to alter other characteristics or properties of a drug. By virtue of knowledge of pharmacodynamic processes and drug metabolism *in vivo*, those of skill in this art, once a pharmaceutically active compound is known, can design prodrugs of the compound (see, e.g., Nogrady (1985) Medicinal Chemistry A Biochemical Approach, Oxford University Press, New York, pages 388-392).

As used herein, an anti-cancer agent or compound (used interchangeably with "anti-tumor or anti-neoplastic agent") refers to any agents, or compounds, used in anti-cancer treatment. These include any agents, when used alone or in combination with other compounds, that can alleviate, reduce, ameliorate, prevent, or place or maintain in a state of remission of clinical symptoms or diagnostic markers associated with neoplastic disease, tumors and cancer, and can be used in methods, combinations and compositions provided herein. Exemplary anti-cancer agent agents include, but are not limited to, the viruses provided herein used singly or in combination and/or in combination with other anti-cancer agents, such as cytokines, growth factors, hormones, photosensitizing agents, radionuclides, toxins, anti-metabolites, signaling modulators, anti-cancer antibiotics, anti-cancer antibodies, anti-cancer oligopeptides, angiogenesis inhibitors, radiation therapy, hypothermia therapy, hyperthermia therapy, laser therapy, chemotherapeutic compounds, or a combination thereof.

Chemotherapeutic compounds include, but are not limited to platinum; platinum analogs anthracenediones; vinblastine; alkylating agents; alkyl sulfonates; aziridines; ethylenimines and methylamelamines; nitrosureas; antibiotics; anti-metabolites; folic acid analogues; androgens; anti-adrenals; folic acid replenisher; aminolevulinic acid; amsacrine; bestrabucil; bisantrene; edatraxate; defofamine;

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demecolcine; diaziquone; elfornithine; elliptinium acetate; etoglucid; gallium nitrate; substituted ureas; hydroxyurea; lentinan; lonidamine; mitoguazone; mitoxantrone; mopidamol; nitracrine; pentostatin; phenamet; pirarubicin; podophyllinic acid; 2-ethylhydrazide; procarbazine; anti-cancer polysaccharides; polysaccharide-K; razoxane; sizofiran; spirogermanium; tenuazonic acid; triaziquone; 2, 2',2"-trichlorotriethylamine; urethan; vindesine; dacarbazine; mannomustine; mitobronitol; mitolactol; pipobroman; gacytosine; cytosine arabinoside; cyclophosphamide; thiotepa; taxoids, such as paclitaxel and doxetaxel; chlorambucil; gemcitabine; 6-thioguanine; mercaptopurine; methotrexate; etoposide (VP-16); ifosfamide; mitomycin C; vincristine; vinorelbine; navelbine; novantrone; teniposide; daunomycin; aminopterin; xeloda; ibandronate; CPT11; topoisomerase inhibitor RFS 2000; difluoromethylornithine (DMFO); retinoic acid; esperamicins; capecitabine; methylhydrazine derivatives; and pharmaceutically acceptable salts, acids or derivatives of any of the above. Chemotherapeutic compounds also include, but are not limited to, adriamycin, non-sugar containing chloroethylnitrosoureas, 5-fluorouracil, bleomycin, doxorubicin, taxol, fragyline, Meglamine GLA, valrubicin, carmustine and polifeprosan, MM1270, BAY 12-9566, RAS famesyl transferase inhibitor, famesyl transferase inhibitor, MMP, MTA/LY231514, LY264618/Lometrexol, Glamolec, CI-994, TNP-470, Hycamtin/Topotecan, PKC412, Valspodar/PSC833, Novantrone/Mitroxantrone, Metaret/Suramin, Batimastat, E7070, BCH-4556, CS-682, 9-AC, AG3340, AG3433, Incel/VX-710, VX-853, ZD0101, IS1641, ODN 698, TA 2516/Marmistat, BB2516/Marmistat, CDP 845, D2163, PD183805, DX8951f, Lemonal DP 2202, FK 317, Picibanil/OK-432, AD 32/Valrubicin, Metastron/strontium derivative, Temodal/Temozolomide, Evacet/liposomal doxorubicin, Yewtaxan/Paclitaxel, Taxol®/Paclitaxel, Xeload/Capecitabine, Furtulon/Doxifluridine, Cyclopax/oral paclitaxel, Oral Taxoid, SPU-077/Cisplatin, HMR 1275/Flavopiridol, CP-358 (774)/EGFR, CP-609 (754)/RAS oncogene inhibitor, BMS-182751/oral platinum, UFT(Tegafur/Uracil), Ergamisol/Levamisole, Eniluracil/776C85/5FU enhancer, Campto/Levamisole, Camptosar/Irinotecan, Tumodex/Ralitrexed, Leustatin/Cladribine, Paxex/Paclitaxel, Doxil/liposomal doxorubicin, Caelyx/liposomal doxorubicin, Fludara/Fludarabine, Pharmarubicin/Epirubicin, DepoCyt, ZD1839, LU 79553/Bis-Naphtalimide, LU

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103793/Dolastain, Gemzar/Gemcitabine, ZD 0473/Anormed, YM 116, Iodine seeds, CDK4 and CDK2 inhibitors, PARP inhibitors, D4809/Dexifosamide, Ifes/Mesnex/Ifosfamide, Vumon®/Teniposide, Paraplatin/Carboplatin, Plantinol/cisplatin, Vepeside/Etoposide, ZD 9331, Taxotere/Docetaxel, prodrug of  
5 guanine arabinoside, Taxane Analog, nitrosoureas, alkylating agents such as melphelan and cyclophosphamide, Aminoglutethimide, Anastrozole, Asparaginase, Busulfan, Carboplatin, Chlorombucil, Cladribine, Cytarabine HCl, Dactinomycin, Daunorubicin HCl, Denileukin diftitox, Estramustine phosphate sodium, Etoposide (VP16-213), Exemestane, Floxuridine, Fluorouracil (5-FU®), Flutamide,  
10 Hydroxyurea (hydroxycarbamide), Interferon Alfa-2a, Interferon Alfa-2b, Interferon Gamma-1b, Letrozole, Leuprolide acetate (LHRH-releasing factor analogue), Lomustine (CCNU), Mechlorethamine HCl (nitrogen mustard), Megestrol, Mercaptopurine, Mesna, Mitotane (o.p'-DDD), Mitoxantrone HCl, Octreotide, Pegaspargase, Plicamycin, Procarbazine HCl, Streptozocin, Tamoxifen citrate,  
15 Thioguanine, Thiotepa, Tretinoin, Vinblastine sulfate, Amsacrine (m-AMSA), Azacitidine, Erythropoietin, Hexamethylmelamine (HMM), Interleukin 2, Mitoguazone (methyl-GAG; methyl glyoxal bis-guanyldrazone; MGBG), Pentostatin (2'deoxycoformycin), Semustine (methyl-CCNU), Teniposide (VM-26®), Vindesine sulfate, Altretamine, Carmustine, Estramustine, Gemtuzumab ozogamicin,  
20 Idarubicin, Isotretinoin, Leuprolide, Melphalan, Testolactone, Uracil mustard, and the like. Also included in this definition are anti-hormonal agents that act to regulate or inhibit hormone action on tumors such as anti-estrogens, adrenocortical suppressants, antiandrogens and pharmaceutically acceptable salts, acids or derivatives of any of the above. Such chemotherapeutic compounds that can be used  
25 herein include compounds whose toxicities preclude use of the compound in general systemic chemotherapeutic methods.

As used herein the term assessing or determining is intended to include quantitative and qualitative determination in the sense of obtaining an absolute value for the activity of a product, and also of obtaining an index, ratio, percentage, visual  
30 or other value indicative of the level of the activity. Assessment can be direct or indirect. As used herein, activity refers to the *in vivo* activities of a compound or viruses on physiological responses that result following *in vivo* administration thereof

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(or of a composition or other mixture). Activity, thus, encompasses resulting therapeutic effects and pharmaceutical activity of such compounds, compositions and mixtures. Activities can be observed in *in vitro* and/or *in vivo* systems designed to test or use such activities.

5           As used herein, a vaccine refers to a composition which, upon administration to a subject, elicits an immune response in a subject to which it is administered and which protects the immunized subject against subsequent challenge by the immunizing agent or an immunologically cross-reactive agent. A vaccine can be used to enhance the immune response against a pathogen, such as a virus, that expresses  
10 the immunological agent and/or has already infected the subject. Protection can be complete or partial (i.e., a reduction in symptoms or infection as compared with an unvaccinated subject). Typically a vaccine is administered to a subject that is a mammal. An immunologically cross-reactive agent can be, for example, the whole protein (e.g., tumor antigen) from which a subunit peptide used as the immunogen is  
15 derived. Alternatively, an immunologically cross-reactive agent can be a different protein which is recognized in whole or in part by the antibodies elicited by the immunizing agent. Exemplary vaccines can be modified vaccinia viruses that express an immunologically cross-reactive agent.

          An oncolytic virus is a virus that preferentially replicates in, and kills,  
20 neoplastic or cancer cells. The virus can be a naturally-occurring virus or an engineered virus. Preferably, the virus is a modified vaccinia virus.

          As used herein, the phrase “immunoprivileged cells and tissues” refers to cells and tissues, such as solid tumors and wounded tissues, which are sequestered from the immune system.

25           As used herein, nanoparticle refers to a microscopic particle whose size is measured in nanometers. Often such particles in nanoscale are used in biomedical applications acting as drug carriers or imaging agents. Nanoparticles can be conjugated to other agents, including, but not limited to detectable/diagnostic agents or therapeutic agents.

30           As used herein, “a combination” refers to any association between two or among more items. Such combinations can be packaged as kits.

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As used herein, a composition refers to any mixture. It can be a solution, a suspension, an emulsion, liquid, powder, a paste, aqueous, non-aqueous or any combination of such ingredients.

As used herein, fluid refers to any composition that can flow. Fluids thus  
5 encompass compositions that are in the form of semi-solids, pastes, solutions, aqueous mixtures, gels, lotions, creams and other such compositions.

As used herein, a kit is a packaged combination, optionally, including instructions for use of the combination and/or other reactions and components for such use.

## 10 **B. METHODS FOR TREATMENT AND DIAGNOSIS**

Provided herein are uses of and methods of administering chemotherapeutic agents in combination with modified vaccinia viruses, and/or other viruses or therapeutic viral vectors, to a subject for treatment of diseases, such as cancer. In particular, the methods involve administration of chemotherapeutic agents in  
15 combination with viruses.

In particular, methods for ameliorating or reducing toxicity and/or side-effects associated with viral therapy of diseases such as cancer are provided. The methods employ intermediate doses of chemotherapeutic agents in combination with the viruses or viral vectors. Regimens that exploit this benefit are provided.  
20 Administration of intermediate dosages of chemotherapeutic agents at appropriate times or intervals during viral therapy can promote the arrest and shrinkage of neoplastic cell masses and solid or nonsolid tumors in patients, while reducing or preventing the patient from experiencing undesirable side effects or systemic toxicity that can result treatment with viruses or viral vectors. In certain embodiments, higher  
25 doses of chemotherapeutic agents can be administered to a patient who has received an injection of virus or viral vector for disease treatment.

For example, as described herein, low doses of chemotherapeutic agents (for example, approximately 10-50 mg/kg of gemcitabine), delivered to a subject treated with modified vaccinia viruses or other viral vectors, have been effective in arresting  
30 and/or inhibiting tumor cell growth. Higher doses of the chemotherapeutic agents (for example, approximately 100-200 mg/kg of gemcitabine) delivered in combination with administration of the virus or viral vector do not provide a more potent effect.

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The higher dose instead have a negative effect on viral titer. As described herein, the chemotherapeutic agents can interfere with the ability of the virus or viral vector to replicate. Without wishing to be bound by theory, it is believed that the mechanisms by which the agents control or shrink cancerous cell growths (*e.g.* inhibition of DNA transcription and replication) also contribute to interference of viral replication. Consequently, chemotherapeutic agents can be co-administered with the virus to control viral replication, thereby maintaining viral titers at a level that prevents a patient from experiencing side effects or symptoms associated with viral toxicity. Chemotherapeutic agents also can be administered to a patient who has received a dose of modified vaccinia virus for treatment of a disease. For example, a chemotherapeutic agent can be administered to a patient who experiences adverse effects or systemic toxicity following administration of the virus. In such case, the chemotherapeutic agent is delivered to the patient in order to elicit rapid clearance of the virus from the subject's body.

Exemplary methods provided herein include methods for treatment of a disease where a modified vaccinia virus is administered to a subject in combination with at least one dose of a chemotherapeutic agent, whereby the administration of agent with virus maintains or controls viral unit numbers, or viral titers, within the subject as compared to administration of the virus without the agent. In such methods, the subject is exposed to minimal physiological side effects associated with administration of the virus. In some embodiments, the virus is first administered to a patient, followed by regularly scheduled doses with a chemotherapeutic agent over a period of time. In further embodiments, the virus is first administered to a patient, followed by sustained release of a chemotherapeutic agent from a release vehicle placed within the patient. In some embodiments, the virus is administered concurrently with a chemotherapeutic agent in regularly scheduled doses to the patient over a period of time. In further embodiments, the virus is released concurrently with a chemotherapeutic agent from a sustained release vehicle placed within the patient.

Exemplary methods provided herein include methods to prevent the appearance of symptoms or side effects associated with administration of a modified vaccinia virus for treatment of a disease, by delivering a dose of a chemotherapeutic



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agent prior to administration of the virus to a subject. In some embodiments, a chemotherapeutic agent is first administered to a patient as a single dose before the virus is introduced. In other embodiments, a chemotherapeutic agent is administered to a patient as regularly scheduled doses before the virus is introduced. Subsequent  
5 administration of the virus can be as a single dose to the patient. The virus also can be introduced to the patient concurrently with the chemotherapeutic agent in one or more further regularly scheduled doses over a period of time.

Exemplary methods provided herein include methods to improve symptoms or side effects associated with delivery of a modified vaccinia virus to a subject for  
10 treatment of disease, by administration of a dose of chemotherapeutic agent to the subject for clearing the virus from the subject's body. In methods provided, the virus is administered in combination with a chemotherapeutic agent for controlling viral titer. The chemotherapeutic agent acts to control viral replication in the subject, which can minimize any immune response raised against the virus and prevent the  
15 subject from experiencing toxic side effects. For example, subjects who are immune-compromised can suffer side effects from uncontrolled replication of viruses, including modified vaccinia viruses delivered for treatment of a disease. Exemplary side effects or symptoms include, but are not limited to fever, abdominal pain, aches or pains in muscles, cough, diarrhea, or general feeling of discomfort or illness that  
20 are associated with virus toxicity and are related to the subject's immune and inflammatory responses to the virus. Exemplary side effects or symptoms can also include escalation of symptoms due to a systemic inflammatory response to the virus, such as, but not limited to, jaundice, blood-clotting disorders, generalized vaccinia, eczema vaccinatum, uncontrolled progressive vaccinia, encephalitis, multiple-organ  
25 system failure, and the like. Methods are also contemplated wherein the subject, when suffering from adverse side effects associated with modified vaccinia virus administered for treatment of a disease, is provided a chemotherapeutic agent to clear the virus from the subject's body, thereby alleviating symptoms or side effects associated with viral toxicity.

30 In addition, methods are herein provided for the optimization of dosage administration of a chemotherapeutic agent to a patient, wherein the agent is administered in combination with a modified vaccinia virus for treatment of a disease.

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The optimization of dosage administration is contemplated for targeting DNA replication in the modified vaccinia virus, such that viral replication is carefully controlled and side effects associated with the virus are reduced or minimized. The optimal dose of the chemotherapeutic agent is sufficiently high to lower the virus-associated side effects, such as for example, pock formation, weight loss, fever, abdominal pain, aches or pains in muscles, cough, diarrhea, and feeling of discomfort or illness. In addition, the optimal dose is within a range such that it does not adversely interfere the oncolytic therapeutic effects of the virus.

Optimized doses of a chemotherapeutic agent are contemplated wherein the virus is first administered to a patient, followed by regularly scheduled doses with the agent over a period of time. Methods are also provided wherein an optimized dose of chemotherapeutic agent wherein the virus is administered concurrently with the agent in regularly scheduled doses over a period of time. Methods are also provided wherein an optimized dose of chemotherapeutic agent wherein the agent is first administered to a patient as regularly scheduled doses before the virus is introduced and the virus is subsequently introduced as a single dose or administered concurrently with agent in further regularly scheduled doses to the patient over a period of time.

Further, methods are herein described wherein an optimized chemotherapeutic agent dosage is administered to a patient, wherein the agent is administered subsequent to delivery of a modified vaccinia virus to the patient for treatment of a disease, and wherein the agent is provided to clear the virus from the patient's body to reduce physiological toxicity effects associated with the virus. The optimized chemotherapeutic agent dosage is provided such that the subject, when suffering from adverse side effects due to administration of a modified vaccinia virus for treatment of a disease, is administered a chemotherapeutic agent to clear the virus from the subject's body, alleviating symptoms or side effects associated with viral toxicity.

In some embodiments, the methods provided can be used for treatment of a neoplastic disease. In some embodiments, the methods provided herein can be used for the treatment of cancer. In some embodiments, the methods provided can be used to inhibit or slow tumor cell growth. In some embodiments, the methods provided herein can be used to decrease or shrink tumor cell volume. In some examples, the tumor cells are lung, ovarian, breast or pancreatic tumor cells.

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Exemplary modified vaccinia viruses that can be used in the methods or uses provided include, but are not limited to, the recombinant vaccinia LVP strain GLV-1h68 (described in U.S. Pat. Pub. No. 2005-0031643, incorporated herein by reference in its entirety) and related strains GLV-1h22, GLV-1i69, GLV-1h70, GLV-1h71, GLV-1h72, GLV-1h73, GLV-1h74, GLV-1h81, GLV-1h82, GLV-1h83, GLV-1h84, GLV-1h85, GLV-1h86, GLV-1h90, GLV-1h91, GLV-1h92, GLV-1h96, GLV-1h97, GLV-1h98, GLV-1h99, GLV-1h100, GLV-1h101, GLV-1h104, GLV-1h105, GLV-1h106, GLV-1h107, GLV-1h108 and GLV-1h109, as described elsewhere herein.

Exemplary chemotherapeutic agents that can be used in the methods or uses provided include, but are not limited to cisplatin, gemcitabine, doxorubicin, irinotecan and 5'-fluorouracil.

As shown previously, solid tumors can be treated with therapeutic viruses, such as vaccinia viruses, resulting in an enormous tumor-specific virus replication, which can be used to produce large amounts of tumor protein antigen and viral protein in the tumors (U.S. Patent Publication No. 2005/0031643). Vaccinia virus administration to mice resulted in lysis of the infected tumor cells and a resultant release of tumor-cell-specific antigens. Continuous leakage of these antigens into the body led to a very high level of antibody titer (in approximately 7-14 days) against tumor proteins, viral proteins, and the virus encoded engineered proteins in the mice. The newly synthesized anti-tumor antibodies and the enhanced macrophage, neutrophils count were continuously delivered via the vasculature to the tumor and thereby provided for the recruitment of an activated immune system against the tumor. The activated immune system then eliminated the foreign compounds of the tumor including the viral particles. This interconnected release of foreign antigens boosted antibody production and continuous response of the antibodies against the tumor proteins to function like an autoimmunizing vaccination system initiated by vaccinia viral infection and replication, followed by cell lysis, protein leakage and enhanced antibody production. Thus, the therapeutic viruses provided herein can be administered, alone or in combination with a chemotherapeutic agent, in a complete process that can be applied to all tumor systems with immunoprivileged tumor sites as

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site of privileged viral growth, which can lead to tumor elimination by the host's own immune system.

In some embodiments, the therapeutic virus can act as an oncolytic virus. For example, the therapeutic virus can utilize multiple mechanisms of action to directly  
5 kill tumor and cancer cells, such as, for example, by cell lysis, cell apoptosis, anti-angiogenesis and cell necrosis. The virus can infect the tumor cell and begin to replicate. The virus continues to replicate until the membrane of the host cell lyses, or bursts, due to the inability of the tumor cell to contain the virus. The tumor cell is destroyed, and the newly created viruses can spread to neighboring cancer cells to  
10 continue the cycle. Preferably, the virus replicates only in cancer cells and leaves normal tissue unharmed.

Provided herein are therapeutic methods, including methods of treating and/or preventing disease or disorders associated with immunoprivileged cells or tissue, including cancerous cells, tumors and metastases. Such sites, diseases and disorders  
15 include sites of cell proliferation, proliferative conditions, neoplasms, tumors, neoplastic disease, wounds and inflammation. The therapeutic methods provided herein include, but are not limited to, administering a therapeutic virus provided herein to a subject containing a tumor and/or metastases, wherein the virus is administered alone or in combination with a chemotherapeutic agent. Viruses  
20 provided herein include viruses that have been modified as described herein and elsewhere. The administered viruses can possess one or more characteristics including, but not limited to, attenuated pathogenicity, low toxicity, preferential accumulation in tumor, ability to activate an immune response against tumor cells, immunogenicity, replication competence, ability to express exogenous genes, and  
25 ability to elicit antibody production against an expressed gene product.

In the methods provided, the chemotherapeutic agent is administered to control viral replication or viral titer of the administered therapeutic virus in a subject such that the subject to which the chemotherapeutic agent and therapeutic virus is administered experiences minimal side effects associated with the therapeutic virus.  
30 In some examples, the chemotherapeutic agent is administered to a subject to which a therapeutic virus has been administered whereby the chemotherapeutic agent decreases the viral titer in the subject. In other examples, the chemotherapeutic agent

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is administered to a subject to which a therapeutic virus has been administered whereby the chemotherapeutic agent eliminates or clears the virus from the subject. In some embodiments, the therapeutic viruses provided herein can be administered in combination with a chemotherapeutic agent to a subject such that the combination prevents the therapeutic virus from causing adverse side effects, systemic toxicity or disease in the subject.

The chemotherapeutic agent can be administered simultaneously in combination with the therapeutic virus or can be administered sequentially, prior to or following treatment with the therapeutic virus.

The chemotherapeutic agent can be administered in combination with or sequentially with the therapeutic virus to control viral replication or viral titer of the therapeutic virus in a subject in addition to treating a disease or disorder in the subject. In such methods, the chemotherapeutic agent contributes to the treatment of the disease or disorder as well as the control of viral replication or viral titer. The chemotherapeutic agent can also be administered separately to a patient for the treatment of a disease or disorder in the subject.

In some embodiments, the therapeutic viruses can accumulate in tumors or metastases. In some embodiments, the therapeutic methods provided herein inhibit tumor growth in a subject, where the methods include administering to a subject a therapeutic virus, alone or in combination with a chemotherapeutic agent, where the therapeutic virus can accumulate in a tumor and/or metastasis and can cause or enhance an anti-tumor response. In some embodiments, the administration of a therapeutic virus as provided herein, alone or in combination with a chemotherapeutic agent, results in a slowing or inhibition of tumor growth. In other embodiments, the administration of a therapeutic virus in combination with a chemotherapeutic agent as provided herein results in a decrease in tumor volume or elimination of the tumor from the subject. The therapeutic methods provided herein, however, do not require the administered combination of virus and chemotherapeutic agent to directly kill tumor cells or decrease the tumor size. Instead, the therapeutic methods provided herein include administering to a subject a therapeutic virus and chemotherapeutic agent where the therapeutic virus and/or the combination of the therapeutic virus with chemotherapeutic agent can cause or enhance an anti-tumor response in the subject.

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The anti-tumor response induced as a result of tumor or metastases-accumulated viruses can result in inhibition of tumor growth, a decrease in tumor volume and/or elimination of the tumor.

In some embodiments, the therapeutic viruses, alone or combination with a  
5 chemotherapeutic agent, can elicit an anti-tumor response in the subject, where typically the viral-mediated anti-tumor response can develop, for example, over several days, a week or more, 10 days or more, two weeks or more, or a month or more. In some exemplary methods, the therapeutic virus can be present in the tumor, and can cause an anti-tumor immune response without the virus itself causing enough  
10 tumor cell death to prevent tumor growth. In some embodiments, the tumor is a monotherapeutic tumor or monotherapeutic cancer, where the tumor or cancer does not decrease, or does not decrease significantly or satisfactorily in volume when treated with the therapeutic virus or a therapeutic agent alone.

In some embodiments, the anti-tumor response is a result of oncolysis of  
15 tumor cells by the administered virus and/or leakage of antigens from the lysed tumor cell, whereby the subject develops an immune response against the antigen. In other embodiments, the anti-tumor response is a result of leakage of antigens from the viral-infected tumor cell, whereby the subject develops an immune response against the antigen.

20 The methods provided herein include eliciting or enhancing antibody production against a selected antigen or a selected antigen type in a subject. For example, such methods include administering to a subject a therapeutic virus, alone or in combination with a chemotherapeutic agent, that can accumulate in a tumor and/or metastasis, and can cause release of a selected antigen or selected antigen type from  
25 the tumor, resulting in antibody production against the selected antigen or selected antigen type. Any of a variety of antigens can be targeted in the methods provided herein, including a selected antigen such as an exogenous gene product expressed by the virus, or a selected antigen type such as one or more tumor antigens released from the tumor as a result of viral infection of the tumor (*e.g.*, by lysis, apoptosis, secretion  
30 or other mechanism of causing antigen release from the tumor).

In some embodiments, it can be desirable to maintain release of the selected antigen or selected antigen type over a series of days, for example, at least a week, at

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least ten days, at least two weeks or at least a month. Provided herein are methods for providing a sustained antigen release within a subject, where the methods include administering to a subject a therapeutic virus, alone or in combination with a chemotherapeutic agent, whereby the virus accumulates in a tumor and/or metastasis, and can cause sustained release of an antigen, resulting in antibody production against the antigen. The sustained release of antigen can cause an immune response by the viral-infected host, in which the host can develop antibodies against the antigen and/or the host generates an immune response against cells expressing the antigen, including tumor cells expressing the antigen. In such methods, the viral-infect host can develop an immune response against tumor cells. Thus, the sustained release of antigen can result in immunization against tumor cells. In some embodiments, the anti-tumor immune response induced by the viral-mediated sustained release of antigen can result in complete removal or killing of all tumor cells. In some embodiments, the therapeutic virus is administered in combination with a chemotherapeutic agent, whereby an anti-tumor immune response is induced by the viral-mediated sustained release of antigen and where the chemotherapeutic agent is administered over a period of time (*e.g.*, repeated administration or sustained release) to control viral replication or viral titer, such that the virus does not cause adverse side effects, systemic toxicity or disease in the subject.

Such methods of antigen production or tumor and/or metastasis treatment can include administration of a therapeutic virus provided herein, alone or in combination with a chemotherapeutic agent, for therapy, such as for gene therapy, for cancer gene therapy, for oncolytic virotherapy, or for vaccine therapy. Such a virus can be used to stimulate humoral and/or cellular immune response, induce strong cytotoxic T lymphocytes responses in subjects who can benefit from such responses. For example, the virus can provide prophylactic and therapeutic effects against a tumor infected by the virus or other infectious diseases, by rejection of cells from tumors or lesions using viruses that express immunoreactive antigens (Earl *et al.*, *Science* 234: 728-831 (1986); Lathe *et al.*, *Nature* (London) 32: 878-880 (1987)), cellular tumor-associated antigens (Bernards *et al.*, *Proc. Natl. Acad. Sci. USA* 84: 6854-6858 (1987); Estin *et al.*, *Proc. Natl. Acad. Sci. USA* 85: 1052-1056 (1988); Kantor *et al.*, *J. Natl. Cancer Inst.* 84: 1084-1091 (1992); Roth *et al.*, *Proc. Natl. Acad. Sci. USA* 93:

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4781-4786 (1996)) and/or cytokines (e.g., IL-2, IL-12), costimulatory molecules (B7-1, B7-2) (Rao *et al.*, *J. Immunol.* 156: 3357-3365 (1996); Chamberlain *et al.*, *Cancer Res.* 56: 2832-2836 (1996); Oertli *et al.*, *J. Gen. Virol.* 77: 3121-3125 (1996); Qin and Chatterjee, *Human Gene Ther.* 7: 1853-1860 (1996); McAneny *et al.*, *Ann. Surg. Oncol.* 3: 495-500 (1996)), or other therapeutic proteins.

In some embodiments, the therapeutic methods provided herein inhibit growth or formation of a metastasis in a subject, where the methods include administering to a subject a therapeutic virus provided herein, alone or in combination with a chemotherapeutic agent, where the virus can accumulate in a tumor and/or metastasis and can cause or enhance an anti-tumor immune response. The anti-tumor immune response induced as a result of tumor or metastasis-accumulated viruses can result in inhibition of metastasis growth or formation. In some embodiments, the anti-tumor response is a result of oncolysis of tumor cells by the administered virus.

In other embodiments, the therapeutic methods provided herein decrease the size of a tumor and/or metastasis in a subject, where the methods include administering to a subject a therapeutic virus provided herein, alone or in combination with a chemotherapeutic agent, where the virus can accumulate in a tumor and/or metastasis and can cause or enhance an anti-tumor immune response. The anti-tumor immune response induced as a result of tumor or metastasis-accumulated viruses can result in a decrease in the size of the tumor and/or metastasis.

In some embodiments, the therapeutic methods provided herein eliminate a tumor and/or metastasis from a subject, where the methods include administering to a subject a therapeutic virus provided herein, alone or in combination with a chemotherapeutic agent, where the virus can accumulate in a tumor and/or metastasis and can cause or enhance an anti-tumor immune response. The anti-tumor immune response induced as a result of tumor or metastasis-accumulated viruses can result in elimination of the tumor and/or metastasis from the subject.

Furthermore, provided herein are methods of reducing or inhibiting tumor growth, inhibiting metastasis growth and/or formation, decreasing the size of a tumor or metastasis, eliminating a tumor or metastasis, or other tumor therapeutic methods, where the method includes administering to a subject a therapeutic virus provided herein, alone or in combination with a chemotherapeutic agent, where the virus



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accumulates in at least one tumor or metastasis and causes or enhances an anti-tumor immune response in the subject, and the immune response also is mounted against a tumor and/or metastasis in which the virus cell did not accumulate.

In another embodiment, methods are provided for inhibiting or preventing  
5 recurrence of a neoplastic disease or inhibiting or preventing new tumor growth,  
where the methods include administering to a subject a therapeutic virus provided  
herein, alone or in combination with a chemotherapeutic agent, where the virus can  
accumulate in a tumor and/or metastasis and can cause or enhance an anti-tumor  
immune response, which can inhibit or prevent recurrence of a neoplastic disease or  
10 inhibit or prevent new tumor growth.

The therapeutic methods provided herein for the treatment of tumor or  
neoplastic disease, such as, for example, methods of reducing or inhibiting tumor  
growth, inhibiting metastasis growth and/or formation, decreasing the size of a tumor  
or metastasis, eliminating a tumor or metastasis, or other tumor therapeutic methods,  
15 also can include administering to a subject a therapeutic virus provided herein, alone  
or in combination with a chemotherapeutic agent, where the virus can cause tumor  
cell lysis or tumor cell death. In such methods, the virus can cause tumor cell lysis or  
tumor cell death and also can cause or enhance an anti-tumor immune response in the  
subject. Viruses, such as the therapeutic viruses provided herein, can cause cell lysis  
20 or tumor cell death as a result of expression of an endogenous gene or as a result of an  
exogenous gene. Endogenous or exogenous genes can cause tumor cell lysis or  
inhibit cell growth as a result of direct or indirect actions, as is known in the art,  
including lytic channel formation or activation of an apoptotic pathway. Gene  
products, such as exogenous gene products can function to activate a prodrug to an  
25 active, cytotoxic form, resulting in cell death where such genes are expressed.

In one embodiment, the tumor treated is a cancer such as pancreatic cancer,  
non-small cell lung cancer, ovarian cancer, breast cancer, prostate cancer, multiple  
myeloma, or leukemia, although the cancer is not limited in this respect, and other  
metastatic diseases can be treated by the combinations provided herein. For example,  
30 the tumor treated can be a solid tumor, such as of the lung and bronchus, breast, colon  
and rectum, kidney, stomach, esophagus, liver and intrahepatic bile duct, urinary  
bladder, brain and other nervous system, head and neck, oral cavity and pharynx,

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cervix, uterine corpus, thyroid, ovary, testes, prostate, malignant melanoma, cholangiocarcinoma, thymoma, non-melanoma skin cancers, as well as hematologic tumors and/or malignancies, such as childhood leukemia and lymphomas, multiple myeloma, Hodgkin's disease, lymphomas of lymphocytic and cutaneous origin, acute and chronic leukemia such as acute lymphoblastic, acute myelocytic or chronic myelocytic leukemia, plasma cell neoplasm, lymphoid neoplasm and cancers associated with AIDS. Exemplary tumors include, for example, pancreatic tumors, ovarian tumors, lung tumors, colon tumors, prostate tumors, cervical tumors and breast tumors. In one embodiment, the tumor is a carcinoma such as, for example, an ovarian tumor or a pancreatic tumor.

### 1. Administration

In performing the therapeutic methods provided herein, a therapeutic virus can be administered, alone or in combination with a chemotherapeutic agent, to a subject. Exemplary subjects to whom a therapeutic virus can be administered include a subject having a tumor, metastases, neoplastic cells, wounded or inflamed tissue or a subject to be immunized. An administered therapeutic virus can be a virus provided herein or any other virus generated using the methods provided herein. In some embodiments, the therapeutic virus administered is a virus that exhibits a characteristic, such as attenuated pathogenicity, low toxicity, preferential accumulation in tumor, ability to activate an immune response against tumor cells, high immunogenicity, replication competence, and ability to express exogenous proteins and combinations thereof.

In some embodiments, one or more steps can be performed prior to administration of the therapeutic virus to the subject. Any of a variety of preceding steps can be performed, including, but not limited to, diagnosing the subject with a condition appropriate for virus administration, determining the immunocompetence of the subject, immunizing the subject, treating the subject with a chemotherapeutic agent, treating the subject with radiation, or surgically treating the subject. Therapeutic methods or steps performed prior to administration of the therapeutic virus to the subject are well known in the art and are described elsewhere, for example, in U.S. Patent Publication No. 2005-0031643 and U.S. Application Serial Nos. 11/975,088 and 11/975,090.

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Any mode of administration of a virus to a subject can be used, provided the mode of administration permits the virus to enter a tumor or metastasis. Modes of administration can include, but are not limited to, intravenous, intraperitoneal, subcutaneous, intramuscular, transdermal, intradermal, intra-arterial (*e.g.*, hepatic artery infusion), intravesicular perfusion, intrapleural, intraarticular, topical, intratumoral, intralesional, multipuncture (*e.g.*, as used with smallpox vaccines), inhalation, percutaneous, subcutaneous, intranasal, intratracheal, oral, intracavity (*e.g.*, administering to the bladder via a catheter, administering to the gut by suppository or enema), vaginal, rectal, intracranial, intraprostatic, intravitreal, aural, or ocular administration.

Also provided are methods in which an additional therapeutic agent, such as an additional therapeutic virus or a therapeutic compound is administered. These can be administered simultaneously, sequentially or intermittently with the first therapeutic virus. The additional therapeutic agent can interact with the virus or a gene product thereof, or the additional therapeutic agent can act independently of the virus.

One skilled in the art can select any mode of administration compatible with the subject and the virus, which is administered alone or in combination with a chemotherapeutic agent, and that also is likely to result in the virus reaching tumors and/or metastases. The route of administration can be selected by one skilled in the art according to any of a variety of factors, including the nature of the disease, the kind of tumor, and the particular virus to be administered. Administration to the target site can be performed, for example, by direct injection into a tumor or by systemic administration at a site distal to the tumor, such as by injection into the bloodstream (*e.g.*, artery or vein) or other parenteral route or by ballistic delivery, such as a colloidal dispersion system. Typically, the therapeutic viruses provided herein are administered systemically.

**a. Virus Administration and Dosages**

The dosage regimen can be any of a variety of methods of administration and amounts of each administered agent, and can be determined by one skilled in the art according to known clinical factors. As is known in the medical arts, dosages for any one patient can depend on many factors, including the subject's species, size, body

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surface area, age, sex, immunocompetence, and general health, the particular therapeutic virus to be administered, duration and route of administration, the kind and stage of the disease, for example, tumor size, and other treatments or compounds, such as chemotherapeutic agents that are administered concurrently. In addition to the above factors, such levels can be affected by the infectivity of the virus, and the nature of the virus, as can be determined by one skilled in the art. In the present methods, appropriate minimum dosage levels of viruses can be levels sufficient for the virus to survive, grow and replicate in a tumor or metastasis. Exemplary minimum levels for administering a virus to a 65 kg human can include at least about  $1 \times 10^5$  plaque forming units (PFU), at least about  $5 \times 10^5$  PFU, at least about  $1 \times 10^6$  PFU, at least about  $5 \times 10^6$  PFU, at least about  $1 \times 10^7$  PFU, at least about  $1 \times 10^8$  PFU, at least about  $1 \times 10^9$  PFU, or at least about  $1 \times 10^{10}$  PFU. In the present methods, appropriate maximum dosage levels of viruses can be levels that are not toxic to the host, levels that do not cause splenomegaly of 3 times or more, levels that do not result in colonies or plaques in normal tissues or organs after about 1 day or after about 3 days or after about 7 days. Exemplary maximum levels for administering a virus to a 65 kg human can include no more than about  $1 \times 10^{11}$  PFU, no more than about  $5 \times 10^{10}$  PFU, no more than about  $1 \times 10^{10}$  PFU, no more than about  $5 \times 10^9$  PFU, no more than about  $1 \times 10^9$  PFU, or no more than about  $1 \times 10^8$  PFU.

**b. Chemotherapeutic Agent Administration Dosage**

For combination therapies with chemotherapeutic compounds, dosages for the administration of such compounds are known in the art or can be determined by one skilled in the art according to known clinical factors (*e.g.*, subject's species, size, body surface area, age, sex, immunocompetence, and general health, duration and route of administration, the kind and stage of the disease, for example, tumor size, and other viruses, treatments, or compounds, such as other chemotherapeutic drugs, being administered concurrently). In addition to the above factors, such levels can be affected by the infectivity of the virus, and the nature of the virus, as can be determined by one skilled in the art.

One skilled in the art can select any mode of administration compatible with the chemotherapeutic agent to be administered including, but not limited to systemic

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or local injection. Exemplary methods of administration include, but are not limited to, systemically, intravenously, intraarterially, intratumorally, endoscopically, intralesionally, intramuscularly, intradermally, intraperitoneally, intravesicularly, intraarticularly, intrapleurally, percutaneously, subcutaneously, orally, parenterally, 5 intranasally, intratracheally, by inhalation, intracranially, intraprostatically, intravitreally, topically, ocularly, vaginally, or rectally. When administered simultaneously with the therapeutic virus, the chemotherapeutic agents typically are administered by the same route, but can be administered by a different route.

**i. Gemcitabine Dosage and Administration**

10 Gemcitabine (GEMZAR<sup>®</sup>) is a nucleoside analogue that exhibits antitumor activity. Gemcitabine is employed in the therapy of breast cancer, non-small cell lung cancer and pancreatic cancer. Methods of employing gemcitabine clinically are well known in the art. For example, for the treatment of pancreatic cancer, gemcitabine has been administered by intravenous infusion at a dose of 1000 mg/m<sup>2</sup> over 30 15 minutes once weekly for up to 7 weeks (or until toxicity necessitates reducing or holding a dose), followed by a week of no treatment. Subsequent cycles can consist of infusions once weekly for 3 consecutive weeks out of every 4 weeks. Gemcitabine has also been employed in combination with cisplatin in cancer therapy.

In one exemplary embodiment, a therapeutic virus, such as a modified 20 vaccinia virus, is administered to a subject for the treatment of a tumor or metastasis about once, twice, three times or four times with approximately 0-60 days between each administration, followed by approximately 1-30 days where no anti-cancer treatment is administered, then gemcitabine is administered about once, twice, three times, four times, five times, six times or seven times with approximately 0-30 days 25 between each administration, followed by approximately 1-30 days where no anti-cancer treatment is administered. Such treatment scheme can be repeated.

In another exemplary embodiment, gemcitabine is administered 1-7 times with approximately 0-30 days between each administration, followed by approximately 1- 10 days where no anti-cancer treatment is administered, then the mutant vaccinia 30 virus is administered once or 2-4 times with approximately 0-60 days between each administration. This is followed by approximately 5-60 days where no anti-cancer treatment is administered. Such treatment scheme can be repeated.

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In another exemplary embodiment, gemcitabine is administered 1-7 times with approximately 0-30 days between each administration, followed by approximately 1-10 days where no anti-cancer treatment is administered, then the mutant vaccinia virus is administered once or 2-4 times with approximately 0-60 days between each administration. This is followed by approximately 5-60 days where no anti-cancer treatment is administered, then gemcitabine is administered again for 1-7 times with approximately 0-30 days between each administration. Such treatment scheme can be repeated.

In another exemplary embodiment, gemcitabine is first administered to a patient 1-7 times with approximately 0-30 days between each administration, followed by approximately 1-30 days where no anti-cancer treatment is administered. The mutant vaccinia virus is then administered once or 2-4 times with approximately 0-60 days between each administration, followed by approximately 1-30 days where no anti-cancer treatment is administered, then gemcitabine is administered 1-7 times with approximately 0-30 days between each administration, followed by approximately 1-30 days where no anti-cancer treatment is administered. Such treatment scheme can be repeated.

In another exemplary embodiment, gemcitabine is first administered to a patient 1-7 times with approximately 0-30 days between each administration, followed by approximately 1-10 days where no anti-cancer treatment is administered, then the mutant vaccinia virus is administered once or 2-4 times with approximately 0-60 days between each administration. This is followed by approximately 5-60 days where no anti-cancer treatment is administered. Such treatment scheme can be repeated.

In another exemplary embodiment, gemcitabine is first administered to a patient 1-7 times with approximately 0-30 days between each administration, followed by approximately 1-10 days where no anti-cancer treatment is administered, then the mutant vaccinia virus is administered once or 2-4 times with approximately 0-60 days between each administration. This is followed by approximately 5-60 days where no anti-cancer treatment is administered, then gemcitabine is administered again for 1-7 times with approximately 0-30 days between each administration. Such treatment scheme can be repeated.

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In another exemplary embodiment, the mutant vaccinia virus is administered once or 2-4 times with approximately 0-60 days between each administration, followed by approximately 1-30 days where no anti-cancer treatment is administered. Symptoms associated with virus toxicity or with a virus-induced disease state appear in the patient, wherein the appearance of symptoms results from virus administration. Gemcitabine is then administered 1-7 times with approximately 0-30 days between each administration, followed by approximately 1-30 days where no anti-cancer treatment is administered. Such treatment scheme can be repeated.

**ii. Irinotecan Dosage and Administration**

Irinotecan (Camptosar<sup>®</sup>) is a compound primarily employed in the therapy of colon cancer, particularly in combination with other chemotherapy agents such as 5-FU and leucovorin. Irinotecan is a topoisomerase 1 inhibitor, which leads to inhibition of both DNA replication and transcription.

Methods of employing irinotecan clinically are well known in the art and are recommended over a dose range of from about 50 to about 350 mg/m<sup>2</sup>. For example, irinotecan has been administered by intravenous infusion at about 350 mg/m<sup>2</sup> over a 30 minute period once every three weeks for up to 4 months (or until toxicity necessitates reducing or holding a dose) for colorectal cancer. Irinotecan has also been administered by intravenous infusion at doses ranging from about 100 to 150 mg/m<sup>2</sup> over a 90 minute period once weekly for 4 weeks, followed by a 2-week rest period; subsequent 6-week cycles were then repeated over a period of between 3 to 5 months. Irinotecan has also been employed in combination with 5-FU and leucovorin in colorectal cancer therapy.

In one exemplary embodiment, the mutant vaccinia virus is administered once or 2-4 times with 0-60 days between each administration, followed by 1-30 days where no anti-cancer treatment is administered, then irinotecan is administered 1-7 times with 0-30 days between each administration, followed by 1-30 days where no anti-cancer treatment is administered. Such treatment scheme can be repeated. In another exemplary embodiment, irinotecan is administered 1-7 times with 0-30 days between each administration, followed by 1-10 days where no anti-cancer treatment is administered, then the mutant vaccinia virus is administered once or 2-4 times with 0-60 days between each administration. This is followed by 5-60 days where no anti-

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cancer treatment is administered. Such treatment scheme can be repeated. In another exemplary embodiment, irinotecan is administered 1-7 times with 0-30 days between each administration, followed by 1-10 days where no anti-cancer treatment is administered, then the mutant vaccinia virus is administered once or 2-4 times with 0-60 days between each administration. This is followed by 5-60 days where no anti-cancer treatment is administered, then irinotecan is administered again for 1-7 times with 0-30 days between each administration. Such treatment scheme can be repeated.

In another exemplary embodiment, irinotecan is first administered to a patient 1-7 times with 0-30 days between each administration, followed by 1-30 days where no anti-cancer treatment is administered. The mutant vaccinia virus is then administered once or 2-4 times with 0-60 days between each administration, followed by 1-30 days where no anti-cancer treatment is administered, then irinotecan is administered 1-7 times with 0-30 days between each administration, followed by 1-30 days where no anti-cancer treatment is administered. Such treatment scheme can be repeated. In another exemplary embodiment, irinotecan is first administered to a patient 1-7 times with 0-30 days between each administration, followed by 1-10 days where no anti-cancer treatment is administered, then the mutant vaccinia virus is administered once or 2-4 times with 0-60 days between each administration. This is followed by 5-60 days where no anti-cancer treatment is administered. Such treatment scheme can be repeated. In another exemplary embodiment, irinotecan is first administered to a patient 1-7 times with 0-30 days between each administration, followed by 1-10 days where no anti-cancer treatment is administered, then the mutant vaccinia virus is administered once or 2-4 times with 0-60 days between each administration. This is followed by 5-60 days where no anti-cancer treatment is administered, then irinotecan is administered again for 1-7 times with 0-30 days between each administration. Such treatment scheme can be repeated.

In another exemplary embodiment, the mutant vaccinia virus is administered once or 2-4 times with 0-60 days between each administration, followed by 1-30 days where no anti-cancer treatment is administered. Symptoms associated with virus toxicity or with a virus-induced disease state appear in the patient, wherein the appearance of symptoms results from virus administration. Irinotecan is then administered 1-7 times with 0-30 days between each administration, followed by 1-30



days where no anti-cancer treatment is administered. Such treatment scheme can be repeated.

### iii. Doxorubicin Dosage Regimens

Doxorubicin is a DNA-interacting drug that is widely used in chemotherapy. It is an anthracycline antibiotic that is structurally related to daunomycin, which also intercalates DNA. The interactions between doxorubicin and DNA appear to interfere with the action of topoisomerase II, thus leading to inhibition of DNA replication and transcription.

Methods of employing doxorubicin clinically are well known in the art and are recommended over a dose range of from about 30 to about 75 mg/m<sup>2</sup>. For example, doxorubicin has been administered by intravenous infusion at about 60 to about 75 mg/m<sup>2</sup> over a 30 minute period once every three weeks to four weeks until toxicity necessitates reducing or holding a dose.

In one exemplary embodiment, the mutant vaccinia virus is administered once or 2-4 times with 0-60 days between each administration, followed by 1-30 days where no anti-cancer treatment is administered, then doxorubicin is administered 1-7 times with 0-30 days between each administration, followed by 1-30 days where no anti-cancer treatment is administered. Such treatment scheme can be repeated. In another exemplary embodiment, doxorubicin is administered 1-7 times with 0-30 days between each administration, followed by 1-10 days where no anti-cancer treatment is administered, then the mutant vaccinia virus is administered once or 2-4 times with 0-60 days between each administration. This is followed by 5-60 days where no anti-cancer treatment is administered. Such treatment scheme can be repeated. In another exemplary embodiment, doxorubicin is administered 1-7 times with 0-30 days between each administration, followed by 1-10 days where no anti-cancer treatment is administered, then the mutant vaccinia virus is administered once or 2-4 times with 0-60 days between each administration. This is followed by 5-60 days where no anti-cancer treatment is administered, then doxorubicin is administered again for 1-7 times with 0-30 days between each administration. Such treatment scheme can be repeated.

In another exemplary embodiment, doxorubicin is first administered to a patient 1-7 times with 0-30 days between each administration, followed by 1-30 days where no anti-cancer treatment is administered. The mutant vaccinia virus is then

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administered once or 2-4 times with 0-60 days between each administration, followed by 1-30 days where no anti-cancer treatment is administered, then doxorubicin is administered 1-7 times with 0-30 days between each administration, followed by 1-30 days where no anti-cancer treatment is administered. Such treatment scheme can be repeated. In another exemplary embodiment, doxorubicin is first administered to a patient 1-7 times with 0-30 days between each administration, followed by 1-10 days where no anti-cancer treatment is administered, then the mutant vaccinia virus is administered once or 2-4 times with 0-60 days between each administration. This is followed by 5-60 days where no anti-cancer treatment is administered. Such treatment scheme can be repeated. In another exemplary embodiment, doxorubicin is first administered to a patient 1-7 times with 0-30 days between each administration, followed by 1-10 days where no anti-cancer treatment is administered, then the mutant vaccinia virus is administered once or 2-4 times with 0-60 days between each administration. This is followed by 5-60 days where no anti-cancer treatment is administered, then doxorubicin is administered again for 1-7 times with 0-30 days between each administration. Such treatment scheme can be repeated.

In another exemplary embodiment, the mutant vaccinia virus is administered once or 2-4 times with 0-60 days between each administration, followed by 1-30 days where no anti-cancer treatment is administered. Symptoms associated with virus toxicity or with a virus-induced disease state appear in the patient, wherein the appearance of symptoms results from virus administration. Doxorubicin is then administered 1-7 times with 0-30 days between each administration, followed by 1-30 days where no anti-cancer treatment is administered. Such treatment scheme can be repeated.

#### iv. Cisplatin Dosage Regimens

Cisplatin (also known as cisplatinum and CDDP) is a platinum-based chemotherapy that acts by crosslinking DNA, making it difficult for dividing cells to duplicate their DNA during mitosis.

Methods of employing cisplatin clinically are well known in the art and are recommended over a dose range of from about 20 mg/m<sup>2</sup> to about 140 mg/m<sup>2</sup>. For example, cisplatin has been administered by intravenous infusion at about 20 mg/m<sup>2</sup> over at least a one hour period, typically over a 6- to 8 hour period, daily for 5 days

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per cycle for testicular cancer. Cisplatin has also been administered by intravenous infusion at about 75 mg/m<sup>2</sup> to about 100 mg/m<sup>2</sup> over at least a one hour period, typically over a 6- to 8-hour period, once every four weeks (until toxicity necessitates reducing or holding a dose) for ovarian cancer. The cisplatin can be administered in combination with another chemotherapeutic agent or as a single agent. In addition, cisplatin has been administered as a single agent by intravenous infusion at about 50 mg/m<sup>2</sup> to about 70 mg/m<sup>2</sup> over at least a one hour period, typically over a 6- to 8-hour period, once every three to four weeks (until toxicity necessitates reducing or holding a dose ) for bladder cancer.

10 In one exemplary embodiment, the mutant vaccinia virus is administered once or 2-4 times with 0-60 days between each administration, followed by 1-30 days where no anti-cancer treatment is administered, then cisplatin is administered 1-7 times with 0-30 days between each administration, followed by 1-30 days where no anti-cancer treatment is administered. Such treatment scheme can be repeated. In 15 another exemplary embodiment, cisplatin is administered 1-7 times with 0-30 days between each administration, followed by 1-10 days where no anti-cancer treatment is administered, then the mutant vaccinia virus is administered once or 2-4 times with 0-60 days between each administration. This is followed by 5-60 days where no anti-cancer treatment is administered. Such treatment scheme can be repeated. In another 20 exemplary embodiment, cisplatin is administered 1-7 times with 0-30 days between each administration, followed by 1-10 days where no anti-cancer treatment is administered, then the mutant vaccinia virus is administered once or 2-4 times with 0-60 days between each administration. This is followed by 5-60 days where no anti-cancer treatment is administered, then cisplatin is administered again for 1-7 times 25 with 0-30 days between each administration. Such treatment scheme can be repeated.

In another exemplary embodiment, cisplatin is first administered to a patient 1-7 times with 0-30 days between each administration, followed by 1-30 days where no anti-cancer treatment is administered. The mutant vaccinia virus is then administered once or 2-4 times with 0-60 days between each administration, followed 30 by 1-30 days where no anti-cancer treatment is administered, then cisplatin is administered 1-7 times with 0-30 days between each administration, followed by 1-30 days where no anti-cancer treatment is administered. Such treatment scheme can be

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repeated. In another exemplary embodiment, cisplatin is first administered to a patient 1-7 times with 0-30 days between each administration, followed by 1-10 days where no anti-cancer treatment is administered, then the mutant vaccinia virus is administered once or 2-4 times with 0-60 days between each administration. This is followed by 5-60 days where no anti-cancer treatment is administered. Such treatment scheme can be repeated. In another exemplary embodiment, cisplatin is first administered to a patient 1-7 times with 0-30 days between each administration, followed by 1-10 days where no anti-cancer treatment is administered, then the mutant vaccinia virus is administered once or 2-4 times with 0-60 days between each administration. This is followed by 5-60 days where no anti-cancer treatment is administered, then cisplatin is administered again for 1-7 times with 0-30 days between each administration. Such treatment scheme can be repeated.

In another exemplary embodiment, the mutant vaccinia virus is administered once or 2-4 times with 0-60 days between each administration, followed by 1-30 days where no anti-cancer treatment is administered. Symptoms associated with virus toxicity or with a virus-induced disease state appear in the patient, wherein the appearance of symptoms results from virus administration. Cisplatin is then administered 1-7 times with 0-30 days between each administration, followed by 1-30 days where no anti-cancer treatment is administered. Such treatment scheme can be repeated.

As will be understood by one of skill in the art, the optimal treatment regimen will vary and it is within the scope of the treatment methods to evaluate the status of the disease under treatment and the general health of the patient prior to, and following one or more cycles of combination therapy in order to determine the optimal therapeutic combination.

## **2. Number of administrations**

The methods provided herein can include a single administration of a virus, alone or in combination with a chemotherapeutic agent, to a subject or multiple administrations of a virus to a subject. In some embodiments, a single administration is sufficient to establish a virus in a tumor, where the virus can proliferate and can cause or enhance an anti-tumor response in the subject; such methods do not require additional administrations of a virus in order to cause or enhance an anti-tumor

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response in a subject, which can result, for example in inhibition of tumor growth, inhibition of metastasis growth or formation, reduction in tumor or size, elimination of a tumor or metastasis, inhibition or prevention of recurrence of a neoplastic disease or new tumor formation, or other cancer therapeutic effects. In other embodiments, a virus can be administered on different occasions, alone or in combination with a chemotherapeutic agent, separated in time typically by at least one day. Separate administrations can increase the likelihood of delivering a virus to a tumor or metastasis, where a previous administration has been ineffective in delivering a virus to a tumor or metastasis. Separate administrations can increase the locations on a tumor or metastasis where virus proliferation can occur or can otherwise increase the titer of virus accumulated in the tumor, which can increase the scale of release of antigens or other compounds from the tumor in eliciting or enhancing a host's anti-tumor immune response, and also can, optionally, increase the level of virus-based tumor lysis or tumor cell death. Separate administrations of a virus can further extend a subject's immune response against viral antigens, which can extend the host's immune response to tumors or metastases in which viruses have accumulated, and can increase the likelihood of a host mounting an anti-tumor immune response. In other embodiments, a virus can be administered on different occasions, wherein the virus is sometimes administered alone and at other times administered with a chemotherapeutic agent, separated in time typically by at least one day.

When separate administrations are performed, each administration can be a dosage amount that is the same or different relative to other administration dosage amounts. Dosage amount can refer to dosage of virus, dosage of chemotherapeutic agent, or dosage of both. In one embodiment, all administration dosage amounts are the same. In other embodiments, a first dosage amount, with respect to the dosage of virus, dosage of chemotherapeutic agent, or dosage of both, can be a larger dosage amount than one or more subsequent dosage amounts, for example, at least 10x larger, at least 100x larger, or at least 1000x larger than subsequent dosage amounts. Any combination of dosage amount for the virus, either administered alone or in combination with a chemotherapeutic agent, is contemplated. In one example of a method of separate administrations in which a virus is administered alone or in combination with a chemotherapeutic agent, the first virus dosage amount is greater

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than one or more subsequent virus dosage amounts, and all subsequent dosage amounts can be the same, smaller amount relative to the first administration. In another example of a method of separate administrations in which a virus is in combination with a chemotherapeutic agent, the first chemotherapeutic agent dosage amount is greater than one or more subsequent agent dosage amounts, and all subsequent dosage amounts can be the same, smaller amount relative to the first administration. In another example of a method of separate administrations in which a virus is in combination with a chemotherapeutic agent, the first virus dosage amount and first chemotherapeutic agent dosage amount are both greater than one or more subsequent virus and agent dosage amounts, and all subsequent virus and agent dosage amounts can be the same, smaller amount relative to the first administration.

Separate administrations can include any number of two or more administrations, including two, three, four, five, six, seven, eight, nine, ten or more administrations. One skilled in the art can readily determine the number of administrations to perform or the desirability of performing one or more additional administrations according to methods known in the art for monitoring therapeutic methods and other monitoring methods provided herein. Accordingly, the methods provided herein include methods of providing to the subject one or more administrations of a virus, alone or in combination with a chemotherapeutic agent, where the number of administrations can be determined by monitoring the subject, and, based on the results of the monitoring, determining whether or not to provide one or more additional administrations. Deciding on whether or not to provide one or more additional administrations can be based on a variety of monitoring results, including, but not limited to, indication of tumor growth or inhibition of tumor growth, appearance of new metastases or inhibition of metastasis, the subject's anti-virus antibody titer, the subject's anti-tumor antibody titer, the overall health of the subject, the weight of the subject, the presence of virus solely in tumor and/or metastases, the presence of virus in normal tissues or organs.

The time period between administrations can be any of a variety of time periods. The time period between administrations can be a function of any of a variety of factors, including monitoring steps, as described in relation to the number

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of administrations, the time period for a subject to mount an immune response, the time period for a subject to clear the virus from normal tissue, or the time period for virus proliferation in the tumor or metastasis. As described in U.S. Patent Publication No. 2005-0031643 and U.S. Provisional Application No. 60/852,390, one of skill in  
5 the art can determine the time period between administrations.

### 3. Co-administrations

Any therapeutic or anti-cancer agent can be used as the second, therapeutic or anti-cancer agent in the combined cancer treatment methods provided herein. The methods can include administering one or more therapeutic compounds to the subject  
10 in addition to administering a virus or plurality thereof to a subject. Therapeutic compounds can act independently, or in conjunction with the virus, for tumor therapeutic effects.

Therapeutic compounds that act in conjunction with the viruses include, for example, compounds that alter the expression of the viruses or compounds that can  
15 interact with a virally-expressed gene, or compounds that can inhibit virus proliferation, including compounds toxic to the virus. Therapeutic compounds that can act in conjunction with the virus include, for example, therapeutic compounds that increase the proliferation, toxicity, tumor cell killing, or immune response eliciting properties of a virus, and also can include, for example, therapeutic compounds that  
20 decrease the proliferation, toxicity, or cell killing properties of a virus. Optionally, the therapeutic agent can exhibit or manifest additional properties, such as, properties that permit its use as an imaging agent, as described elsewhere herein.

Therapeutic compounds also include, but are not limited to, chemotherapeutic agents, nanoparticles, radiation therapy, siRNA molecules, enzyme/pro-drug pairs,  
25 photosensitizing agents, toxins, microwaves, a radionuclide, an angiogenesis inhibitor, a mitosis inhibitor protein (e.g., cdc6), an antitumor oligopeptide (e.g., antimitotic oligopeptides, high affinity tumor-selective binding peptides), a signaling modulator, anti-cancer antibiotics, or a combination thereof.

Toxins include, but are not limited to, chemotherapeutic compounds such as,  
30 but not limited to, 5-fluorouridine, calicheamicin and maytansine. Signaling modulators include, but are not limited to, for example, inhibitors of macrophage inhibitory factor, toll-like receptor agonists and stat 3 inhibitors. In one embodiment,

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a vaccinia virus, such as a vaccinia virus provided herein, is administered to a subject having a tumor, cancer or metastasis in combination with a toxin or a signaling modulator.

Chemotherapeutic compounds include, but are not limited to, alkylating agents  
5 such as thiotepa and cyclophosphamide; alkyl sulfonates such as busulfan,  
improsulfan and piposulfan; aziridines such as benzodopa, carboquone, meturedopa  
and uredopa; ethylenimines and methylamelamines including altretamine,  
triethylenemelamine, trietylenephosphoramidate, triethylenethiophosphoramidate and  
10 trimethylolmelamine nitrogen mustards such as chlorambucil, chlornaphazine,  
cholophosphamide, estramustine, ifosfamide, mechlorethamine, mechlorethamine  
oxide hydrochloride, melphalan, novembichin, phenesterine, prednimustine,  
trofosfamide, uracil mustard; nitrosureas such as carmustine, chlorozotocin,  
fotemustine, lomustine, nimustine, ranimustine; antibiotics such as aclacinomysins,  
actinomycin, anthramycin, azaserine, bleomycins, cactinomycin, calicheamicin,  
15 carabycin, carminomycin, carzinophilin, chromomycins, dactinomycin, daunorubicin,  
detorubicin, 6-diazo-5-oxo-L-norleucine, doxorubicin, epirubicin, esorubicin,  
idarubicin, marcellomycin, mitomycins, mycophenolic acid, nogalamycin,  
olivomycins, peplomycin, potfiromycin, puromycin, quelamycin, rodorubicin,  
streptonigrin, streptozocin, tubercidin, ubenimex, zinostatin, zorubicin; anti-  
20 metabolites such as methotrexate and 5-fluorouracil (5-FU®); folic acid analogues  
such as denopterin, methotrexate, pteropterin, trimetrexate; purine analogs such as  
fludarabine, 6-mercaptopurine, thiamiprine, thioguanine; pyrimidine analogs such as  
ancitabine, azacitidine, 6-azauridine, carmofur, cytarabine, dideoxyuridine,  
doxifluridine, enocitabine, floxuridine; androgens such as calusterone,  
25 dromostanolone propionate, epitiostanol, mepitiothane, testolactone; anti-adrenals  
such as aminoglutethimide, mitotane, trilostane; folic acid replenishers such as  
frolinic acid; aceglatone; aldophosphamide glycoside; aminolevulinic acid;  
amsacrine; bestrabucil; bisantrene; edatraxate; defofamine; demecolcine; diaziquone;  
elfornithine; elliptinium acetate; etoglucid; gallium nitrate; hydroxyurea; lentinan;  
30 lonidamine; mitoguazone; mitoxantrone; mopidamol; nitracrine; pentostatin;  
phenamet; pirarubicin; podophyllinic acid; 2-ethylhydrazide; procarbazine;  
polysaccharide-K; razoxane; sizofiran; spirogermanium; tenuazonic acid; triaziquone;



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2, 2',2''-trichlorotriethylamine; urethan; vindesine; dacarbazine; mannomustine; mitobronitol; mitolactol; pipobroman; gacytosine; cytosine arabinoside; cyclophosphamide; thiotepa; taxoids, e.g., paclitaxel and doxorubicin; chlorambucil; gemcitabine; 6-thioguanine; mercaptopurine; methotrexate; platinum analogs such as cisplatin, carboplatin and oxaliplatin; vinblastine; platinum; etoposide (VP-16); ifosfamide; mitomycin C; mitoxantrone; vincristine; vinorelbine; navelbine; novantrone; teniposide; daunomycin; aminopterin; xeloda; ibandronate; CPT11; topoisomerase inhibitor RFS 2000; difluoromethylornithine (DMFO); retinoic acid; esperamicins; capecitabine; interleukin 2; cladribine; denileukin diftitox; docetaxel; exemestane; gemtuzumab ozogamicin; interferon alfa-2a; interferon alfa-2b; interferon gamma-1b; isotretinoin; letrozole; mechlorethamine HCL; megestrol; mercaptopurine; pegaspargase; plicamycin; temozolomide, tretinoin, valrubicin, and pharmaceutically acceptable salts, acids or derivatives of any of the above. Also included are anti-hormonal agents that act to regulate or inhibit hormone action on tumors such as anti-estrogens including for example tamoxifen, raloxifene, aromatase inhibiting 4(5)-imidazoles, 4-hydroxytamoxifen, trioxifene, keoxifene, LY117018, onapristone and toremifene (Fareston); and antiandrogens such as flutamide, nilutamide, bicalutamide, leuprolide and goserelin; and pharmaceutically acceptable salts, acids or derivatives of any of the above. Such chemotherapeutic compounds that can be used herein include compounds whose toxicities preclude use of the compound in general systemic chemotherapeutic methods. Chemotherapeutic agents also include new classes of targeted chemotherapeutic agents such as, for example, imatinib (sold by Novartis under the trade name Gleevec in the United States), gefitinib (developed by Astra Zeneca under the trade name Iressa) and erlotinib. Particular chemotherapeutic agents include, but are not limited to, cisplatin, carboplatin, oxaliplatin, DWA2114R, NK121, IS 3 295, and 254-S vincristine, prednisone, doxorubicin and L-asparaginase; mechlorethamine, vincristine, procarbazine and prednisone (MOPP), cyclophosphamide, irinotecan, doxorubicin, bleomycin, vinblastine, gemcitabine and 5-fluorouracil. Exemplary chemotherapeutic agents are, for example, cisplatin, carboplatin, oxaliplatin, DWA2114R, NK121, IS 3 295, and 254-S. In a non-limiting embodiment, a vaccinia virus, such as a vaccinia virus provided herein, is administered to a subject having a tumor, cancer or

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metastasis in combination with a platinum coordination complex, such as cisplatin, carboplatin, oxaliplatin, DWA2114R, NK121, IS 3 295, and 254-S. Tumors, cancers and metastasis can be any of those provided herein, and in particular, can be a pancreatic tumor, an ovarian tumor, a lung tumor, a colon tumor, a prostate tumor, a cervical tumor or a breast tumor; exemplary tumors are pancreatic and ovarian tumors. Tumors, cancers and metastasis can be a monotherapy-resistant tumor such as, for example, one that does not respond to or poorly responds to therapy with virus alone or anti-cancer agent alone, but that does respond to therapy with a combination of virus and anti-cancer agent. Typically, a therapeutically effective amount of virus is systemically administered to the subject and the virus localizes and accumulates in the tumor. Subsequent to administering the virus, the subject is administered a therapeutically effective amount of an anti-cancer agent, such as cisplatin. In one example, cisplatin is administered once-daily for five consecutive days. One of skill in the art could determine when to administer the anti-cancer agent subsequent to the virus using, for example, *in vivo* animal models. Using the methods provided herein, administration of a virus and anti-cancer agent, such as cisplatin can cause a reduction in tumor volume, can cause tumor growth to stop or be delayed or can cause the tumor to be eliminated from the subject. The status of tumors, cancers and metastasis following treatment can be monitored using any of the methods provided herein and known in the art.

In one embodiment, nanoparticles can be designed such that they carry one or more therapeutic agents provided herein. Additionally, nanoparticles can be designed to carry a molecule that targets the nanoparticle to the tumor cells. In one non-limiting example, nanoparticles can be coated with a radionuclide and, optionally, an antibody immunoreactive with a tumor-associated antigen. In one embodiment, a vaccinia virus, such as a vaccinia virus provided herein, is administered to a subject having a tumor, cancer or metastasis in combination with a nanoparticle carrying any of the therapeutic agents provided herein.

Thus, provided herein are methods of administering to a subject one or more therapeutic compounds that can act in conjunction with the virus to increase the proliferation, toxicity, tumor cell killing, or immune response eliciting properties of a virus. Also provided herein are methods of administering to a subject one or more

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therapeutic compounds that can act in conjunction with the virus to decrease the proliferation, toxicity, or cell killing properties of a virus. Therapeutic compounds to be administered can be any of those provided herein or in the art.

In some embodiments, therapeutic compounds that can act in conjunction with the virus to decrease the proliferation, toxicity, or cell killing properties of a virus are compounds that can inhibit viral replication, inhibit viral toxins, or cause viral death. A therapeutic compound that can inhibit viral replication, inhibit viral toxins, or cause viral death can generally include a compound that can block one or more steps in the viral life cycle, including, but not limited to, compounds that can inhibit viral DNA replication, viral RNA transcription, viral coat protein assembly, outer membrane or polysaccharide assembly. Any of a variety of compounds that can block one or more steps in a viral life cycle are known in the art, including any known antiviral compound (e.g., cidofovir), viral DNA polymerase inhibitors, viral RNA polymerase inhibitors, inhibitors of proteins that regulate viral DNA replication or RNA transcription. In another example, a virus can contain a gene encoding a viral life cycle protein, such as DNA polymerase or RNA polymerase that can be inhibited by a compound that is, optionally, non-toxic to the host organism.

Effective delivery of each components of the combination therapy is an important aspect of the methods provided herein. In accordance with one aspect, the modes of administration discussed below exploit one or more of the key features: (i) delivery of a virus provided herein to the tumors by a mode of administration effect to achieve highest titer of virus and highest therapeutic effect; (ii) delivery of any other mentioned therapeutic modalities to the tumor by a mode of administration to achieve the optimal therapeutic effect. The dose scheme of the combination therapy administered is such that the combination of the two or more therapeutic modalities is therapeutically effective. Dosages will vary in accordance with such factors as the age, health, sex, size and weight of the patient, the route of administration, the toxicity of the drugs, frequency of treatment, and the relative susceptibilities of the cancer to each of the therapeutic modalities.

Disclosure of second agents and co-administration and modes of delivery of such that are not described here can be found in U.S. Pat. Pub. No. 2005-0031643 and U.S. Provisional Application No. 60/852,390.

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#### **4. State of the Subject**

In some embodiments, the methods provided herein for administering a virus to a subject can be performed on a subject in any of a variety of states, including an anesthetized subject, an alert subject, a subject with elevated body temperature, a  
5 subject with reduced body temperature, or other state of the subject that is known to affect the accumulation of a virus in the tumor.

### **C. VIRUSES AND CHEMOTHERAPEUTIC AGENTS FOR TREATMENT AND DIAGNOSIS**

#### **1. Viruses, vectors**

10 Provided herein are viruses and compositions containing the viruses, alone or in combination with a chemotherapeutic agent, for therapeutic use. The viruses provided herein are typically attenuated. Attenuated viruses have a decreased capacity to cause disease in a host. The decreased capacity can result from any of a variety of different modifications to the ability of a virus to be pathogenic. For  
15 example, a virus can have reduced toxicity, reduced ability to accumulate in non-tumorous organs or tissue, reduced ability to cause cell lysis or cell death, or reduced ability to replicate compared to the non-attenuated form thereof. Attenuation of virus can be achieved by inserting copies of exogenous expression cassettes into the viral  
20 genome to compete; this causes competition for the transcriptional and translational machineries and as well as for nutritional supplies with the virus' associated with endogenous transcription and translation activities of the virus. The attenuated viruses provided herein, however, retain at least some capacity to replicate and to cause immunoprivileged cells and tissues, such as tumor cells to leak or lyse, undergo cell death, or otherwise cause or enhance an immune response to immunoprivileged  
25 cells and tissues, such as tumor cells.

The viruses provided herein can accumulate in immunoprivileged cells or immunoprivileged tissues, including tumors and/or metastases, and also including wounded tissues and cells. While the viruses provided herein can typically be cleared from the subject to whom the viruses are administered by activity of the subject's  
30 immune system, viruses can nevertheless accumulate, survive and proliferate in immunoprivileged cells and tissues such as tumors because such immunoprivileged areas are sequestered from the host's immune system. Accordingly, the methods

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provided herein, as applied to tumors and/or metastases, and therapeutic methods relating thereto, can readily be applied to other immunoprivileged cells and tissues, including wounded cells and tissues.

Though the viruses provided herein can typically be cleared from the subject to whom the viruses are administered by activity of the subject's immune system, 5 circumstances can arise wherein the virus provokes a response in the subject's immune system. This can lead to the experiencing of physiological side effects associated with the administered virus. Accordingly, methods are provided herein where the virus can be rapidly cleared from a patient by administration of a 10 chemotherapeutic agent to the patient for alleviation of side effects associated with the virus.

The viruses provided herein are modified from their wild type form. Modifications can include any of a variety of changes, and include changes to the genome of the virus. Exemplary nucleic acid modifications include truncations, 15 insertions, deletions and mutations. In an exemplary modification, a viral gene can be modified by truncation, insertion, deletion or mutation. Modifications of the viruses provided herein can result in a modification of virus characteristics, including those provided herein such as pathogenicity, toxicity, ability to preferentially accumulate in tumor, ability to lyse cells or cause cell death, ability to elicit an immune response 20 against tumor cells, immunogenicity, and replication competence.

The viruses can be RNA or DNA viruses. The viruses can be cytoplasmic viruses, such as poxviruses, or can be nuclear viruses such as adenoviruses. The viruses provided herein can have as part of their life cycle lysis of the host cell's plasma membrane. Alternatively, the viruses provided herein can have as part of their 25 life cycle exit of the host cell by non-lytic pathways such as budding or exocytosis.

One skilled in the art can select from any of a variety of viruses, according to a variety of factors, including, but not limited to, the intended use of the virus, such as a diagnostic and/or therapeutic use (*e.g.*, tumor therapy or diagnosis, vaccination, antibody production, or heterologous protein production), the host organism, and the 30 type of tumor.

## 2. Modifications of viruses

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The viruses employed in the methods and use provided typically are modified viruses. Modified viruses, including modified vaccinia viruses, are contemplated for use herein, where the viruses have been modified by insertions, mutations or deletions, as described more generally elsewhere herein. The vaccinia viruses are modified or selected to have low toxicity and to accumulate in the target tissue. Exemplary of such viruses are those derived from the LIVP strain.

Exemplary insertions, mutations or deletions are those that result in an attenuated virus relative to the wild type strain. For example, virus insertions, mutations or deletions can decrease pathogenicity of the virus, for example, by reducing the toxicity, reducing the infectivity, reducing the ability to replicate, or reducing the number of non-tumor organs or tissues to which the virus can accumulate. Other exemplary insertions, mutations or deletions include, but are not limited to, those that increase antigenicity of the virus, those that permit detection or imaging, those that increase toxicity of the virus (optionally, controlled by an inducible promoter).

Also provided herein are modifications of the viruses provided above to enhance one or more characteristics relative to the wild type virus. Such characteristics can include, but are not limited to, attenuated pathogenicity, reduced toxicity, preferential accumulation in tumor, increased ability to activate an immune response against tumor cells, increased immunogenicity, increased or decreased replication competence, and are able to express exogenous proteins, and combinations thereof. In some embodiments, the modified viruses have an ability to activate an immune response against tumor cells without aggressively killing the tumor cells. In other embodiments, the viruses can be modified to express one or more detectable genes, including genes that can be used for imaging. In other embodiments, the viruses can be modified to express one or more genes for harvesting the gene products and/or for harvesting antibodies against the gene products.

### 3. Exemplary viruses

Among the viruses provided herein are cytoplasmic viruses, which do not require entry of viral nucleic acid molecules in to the nucleus of the host cell during the viral life cycle. A variety of cytoplasmic viruses are known, including, but not limited to, pox viruses, African swine flu family viruses, and various RNA viruses

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such as picornaviruses, caliciviruses, togaviruses, coronaviruses and rhabdoviruses. Exemplary cytoplasmic viruses provided herein are viruses of the poxvirus family, including orthopoxviruses. Exemplary of poxviruses provided herein are vaccinia viruses.

5                    **a.        Poxviruses**

In one embodiment, the virus provided herein is selected from the poxvirus family. Poxviruses include Chordopoxviridae such as orthopoxvirus, parapoxvirus, avipoxvirus, capripoxvirus, leporipoxvirus, suipoxvirus, molluscipoxvirus and yatapoxvirus, as well as Entomopoxvirinae such as entomopoxvirus A,  
10 entomopoxvirus B, and entomopoxvirus C. One skilled in the art can select a particular genus or individual chordopoxviridae according to the known properties of the genus or individual virus, and according to the selected characteristics of the virus (e.g., pathogenicity, ability to elicit an immune response, preferential tumor localization), the intended use of the virus, the tumor type and the host organism.  
15 Exemplary chordopoxviridae genera are orthopoxvirus and avipoxvirus.

Avipoxviruses are known to infect a variety of different birds and have been administered to humans. Exemplary avipoxviruses include canarypox, fowlpox, juncopox, mynahpox, pigeonpox, psittacinepox, quailpox, peacockpox, penguinpox, sparrowpox, starlingpox, and turkeypox viruses.

20                    Orthopoxviruses are known to infect a variety of different mammals including rodents, domesticated animals, primates and humans. Several orthopoxviruses have a broad host range, while others have narrower host range. Exemplary orthopoxviruses include buffalopox, camelpox, cowpox, ectromelia, monkeypox, raccoon pox, skunk pox, tatera pox, uasin gishu, vaccinia, variola, and volepox viruses. In some  
25 embodiments, the orthopoxvirus selected can be an orthopoxvirus known to infect humans, such as cowpox, monkeypox, vaccinia, or variola virus. Optionally, the orthopoxvirus known to infect humans can be selected from the group of orthopoxviruses with a broad host range, such as cowpox, monkeypox, or vaccinia virus.

30                    **i.        Vaccinia viruses**

One exemplary orthopoxvirus presented in the methods provided herein is vaccinia virus. Vaccinia is a cytoplasmic virus, thus, it does not insert its genome into

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the host genome during its life cycle. The linear dsDNA viral genome of vaccinia virus is approximately 200 kb in size, encoding a total of approximately 200 potential genes. A variety of vaccinia virus strains are available for the uses and methods provided, including Western Reserve (WR), Copenhagen, Tashkent, Tian Tan, Lister, 5 Wyeth, IHD-J, and IHD-W, Brighton, Ankara, MVA, Dairen I, LIPV, LC16M8, LC16MO, LIVP, WR 65-16, Connaught, New York City Board of Health. Exemplary vaccinia viruses are Lister or LIVP vaccinia viruses. In one embodiment, the Lister strain can be an attenuated Lister strain, such as the LIVP (Lister virus from the Institute of Viral Preparations, Moscow, Russia) strain, which was produced by 10 further attenuation of the Lister strain. The LIVP strain was used for vaccination throughout the world, particularly in India and Russia, and is widely available. In another embodiment, the viruses and methods provided herein can be based on modifications to the Lister strain of vaccinia virus. Lister (also referred to as Elstree) vaccinia virus is available from any of a variety of sources. For example, the Elstree 15 vaccinia virus is available at the ATCC under Accession Number VR-1549. The Lister vaccinia strain has high transduction efficiency in tumor cells with high levels of gene expression.

Vaccinia virus possesses a variety of features for use in cancer gene therapy and vaccination including broad host and cell type range, a large carrying capacity for 20 foreign genes (up to 25 kb of exogenous DNA fragments (approximately 12% of the vaccinia genome size) can be inserted into the vaccinia genome), high sequence homology among different strains for designing and generating modified viruses in other strains, and techniques for production of modified vaccinia strains by genetic engineering are well established (Moss (1993) *Curr. Opin. Genet. Dev.* 3: 86-90; 25 Broder and Earl (1999) *Mol. Biotechnol.* 13: 223-245; Timiryasova et al. (2001) *Biotechniques* 31: 534-540). A variety of vaccinia virus strains are available, including Western Reserve (WR), Copenhagen, Tashkent, Tian Tan, Lister, Wyeth, IHD-J, and IHD-W, Brighton, Ankara, MVA, Dairen I, LIPV, LC16M8, LC16MO, LIVP, WR 65-16, Connaught, New York City Board of Health. Exemplary of 30 vaccinia viruses provided herein include, but are not limited to, Lister strain or LIVP strain of vaccinia viruses.



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The modifications of the Lister strain provided herein also can be adapted to other vaccinia viruses (*e.g.*, Western Reserve (WR), Copenhagen, Tashkent, Tian Tan, Lister, Wyeth, IHD-J, and IHD-W, Brighton, Ankara, MVA, Dairen I, LIPV, LC16M8, LC16MO, LIPV, WR 65-16, Connaught, New York City Board of Health).

5 The modifications of the Lister strain provided herein also can be adapted to other viruses, including, but not limited to, viruses of the poxvirus family, adenoviruses, herpes viruses and retroviruses.

## ii. Modification of Vaccinia Viruses

10 Provided herein are vaccinia viruses with insertions, mutations or deletions, as provided elsewhere herein. Exemplary insertions, mutations or deletions are those that result in an attenuated vaccinia virus relative to the wild type strain. For example, vaccinia virus insertions, mutations or deletions can decrease pathogenicity of the vaccinia virus, for example, by reducing the toxicity, reducing the infectivity, reducing the ability to replicate, or reducing the number of non-tumor organs or  
15 tissues to which the vaccinia virus can accumulate. Other exemplary insertions, mutations or deletions include, but are not limited to, those that increase antigenicity of the virus, those that permit detection or imaging, those that alter attenuation of the virus, and those that alter infectivity. For example, the ability of vaccinia viruses provided herein to infect and replicate within tumors can be enhanced by mutations  
20 that increase the extracellular enveloped form of the virus (EEV) that is released from the host cell, as described elsewhere herein. Modifications can be made, for example, in genes that are involved in nucleotide metabolism, host interactions and virus formation or at other nonessential gene loci. Any of a variety of insertions, mutations or deletions of the vaccinia virus known in the art can be used herein, including  
25 insertions, mutations or deletions of: the thymidine kinase (*TK*) gene, the hemagglutinin (*HA*) gene, and *F14.5L* gene, among others (*e.g.*, E2L/E3L, K1L/K2L, superoxide dismutase locus, 7. 5K, C7-K1L, J2R, B13R+B14R, A56R, A26L or I4L gene loci). The vaccinia viruses provided herein also can contain two or more insertions, mutations or deletions. Thus, included are vaccinia viruses containing two  
30 or more insertions, mutations or deletions of the loci provided herein or other loci known in the art. The viruses provided herein can be based on modifications to the Lister strain and/or LIPV strain of vaccinia virus. Any known vaccinia virus, or

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modifications thereof that correspond to those provided herein or known to those of skill in the art to reduce toxicity of a vaccinia virus. Generally, however, the mutation will be a multiple mutant and the virus will be further selected to reduce toxicity.

The modified viruses provided herein can contain one more heterologous nucleic acid sequences for the expression of a heterologous gene. The heterologous nucleic acid is typically operably linked to a promoter for expression of the heterologous gene in the infected cells. Suitable promoter include viral promoters, such as a vaccinia virus natural and synthetic promoters. Exemplary vaccinia viral promoters include, but are not limited to, P11k, P7.5k early/late, P7.5k early, P28 late, synthetic early P<sub>SE</sub>, synthetic early/late P<sub>SEL</sub> and synthetic late P<sub>SL</sub> promoters.

The viruses provided herein can express one or more genes whose products are useful for tumor therapy. For example, a virus can express a proteins cause cell death or whose products cause an anti-tumor immune response. Such genes can be considered therapeutic genes. A variety of therapeutic gene products, such as toxic or apoptotic proteins, or siRNA, are known in the art, and can be used with the viruses provided herein. The therapeutic genes can act by directly killing the host cell, for example, as a channel-forming or other lytic protein, or by triggering apoptosis, or by inhibiting essential cellular processes, or by triggering an immune response against the cell, or by interacting with a compound that has a similar effect, for example, by converting a less active compound to a cytotoxic compound. Exemplary proteins useful for tumor therapy include, but are not limited to, tumor suppressors, toxins, cytostatic proteins, antiangiogenic proteins, antitumor antibodies, and costimulatory molecules, such as cytokines and chemokines among others provided elsewhere herein and known in the art. The viruses provided herein can also be effective against tumors without the introduction of additional exogenous therapeutic genes.

The viruses provided herein can express one or more genes whose products are useful for tumor detection and/or imaging. Exemplary gene products for imaging or detection include detectable proteins or proteins that induce detectable signals. Exemplary of detectable proteins or proteins that induce detectable signals are proteins, such as luciferases, fluorescent proteins, receptors that can bind imaging agents or proteins linked to imaging or diagnostic moieties. Imaging or diagnostic moieties include those that can emit a signal that is detectable by optical or non-

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optical imaging methods. Detection of the signal by imaging modalities such as, for example, by positron emission tomography (PET) and, thereby allows visualization of the infected tissues, such a tumor or an inflammation.

The viruses provided herein can also encode proteins, such as transporter  
5 proteins (*e.g.*, the human norepinephrine transporter (hNET) or the human sodium iodide symporter (hNIS)), which can provide increase uptake diagnostic and therapeutic moieties across the cell membrane of infected cells for therapy, imaging or detection.

One skilled in the art can select from any of a variety of viruses, according to a  
10 variety of factors, including, but not limited to, the intended use of the virus, such as a diagnostic and/or therapeutic use (*e.g.*, tumor therapy or diagnosis, vaccination, antibody production, or heterologous protein production), the host organism, and the type of tumor. A therapeutic virus for the methods provided herein can exhibit one or  
15 more desired characteristics for use as a therapeutic agent, such as, for example attenuated pathogenicity, reduced toxicity, preferential accumulation in immunoprivileged cells and tissues, such as tumor, ability to activate an immune response against tumor cells, immunogenic, replication competent, and are able to express exogenous proteins, and combinations thereof.

### iii. Exemplary Modified Vaccinia Viruses

20 Exemplary vaccinia viruses contemplated for use in the methods and uses provides include those derived from vaccinia virus strain GLV-1h68 (also named RVGL21, SEQ ID NO: 1), which has been described in U.S. Pat. Pub. No. 2005-0031643 and is incorporated herein by reference in its entirety. GLV-1h68 contains  
25 DNA insertions gene loci of the vaccinia virus LIVP strain (SEQ ID NO: 2, a vaccinia virus strain, originally derived by adapting the Lister strain (ATCC Catalog No. VR-1549) to calf skin (Institute of Viral Preparations, Moscow, Russia, Al'tshtein *et al.*, (1983) Dokl. Akad. Nauk USSR 285:696-699)). GLV-1h68 contains expression cassettes encoding detectable marker proteins in the *F14.5L* (also designated in LIVP as *F3*), thymidine kinase (*TK*) and hemagglutinin (*HA*) gene loci. An expression  
30 cassette containing a *Ruc-GFP* cDNA molecule (a fusion of DNA encoding *Renilla* luciferase and DNA encoding GFP) under the control of a vaccinia synthetic early/late promoter  $P_{SEL}$  ( $(P_{SEL})Ruc-GFP$ ) is inserted into the *F14.5L* gene locus; an expression

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cassette containing a DNA molecule encoding beta-galactosidase under the control of the vaccinia early/late promoter  $P_{7.5k}$  ( $(P_{7.5k})LacZ$ ) and DNA encoding a rat transferrin receptor positioned in the reverse orientation for transcription relative to the vaccinia synthetic early/late promoter  $P_{SEL}$  ( $(P_{SEL})rTrfR$ ) is inserted into the *TK* gene locus (the  
5 resulting virus does not express transferrin receptor protein since the DNA molecule encoding the protein is positioned in the reverse orientation for transcription relative to the promoter in the cassette); and an expression cassette containing a DNA molecule encoding  $\beta$ -glucuronidase under the control of the vaccinia late promoter  $P_{11k}$  ( $(P_{11k})gusA$ ) is inserted into the *HA* gene locus. The GLV-1h68 virus exhibits a  
10 strong preference for accumulation in tumor tissues as compared to non-tumorous tissues following systemic administration of the virus to tumor bearing subjects. This preference is significantly higher than the tumor selective accumulation of other vaccinia viral strains, such as WR (see, e.g. U.S. Pat. Pub. No. 2005-0031643 and Zhang *et al.* (2007) *Cancer Res.* 67(20):10038-46). Modified viruses provided herein  
15 for the uses and methods provided can be derived from GLV-1h68. Exemplary viruses are generated by replacement of one or more expression cassettes of the GLV-1h68 strain with heterologous DNA encoding gene products for therapy and/or imaging.

Non-limiting examples viruses that are derived from attenuated LIVP viruses,  
20 such as GLV-1h68, and can be employed in the methods and uses provided include, but are not limited to, LIVP viruses described in U.S. Patent Publication Nos. 2005/0031643, 2004/0234455 and 2004/0213741 and U.S. Patent Application Serial Nos. 11/975,088. For example, the vaccinia virus can be selected from among GLV-1h22, GLV-1h68, GLV-1i69, GLV-1h70, GLV-1h71, GLV-1h72, GLV-1h73, GLV-  
25 1h74, GLV-1h81, GLV-1h82, GLV-1h83, GLV-1h84, GLV-1h85, or GLV-1h86, which are described in U.S. Application Serial Nos. 11/975,088 and 11/975,090. Other exemplary vaccinia viruses include, but are not limited to, GLV-1h99, GLV-1h100, GLV-1h101, GLV-1h139, GLV-1h146, GLV-1h151, GLV-1h152 and GLV-1h153, which are described in U.S. Application Serial No. 12/157,960, entitled  
30 "MICROORGANISMS FOR IMAGING AND/OR TREATMENT OF TUMORS" and filed June 13, 2008, which is incorporated herein by reference in its entirety as

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well as additional related strains GLV-1h104, GLV-1h105, GLV-1h106, GLV-1h107, GLV-1h108 and GLV-1h109.

Exemplary of viruses which have one or more expression cassettes removed from GLV-1h68 and replaced with a heterologous non-coding DNA molecule include  
5 GLV-1h70, GLV-1h71, GLV-1h72, GLV-1h73, GLV-1h74, GLV-1h85, and GLV-1h86. GLV-1h70 contains ( $P_{\text{SEL}}$ )*Ruc-GFP* inserted into the *F14.5L* gene locus, ( $P_{\text{SEL}}$ )*rTrfR* and ( $P_{7.5k}$ )*LacZ* inserted into the *TK* gene locus, and a non-coding DNA molecule inserted into the *HA* gene locus in place of ( $P_{11k}$ )*gusA*. GLV-1h71 contains  
10 a non-coding DNA molecule inserted into the *F14.5L* gene locus in place of ( $P_{\text{SEL}}$ )*Ruc-GFP*, ( $P_{\text{SEL}}$ )*rTrfR* and ( $P_{7.5k}$ )*LacZ* inserted into the *TK* gene locus, and ( $P_{11k}$ )*gusA* inserted into the *HA* gene locus. GLV-1h72 contains ( $P_{\text{SEL}}$ )*Ruc-GFP* inserted into the *F14.5L* gene locus, a non-coding DNA molecule inserted into the *TK* gene locus in place of ( $P_{\text{SEL}}$ )*rTrfR* and ( $P_{7.5k}$ )*LacZ*, and  $P_{11k}$ *gusA* inserted into the *HA* gene locus. GLV-1h73 contains a non-coding DNA molecule inserted into the  
15 *F14.5L* gene locus in place of ( $P_{\text{SEL}}$ )*Ruc-GFP*, ( $P_{\text{SEL}}$ )*rTrfR* and ( $P_{7.5k}$ )*LacZ* inserted into the *TK* gene locus, and a non-coding DNA molecule inserted into the *HA* gene locus in place of ( $P_{11k}$ )*gusA*. GLV-1h74 contains a non-coding DNA molecule inserted into the *F14.5L* gene locus in place of ( $P_{\text{SEL}}$ )*Ruc-GFP*, a non-coding DNA molecule inserted into the *TK* gene locus in place of ( $P_{\text{SEL}}$ )*rTrfR* and ( $P_{7.5k}$ )*LacZ*, and a  
20 non-coding DNA molecule inserted into the *HA* gene locus in place of ( $P_{11k}$ )*gusA*. GLV-1h85 contains a non-coding DNA molecule inserted into the *F14.5L* gene locus in place of ( $P_{\text{SEL}}$ )*Ruc-GFP*, a non-coding DNA molecule inserted into the *TK* gene locus in place of ( $P_{\text{SEL}}$ )*rTrfR* and ( $P_{7.5k}$ )*LacZ*, and ( $P_{11k}$ )*gusA* inserted into the *HA* gene locus. GLV-1h86 contains ( $P_{\text{SEL}}$ )*Ruc-GFP* inserted into the *F14.5L* gene locus,  
25 a non-coding DNA molecule inserted into the *TK* gene locus in place of ( $P_{\text{SEL}}$ )*rTrfR* and ( $P_{7.5k}$ )*LacZ*, and a non-coding DNA molecule inserted into the *HA* gene locus in place of ( $P_{11k}$ )*gusA*.

Other exemplary viruses include, but are not limited to, LIVP viruses that express one or more therapeutic gene products, such as angiogenesis inhibitors (*e.g.*,  
30 GLV-1h81, which contains DNA encoding the plasminogen K5 domain (SEQ ID NO: 11) under the control of the vaccinia synthetic early-late promoter in place of the *gusA* expression cassette at the *HA* locus in GLV-1h68; GLV-1h104, GLV-1h105 and

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GLV-1h106, which contain DNA encoding a truncated human tissue factor fused to the  $\alpha_v\beta_3$ -integrin RGD binding motif (tTF-RGD) (SEQ ID NO: 7) under the control of a vaccinia synthetic early promoter, vaccinia synthetic early/late promoter or vaccinia synthetic late promoter, respectively, in place of the *LacZ/rTFr* expression cassette at the *TK* locus of GLV-1h68; GLV-1h107, GLV-1h108 and GLV-1h109, which contain DNA encoding an anti-VEGF single chain antibody G6 (SEQ ID NO: 8) under the control of a vaccinia synthetic early promoter, vaccinia synthetic early/late promoter or vaccinia synthetic late promoter, respectively, in place of the *LacZ/rTFr* expression cassette at the *TK* locus of GLV-1h68) and proteins for tumor growth suppression (e.g., GLV-1h90, GLV-1h91 and GLV-1h92, which express a fusion protein containing an IL-6 fused to an IL-6 receptor (sIL-6R/IL-6) (SEQ ID NO: 10) under the control of a vaccinia synthetic early promoter, vaccinia synthetic early/late promoter or vaccinia synthetic late promoter, respectively, in place of the *gusA* expression cassette at the *HA* locus in GLV-1h68; and GLV-1h96, GLV-1h97 and GLV-1h98, which express IL-24 (melanoma differentiation gene, mda-7; SEQ ID NO: 9) under the control of a vaccinia synthetic early promoter, vaccinia synthetic early/late promoter or vaccinia synthetic late promoter, respectively, in place of the *Ruc-GFP* fusion gene expression cassette at the *F14.5L* locus of GLV-1h68). Additional therapeutic gene products that can be engineered in the viruses provided herein also are described elsewhere herein.

Exemplary transporter proteins that can be encoded by the viruses provided herein include, for example, the human norepinephrine transporter (hNET; SEQ ID NO: 3 (cDNA), 4 (protein)) and the human sodium iodide symporter (hNIS; SEQ ID NO: 6 (cDNA), 5 (protein)). Exemplary viruses that can be employed in the methods and use provided herein that encode the human norepinephrine transporter (hNET) include, but are not limited to, GLV-1h99, GLV-1h100, GLV-1h101, GLV-1h139, GLV-1h146, GLV-1h150, GLV-1h151 and GLV-1h152. GLV-1h99 encodes hNET under the control of a vaccinia synthetic early promoter in place of the *Ruc-GFP* fusion gene expression cassette at the *F14.5L* locus of GLV-1h68. GLV-1h100, GLV-1h101 encode hNET under the control of a vaccinia synthetic early promoter or vaccinia synthetic late promoter, respectively, in place of the *LacZ/rTFr* expression cassette at the *TK* locus of GLV-1h68. GLV-1h39 encodes hNET under the control of

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a vaccinia synthetic early promoter in place of the *gusA* expression cassette at the *HA* locus in GLV-1h68. GLV-1h146 and GLV-1h150, encode hNET under the control of a vaccinia synthetic early promoter or vaccinia synthetic late promoter, respectively, in place of the *LacZ/rTFr* expression cassette at the *TK* locus of GLV-1h100 and  
5 GLV-101, respectively. Thus, GLV-1h146 and GLV-1h150 encode both hNET and IL-24. Exemplary viruses that can be employed in the methods and use provided herein that encode the human sodium iodide transporter (hNIS) include, but are not limited to, GLV-1h151, GLV-1h151 and GLV-1h153. GLV-1h151, GLV-1h151 and  
10 GLV-1h153 encode hNIS under the control of a vaccinia synthetic early promoter, vaccinia synthetic early/late promoter or vaccinia synthetic late promoter, respectively, in place of the *gusA* expression cassette at the *HA* locus in GLV-1h68.

Other exemplary viruses include, but are not limited to, LVP viruses that encode additional imaging agents such as ferritin and/or a transferrin receptor (e.g., GLV-1h82 and GLV-1h83 which encode E.coli ferritin at the *HA* locus; GLV-1h82  
15 addition encodes the human transferrin receptor at the *TK* locus) or a click beetle luciferase-red fluorescent protein fusion protein (e.g., GLV-1h84, which encodes CBG99 and mRFP1 at the *TK* locus). During translation, the two proteins are cleaved into two individual proteins at picornavirus 2A element (Osborn *et al.*, *Mol. Ther.* 12: 569-74, 2005). CBG99 produces a more stable luminescent signal than does *Renilla*  
20 luciferase with a half-life of greater than 30 minutes, which makes both *in vitro* and *in vivo* assays more convenient. mRFP1 provides improvements in *in vivo* imaging relative to GFP since mRFP1 can penetrate tissue deeper than GFP.

#### **b. Other cytoplasmic viruses**

Also provided herein are cytoplasmic viruses that are not poxviruses.  
25 Cytoplasmic viruses can replicate without introducing viral nucleic acid molecules into the nucleus of the host cell. A variety of such cytoplasmic viruses are known in the art, and include African swine flu family viruses and various RNA viruses such as arenaviruses, picornaviruses, caliciviruses, togaviruses, coronaviruses, paramyxoviruses, flaviviruses, reoviruses, and rhabdoviruses. Exemplary togaviruses  
30 include Sindbis viruses. Exemplary arenaviruses include lymphocytic choriomeningitis virus. Exemplary rhabdoviruses include vesicular stomatitis viruses. Exemplary paramyxoviruses include Newcastle Disease viruses and measles viruses.

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Exemplary picornaviruses include polio viruses, bovine enteroviruses and rhinoviruses. Exemplary flaviviruses include Yellow fever virus; attenuated Yellow fever viruses are known in the art, as exemplified in Barrett *et al.* (*Biologicals* 25: 17-25 (1997)), and McAllister *et al.* (*J. Virol.* 74: 9197-9205 (2000)).

5 Also provided herein are modifications of the viruses provided above to enhance one or more characteristics relative to the wild type virus. Such characteristics can include, but are not limited to, attenuated pathogenicity, reduced toxicity, preferential accumulation in tumor, increased ability to activate an immune response against tumor cells, increased immunogenicity, increased or decreased  
10 replication competence, and are able to express exogenous proteins, and combinations thereof. In some embodiments, the modified viruses have an ability to activate an immune response against tumor cells without aggressively killing the tumor cells. In other embodiments, the viruses can be modified to express one or more detectable genes, including genes that can be used for imaging. In other embodiments, the  
15 viruses can be modified to express one or more genes for harvesting the gene products and/or for harvesting antibodies against the gene products.

**c. Adenovirus, Herpes, Retroviruses**

Further provided herein are viruses that include in their life cycle entry of a nucleic acid molecule into the nucleus of the host cell. A variety of such viruses is  
20 known in the art, and includes herpesviruses, papovaviruses, retroviruses, adenoviruses, parvoviruses and orthomyxoviruses. Exemplary herpesviruses include herpes simplex type 1 viruses, cytomegaloviruses, and Epstein-Barr viruses. Exemplary papovaviruses include human papillomavirus and SV40 viruses. Exemplary retroviruses include lentiviruses. Exemplary orthomyxoviruses include  
25 influenza viruses. Exemplary parvoviruses include adeno associated viruses.

Also provided herein are modifications of the viruses provided above to enhance one or more characteristics relative to the wild type virus. Such characteristics can include, but are not limited to, attenuated pathogenicity, reduced toxicity, preferential accumulation in tumor, increased ability to activate an immune  
30 response against tumor cells, increased immunogenicity, increased or decreased replication competence, and are able to express exogenous proteins, and combinations thereof. In some embodiments, the modified viruses have an ability to activate an



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immune response against tumor cells without aggressively killing the tumor cells. In other embodiments, the viruses can be modified to express one or more detectable genes, including genes that can be used for imaging. In other embodiments, the viruses can be modified to express one or more genes for harvesting the gene products and/or for harvesting antibodies against the gene products.

#### 4. Chemotherapeutic agents for virus inhibition

The chemotherapeutics agents that can be administered with the viruses provided herein to control or maintain viral titer include any chemotherapeutic agent the adversely affects any step in the viral life cycle. For example, the chemotherapeutic agent can inhibit viral replication, inhibit viral toxins, or cause viral death. The chemotherapeutic agent can block one or more steps in the viral life cycle, including, but not limited to, compounds that can inhibit viral DNA replication, viral RNA transcription, viral coat protein assembly, outer membrane or polysaccharide assembly. Typically, the chemotherapeutic agents employed in the methods and uses provided herein decrease or inhibit viral replication. Exemplary chemotherapeutic agents that can be used in the methods or uses provided include, but are not limited to, cisplatin, gemcitabine, doxorubicin, irinotecan and 5'-fluorouracil.

#### D. Monitoring

The methods provided herein can further include one or more steps of monitoring the subject, monitoring the tumor, and/or monitoring the virus administered to the subject. Any of a variety of monitoring steps can be included in the methods provided herein, including, but not limited to, monitoring tumor size, monitoring anti-(tumor antigen) antibody titer, monitoring the presence and/or size of metastases, monitoring the subject's lymph nodes, monitoring the subject's weight or other health indicators including blood or urine markers, monitoring anti-(viral antigen) antibody titer, monitoring viral expression of a detectable gene product, and directly monitoring viral titer in a tumor, tissue or organ of a subject.

The purpose of the monitoring can be simply for assessing the health state of the subject or the progress of therapeutic treatment of the subject, or can be for determining whether or not further administration of the same or a different virus is warranted, or for determining when or whether or not to administer a compound to the subject where the compound can act to increase the efficacy of the therapeutic

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method, or the compound can act to decrease the pathogenicity of the virus administered to the subject.

**1. Monitoring viral gene expression**

In some embodiments, the methods provided herein can include monitoring  
5 one or more virally expressed genes. Viruses, such as those provided herein or otherwise known in the art, can express one or more detectable gene products, including but not limited to, detectable proteins.

As provided herein, measurement of a detectable gene product expressed by a virus can provide an accurate determination of the level of virus present in the subject.  
10 As further provided herein, measurement of the location of the detectable gene product, for example, by imaging methods including, but not limited to, magnetic resonance, fluorescence, and tomographic methods, can determine the localization of the virus in the subject. Accordingly, the methods provided herein that include monitoring a detectable viral gene product can be used to determine the presence or  
15 absence of the virus in one or more organs or tissues of a subject, and/or the presence or absence of the virus in a tumor or metastases of a subject. Further, the methods provided herein that include monitoring a detectable viral gene product can be used to determine the titer of virus present in one or more organs, tissues, tumors or  
20 metastases. Methods that include monitoring the localization and/or titer of viruses in a subject can be used for determining the pathogenicity of a virus; since viral infection, and particularly the level of infection, of normal tissues and organs can indicate the pathogenicity of the probe, methods of monitoring the localization and/or amount of viruses in a subject can be used to determine the pathogenicity of a virus. Since methods provided herein can be used to monitor the amount of viruses at any  
25 particular location in a subject, the methods that include monitoring the localization and/or titer of viruses in a subject can be performed at multiple time points, and, accordingly can determine the rate of viral replication in a subject, including the rate of viral replication in one or more organs or tissues of a subject; accordingly, the methods of monitoring a viral gene product can be used for determining the  
30 replication competence of a virus. The methods provided herein also can be used to quantitate the amount of virus present in a variety of organs or tissues, and tumors or metastases, and can thereby indicate the degree of preferential accumulation of the

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virus in a subject; accordingly, the viral gene product monitoring methods provided herein can be used in methods of determining the ability of a virus to accumulate in tumor or metastases in preference to normal tissues or organs. Since the viruses used in the methods provided herein can accumulate in an entire tumor or can accumulate at multiple sites in a tumor, and can also accumulate in metastases, the methods provided herein for monitoring a viral gene product can be used to determine the size of a tumor or the number of metastases that are present in a subject. Monitoring such presence of viral gene product in tumor or metastasis over a range of time can be used to assess changes in the tumor or metastasis, including growth or shrinking of a tumor, or development of new metastases or disappearance of metastases, and also can be used to determine the rate of growth or shrinking of a tumor, or development of new metastases or disappearance of metastases, or the change in the rate of growth or shrinking of a tumor, or development of new metastases or disappearance of metastases. Accordingly, the methods of monitoring a viral gene product can be used for monitoring a neoplastic disease in a subject, or for determining the efficacy of treatment of a neoplastic disease, by determining rate of growth or shrinking of a tumor, or development of new metastases or disappearance of metastases, or the change in the rate of growth or shrinking of a tumor, or development of new metastases or disappearance of metastases.

Any of a variety of detectable proteins can be detected in the monitoring methods provided herein; an exemplary, non-limiting list of such detectable proteins includes any of a variety of fluorescent proteins (*e.g.*, green or red fluorescent proteins), any of a variety of luciferases, transferrin or other iron binding proteins; or receptors, binding proteins, and antibodies, where a compound that specifically binds the receptor, binding protein or antibody can be a detectable agent or can be labeled with a detectable substance (*e.g.*, a radionuclide or imaging agent). Viruses expressing a detectable protein can be detected by a combination of the method provided herein and known in the art. Viruses expressing more than one detectable protein or two or more viruses expressing various detectable protein can be detected and distinguished by dual imaging methods. For example, a virus expressing a fluorescent protein and an iron binding protein can be detected *in vitro* or *in vivo* by low light fluorescence imaging and magnetic resonance, respectively. In another

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example, a virus expressing two or more fluorescent proteins can be detected by fluorescence imaging at different wavelength. *In vivo* dual imaging can be performed on a subject that has been administered a virus expressing two or more detectable gene products or two or more viruses each expressing one or more detectable gene products.

## 2. Monitoring tumor size

Also provided herein are methods of monitoring tumor and/or metastasis size and location. Tumor and or metastasis size can be monitored by any of a variety of methods known in the art, including external assessment methods or tomographic or magnetic imaging methods. In addition to the methods known in the art, methods provided herein, for example, monitoring viral gene expression, can be used for monitoring tumor and/or metastasis size.

Monitoring size over several time points can provide information regarding the increase or decrease in size of a tumor or metastasis, and can also provide information regarding the presence of additional tumors and/or metastases in the subject. Monitoring tumor size over several time points can provide information regarding the development of a neoplastic disease in a subject, including the efficacy of treatment of a neoplastic disease in a subject.

## 3. Monitoring antibody titer

The methods provided herein also can include monitoring the antibody titer in a subject, including antibodies produced in response to administration of a virus to a subject. The viruses administered in the methods provided herein can elicit an immune response to endogenous viral antigens. The viruses administered in the methods provided herein also can elicit an immune response to exogenous genes expressed by a virus. The viruses administered in the methods provided herein also can elicit an immune response to tumor antigens. Monitoring antibody titer against viral antigens, viral expressed exogenous gene products, or tumor antigens can be used in methods of monitoring the toxicity of a virus, monitoring the efficacy of treatment methods, or monitoring the level of gene product or antibodies for production and/or harvesting.

In one embodiment, monitoring antibody titer can be used to monitor the toxicity of a virus. Antibody titer against a virus can vary over the time period after

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administration of the virus to the subject, where at some particular time points, a low anti-(viral antigen) antibody titer can indicate a higher toxicity, while at other time points a high anti-(viral antigen) antibody titer can indicate a higher toxicity. The viruses used in the methods provided herein can be immunogenic, and can, therefore, 5 elicit an immune response soon after administering the virus to the subject.

Generally, a virus against which a subject's immune system can quickly mount a strong immune response can be a virus that has low toxicity when the subject's immune system can remove the virus from all normal organs or tissues. Thus, in some embodiments, a high antibody titer against viral antigens soon after 10 administering the virus to a subject can indicate low toxicity of a virus. In contrast, a virus that is not highly immunogenic can infect a host organism without eliciting a strong immune response, which can result in a higher toxicity of the virus to the host. Accordingly, in some embodiments, a high antibody titer against viral antigens soon after administering the virus to a subject can indicate low toxicity of a virus.

15 In other embodiments, monitoring antibody titer can be used to monitor the efficacy of treatment methods. In the methods provided herein, antibody titer, such as anti-(tumor antigen) antibody titer, can indicate the efficacy of a therapeutic method such as a therapeutic method to treat neoplastic disease. Therapeutic methods provided herein can include causing or enhancing an immune response against a 20 tumor and/or metastasis. Thus, by monitoring the anti-(tumor antigen) antibody titer, it is possible to monitor the efficacy of a therapeutic method in causing or enhancing an immune response against a tumor and/or metastasis. The therapeutic methods provided herein also can include administering to a subject a virus that can accumulate in a tumor and can cause or enhance an anti-tumor immune response. 25 Accordingly, it is possible to monitor the ability of a host to mount an immune response against viruses accumulated in a tumor or metastasis, which can indicate that a subject has also mounted an anti-tumor immune response, or can indicate that a subject is likely to mount an anti-tumor immune response, or can indicate that a subject is capable of mounting an anti-tumor immune response.

30 In other embodiments, monitoring antibody titer can be used for monitoring the level of gene product or antibodies for production and/or harvesting. As provided herein, methods can be used for producing proteins, RNA molecules or other

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compounds by expressing an exogenous gene in a virus that has accumulated in a tumor. Further provided herein are methods for producing antibodies against a protein, RNA molecule or other compound produced by exogenous gene expression of a virus that has accumulated in a tumor. Monitoring antibody titer against the protein, RNA molecule or other compound can indicate the level of production of the protein, RNA molecule or other compound by the tumor-accumulated virus, and also can directly indicate the level of antibodies specific for such a protein, RNA molecule or other compound.

#### 4. Monitoring general health diagnostics

The methods provided herein also can include methods of monitoring the health of a subject. Some of the methods provided herein are therapeutic methods, including neoplastic disease therapeutic methods. Monitoring the health of a subject can be used to determine the efficacy of the therapeutic method, as is known in the art. The methods provided herein also can include a step of administering to a subject a virus. Monitoring the health of a subject can be used to determine the pathogenicity of a virus administered to a subject. Any of a variety of health diagnostic methods for monitoring disease such as neoplastic disease, infectious disease, or immune-related disease can be monitored, as is known in the art. For example, the weight, blood pressure, pulse, breathing, color, temperature or other observable state of a subject can indicate the health of a subject. In addition, the presence or absence or level of one or more components in a sample from a subject can indicate the health of a subject. Typical samples can include blood and urine samples, where the presence or absence or level of one or more components can be determined by performing, for example, a blood panel or a urine panel diagnostic test. Exemplary components indicative of a subject's health include, but are not limited to, white blood cell count, hematocrit, or reactive protein concentration.

#### 5. Monitoring coordinated with treatment

Also provided herein are methods of monitoring a therapy, where therapeutic decisions can be based on the results of the monitoring. Therapeutic methods provided herein can include administering to a subject a virus, where the virus can preferentially accumulate in a tumor and/or metastasis, and where the virus can cause or enhance an anti-tumor immune response. Such therapeutic methods can include a

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variety of steps including multiple administrations of a particular virus, administration of a second virus, or administration of a therapeutic compound. Determination of the amount, timing or type of virus or compound to administer to the subject can be based on one or more results from monitoring the subject. For example, the antibody titer in a subject can be used to determine whether or not it is desirable to administer a virus or compound, the quantity of virus or compound to administer, and the type of virus or compound to administer, where, for example, a low antibody titer can indicate the desirability of administering additional virus, a different virus, or a therapeutic compound such as a compound that induces viral gene expression. In another example, the overall health state of a subject can be used to determine whether or not it is desirable to administer a virus or compound, the quantity of virus or compound to administer, and the type of virus or compound to administer, where, for example, determining that the subject is healthy can indicate the desirability of administering additional virus, a different virus, or a therapeutic compound such as a compound that induces viral gene expression. In another example, monitoring a detectable virally expressed gene product can be used to determine whether or not it is desirable to administer a virus or compound, the quantity of virus or compound to administer, and the type of virus or compound to administer. Such monitoring methods can be used to determine whether or not the therapeutic method is effective, whether or not the therapeutic method is pathogenic to the subject, whether or not the virus has accumulated in a tumor or metastasis, and whether or not the virus has accumulated in normal tissues or organs. Based on such determinations, the desirability and form of further therapeutic methods can be derived.

In one embodiment, determination of whether or not a therapeutic method is effective can be used to derive further therapeutic methods. Any of a variety of methods of monitoring can be used to determine whether or not a therapeutic method is effective, as provided herein or otherwise known in the art. If monitoring methods indicate that the therapeutic method is effective, a decision can be made to maintain the current course of therapy, which can include further administrations of a virus or compound, or a decision can be made that no further administrations are required. If monitoring methods indicate that the therapeutic method is ineffective, the monitoring results can indicate whether or not a course of treatment should be discontinued (*e.g.*,

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when a virus is pathogenic to the subject), or changed (*e.g.*, when a virus accumulates in a tumor without harming the host organism, but without eliciting an anti-tumor immune response), or increased in frequency or amount (*e.g.*, when little or no virus accumulates in tumor).

5           In one example, monitoring can indicate that a virus is pathogenic to a subject. In such instances, a decision can be made to terminate administration of the virus to the subject, to administer lower levels of the virus to the subject, to administer a different virus to a subject, or to administer to a subject a compound that reduces the pathogenicity of the virus. In one example, administration of a virus that is  
10           determined to be pathogenic can be terminated. In another example, the dosage amount of a virus that is determined to be pathogenic can be decreased for subsequent administration; in one version of such an example, the subject can be pre-treated with another virus that can increase the ability of the pathogenic virus to accumulate in tumor, prior to re-administering the pathogenic virus to the subject. In another  
15           example, a subject can have administered thereto a virus that is pathogenic to the subject; administration of such a pathogenic virus can be accompanied by administration of, for example, an antiviral compound (*e.g.*, cidofovir), pathogenicity attenuating compound (*e.g.*, a compound that down-regulates the expression of a lytic or apoptotic gene product), or other compound that can decrease the proliferation,  
20           toxicity, or cell killing properties of a virus, as described herein elsewhere. In one variation of such an example, the localization of the virus can be monitored, and, upon determination that the virus is accumulated in tumor and/or metastases but not in normal tissues or organs, administration of the antiviral compound or pathogenicity attenuating compound can be terminated, and the pathogenic activity of the virus can  
25           be activated or increased, but limited to the tumor and/or metastasis. In another variation of such an example, after terminating administration of the antiviral compound or pathogenicity attenuating compound, the presence of the virus and/or pathogenicity of the virus can be further monitored, and administration of such a compound can be reinitiated if the virus is determined to pose a threat to the host by,  
30           for example, spreading to normal organs or tissues, releasing a toxin into the vasculature, or otherwise having pathogenic effects reaching beyond the tumor or metastasis.



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In another example, monitoring can determine whether or not a virus has accumulated in a tumor or metastasis of a subject. Upon such a determination, a decision can be made to further administer additional virus, a different virus or a compound to the subject. In another example, monitoring the presence of a virus in a tumor can be used in deciding to administer to the subject a compound, where the compound can increase the pathogenicity, proliferation, or immunogenicity of a virus or the compound can otherwise act in conjunction with the virus to increase the proliferation, toxicity, tumor cell killing, or immune response eliciting properties of a virus; in one variation of such an example, the virus can, for example, have little or no lytic or cell killing capability in the absence of such a compound; in a further variation of such an example, monitoring of the presence of the virus in a tumor or metastasis can be coupled with monitoring the absence of the virus in normal tissues or organs, where the compound is administered if the virus is present in tumor or metastasis and not at all present or substantially not present in normal organs or tissues; in a further variation of such an example, the amount of virus in a tumor or metastasis can be monitored, where the compound is administered if the virus is present in tumor or metastasis at sufficient levels.

#### **E. PHARMACEUTICAL COMPOSITIONS, COMBINATIONS AND KITS**

Provided herein are pharmaceutical compositions, combinations and kits containing a virus provided herein and one or more components. Pharmaceutical compositions can include a virus provided herein and a pharmaceutical carrier. Combinations can include two or more viruses, a virus and a detectable compound, a virus and a viral expression modulating compound, a virus and a therapeutic compound, or any combination thereof. Kits can include the pharmaceutical compositions and/or combinations provided herein, and one or more components, such as instructions for use, a device for detecting a virus in a subject, a device for administering a compound to a subject, and a device for administering a compound to a subject.

##### **1. Pharmaceutical Compositions**

Provided herein are pharmaceutical compositions containing a virus provided herein and a chemotherapeutic agent and a suitable pharmaceutical carrier.

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Pharmaceutical compositions provided herein can be in various forms, e.g., in solid, liquid, powder, aqueous, or lyophilized form. Suitable pharmaceutical carriers are known in the art. Examples of suitable pharmaceutical carriers are known in the art and include but are not limited to water, buffers, saline solutions, phosphate buffered saline solutions, various types of wetting agents, sterile solutions, alcohols, gum arabic, vegetable oils, benzyl alcohols, gelatin, glycerin, carbohydrates such as lactose, sucrose, amylose or starch, magnesium stearate, talc, silicic acid, viscous paraffin, perfume oil, fatty acid monoglycerides and diglycerides, pentaerythritol fatty acid esters, hydroxy methylcellulose, powders, among others. Pharmaceutical compositions provided herein can contain other additives including, for example, antioxidants and preservatives, analgesic agents, binders, disintegrants, coloring, diluents, excipients, extenders, glidants, solubilizers, stabilizers, tonicity agents, vehicles, viscosity agents, flavoring agents, emulsions, such as oil/water emulsions, emulsifying and suspending agents, such as acacia, agar, alginic acid, sodium alginate, bentonite, carbomer, carrageenan, carboxymethylcellulose, cellulose, cholesterol, gelatin, hydroxyethyl cellulose, hydroxypropyl cellulose, hydroxypropyl methylcellulose, methylcellulose, octoxynol 9, oleyl alcohol, povidone, propylene glycol monostearate, sodium lauryl sulfate, sorbitan esters, stearyl alcohol, tragacanth, xanthan gum, and derivatives thereof, solvents, and miscellaneous ingredients such as crystalline cellulose, microcrystalline cellulose, citric acid, dextrin, dextrose, liquid glucose, lactic acid, lactose, magnesium chloride, potassium metaphosphate, starch, among others. Such carriers and/or additives can be formulated by conventional methods and can be administered to the subject at a suitable dose. Stabilizing agents such as lipids, nuclease inhibitors, polymers, and chelating agents can preserve the compositions from degradation within the body.

Colloidal dispersion systems that can be used for delivery of viruses include macromolecule complexes, nanocapsules, microspheres, beads and lipid-based systems including oil-in-water emulsions (mixed), micelles, liposomes and lipoplexes. Organ-specific or cell-specific liposomes can be used in order to achieve delivery only to the desired tissue. The targeting of liposomes can be carried out by the person skilled in the art by applying commonly known methods. In compositions and

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methods provided, monoclonal antibodies can be used to target liposomes to specific tissues, for example, tumor tissue, via specific cell-surface ligands.

## 2. Combinations

Provided are combinations of the viruses provided herein and a second agent, such as a second virus or other therapeutic or diagnostic agent. For example the combination can include a composition containing a therapeutic virus, wherein the virus is effective for treatment of cancer and a composition comprising a chemotherapeutic agent in an amount effective for clearing the virus from a subject.

A combination can include any virus or reagent for effecting attenuation thereof in accord with the methods provided herein. Combinations can include a virus provided herein with one or more additional viruses. Combinations of the viruses provided can also contain pharmaceutical compositions containing the viruses or host cells containing the viruses as described herein.

In one embodiment, the virus in a combination is an attenuated virus, such as for example, an attenuated vaccinia virus. Exemplary attenuated viruses include vaccinia viruses provided herein, such as, but not limited to, for example, vaccinia viruses such as: GLV-1h22, GLV-1h68, GLV-1i69, GLV-1h70, GLV-1h71, GLV-1h72, GLV-1h73, GLV-1h74, GLV-1h81, GLV-1h82, GLV-1h83, GLV-1h84, GLV-1h85, GLV-1h86, GLV-1h90, GLV-1h91, GLV-1h92, GLV-1h96, GLV-1h97, GLV-1h98, GLV-1h99, GLV-1h100, GLV-1h101, GLV-1h104, GLV-1h105, GLV-1h106, GLV-1h107, GLV-1h108, GLV-1h109, GLV-1h139, GLV-1h146, GLV-1h150 GLV-1h151, GLV-1h152 or GLV-1h153.

Combinations provided herein can contain a virus and a therapeutic compound. Therapeutic compounds for the compositions provided herein can be, for example, an anti-cancer or chemotherapeutic compound. Exemplary therapeutic compounds include, for example, cytokines, growth factors, photosensitizing agents, radionuclides, toxins, siRNA molecules, enzyme/pro-drug pairs, anti-metabolites, signaling modulators, anti-cancer antibiotics, anti-cancer antibodies, angiogenesis inhibitors, chemotherapeutic compounds, or a combination thereof. Viruses provided herein can be combined with a chemotherapeutic agent that can kill or inhibit viral growth or toxicity in addition to enhancing the therapeutic effect of the combination itself. Exemplary chemotherapeutic agents include, but are not limited to,

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methotrexate, vincristine, adriamycin, non-sugar containing chloroethylnitrosoureas,  
 5-fluorouracil, mitomycin C, bleomycin, doxorubicin, dacarbazine, taxol, fragyline,  
 Meglamine GLA, valrubicin, carmustine and polifeprosan, MM1270, BAY 12-9566,  
 RAS famesyl transferase inhibitor, famesyl transferase inhibitor, MMP,  
 5 MTA/LY231514, LY264618/Lometrexol, Glamolec, CI-994, TNP-470,  
 Hycamtin/Topotecan, PKC412, Valspodar/PSC833, Novantrone/Mitroxantrone,  
 Metaret/Suramin, Batimastat, E7070, BCH-4556, CS-682, 9-AC, AG3340, AG3433,  
 Incel/VX-710, VX-853, ZD0101, IS1641, ODN 698, TA 2516/Marmistat,  
 BB2516/Marmistat, CDP 845, D2163, PD183805, DX8951f, Lemonal DP 2202, FK  
 10 317, Picibanil/OK-432, AD 32/Valrubicin, Metastron/strontium derivative,  
 Temodal/Temozolomide, Evacet/liposomal doxorubicin, Yewtaxan/Paclitaxel,  
 Taxol®/Paclitaxel, Xeloda/Capecitabine, Furtulon/Doxifluridine, Cyclopax/oral  
 paclitaxel, Oral Taxoid, SPU-077/Cisplatin, HMR 1275/Flavopiridol, CP-358  
 (774)/EGFR, CP-609 (754)/RAS oncogene inhibitor, BMS-182751/oral platinum,  
 15 UFT(Tegafur/Urâcil), Ergamisol/Levamisole, Eniluracil/776C85/SFU enhancer,  
 Campto/Levamisole, Camptosar/Irinotecan, Tumodex/Ralitrexed,  
 Leustatin/Cladribine, Paxex/Paclitaxel, Doxil/liposomal doxorubicin,  
 Caelyx/liposomal doxorubicin, Fludara®/Fludarabine, Pharmarubicin/Epirubicin,  
 DepoCyt, ZD1839, LU 79553/Bis-Naphtalimide, LU 103793/Dolastain,  
 20 Gemzar/Gemcitabine, ZD 0473/Anormed, YM 116, Iodine seeds, CDK4 and CDK2  
 inhibitors, PARP inhibitors, D4809/Dexifosamide, Ifes/Mesnex/Ifosfamide,  
 Vumon®/Teniposide, Paraplatin/Carboplatin, Plantinol/cisplatin, Vepeside/Etoposide,  
 ZD 9331, Taxotere/Docetaxel, prodrug of guanine arabinoside, Taxane Analog,  
 nitrosoureas, alkylating agents such as melphelan and cyclophosphamide,  
 25 Aminoglutethimide, Anastrozole, Asparaginase, Busulfan, Carboplatin,  
 Chlorombucil, Cladribine, Cytarabine HCl, Dactinomycin, Daunorubicin HCl,  
 Denileukin diftitox, Estramustine phosphate sodium, Etoposide (VP16-213),  
 Exemestane, Floxuridine, Fluorouracil (5-FU®), Flutamide, Hydroxyurea  
 (hydroxycarbamide), Interferon Alfa-2a, Interferon Alfa-2b, Interferon Gamma-1b,  
 30 Letrozole, Leuprolide acetate (LHRH-releasing factor analogue), Lomustine (CCNU),  
 Mechlorethamine HCl (nitrogen mustard), Megestrol, Mercaptopurine, Mesna,  
 Mitotane (o.p'-DDD), Mitoxantrone HCl, Octreotide,

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Pegaspargase, Plicamycin, Procarbazine HCl, Streptozocin, Tamoxifen citrate, Thioguanine, Thiotepa, Tretinoin, Vinblastine sulfate, Amsacrine (m-AMSA), Azacitidine, Erythropoietin, Hexamethylmelamine (HMM), Interleukin 2, Mitoguazone (methyl-GAG; methyl glyoxal bis-guanylhydrazone; MGBG),  
5 Pentostatin (2'deoxycoformycin), Semustine (methyl-CCNU), Teniposide (VM-26®), Vindesine sulfate, Altretamine, Carmustine, Chlorambucil, Estramustine, Gemtuzumab ozogamicin, Idarubicin, Isotretinoin, Leuprolide, Melphalan, Mitoxantrone, Pipobroman, Procarbazine, Testolactone, Uracil mustard, Vinblastine and Vinorelbine.

10 In a further embodiment, the combination can include additional therapeutic compounds such as, for example, compounds that are substrates for enzymes encoded and expressed by the virus, or other therapeutic compounds provided herein or known in the art to act in concert with a virus. For example, the virus can express an enzyme that converts a prodrug into an active chemotherapy drug for killing the cancer cell.  
15 Hence, combinations provided herein can contain therapeutic compounds, such as prodrugs. Any of a variety of known combinations known in the art can be included in the combinations provided herein.

In a further embodiment, combinations can include other compounds other than chemotherapeutic agents that can kill or inhibit viral growth or toxicity.  
20 Combinations provided herein can contain antibiotic, antifungal, anti-parasitic or antiviral compounds for treatment of infections. Exemplary antibiotics which can be included in a combination with a virus provided herein include, but are not limited to, ceftazidime, cefepime, imipenem, aminoglycoside, vancomycin, and antipseudomonal  $\beta$ -lactam. Exemplary antifungal agents which can be included in a combination with a  
25 virus provided herein include, but are not limited to, amphotericin B, dapsona, fluconazole, flucytosine, griseofluvin, intraconazole, ketoconazole, miconazole, clotrimazole, nystatin, and combinations thereof. Exemplary antiviral agents can be included in a combination with a virus provided herein include, but are not limited to, cidofovir, alkoxyalkyl esters of cidofovir (CDV), gancyclovir, cyclic CDV, and (S)-9-  
30 (3-hydroxy-2 phosphonylmethoxypropyl)adenine, 5-(Dimethoxymethyl)-2'-deoxyuridine, isatin-beta-thiosemicarbazone, N-methanocarbothymidine, brivudin, 7-deazaneplanocin A, ST-246, Gleevec, 2'-beta-fluoro-2',3'-dideoxyadenosine,

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indinavir, nelfinavir, ritonavir, nevirapine, AZT, ddI, ddC, vaccinia immunoglobulin, interferon beta-1a, interferon beta 1-b and combinations thereof. Typically, combinations with an antiviral agent contain an antiviral agent known to be effective against the virus of the combination. For example, combinations can contain a  
5 vaccinia virus with an antiviral compound, such as cidofovir, alkoxyalkyl esters of cidofovir, gancyclovir, acyclovir, ST-246, and Gleevec.

In another embodiment, the combination can further include a virus gene expression modulating compound. Compounds that modulate gene expression are known in the art, and include, but are not limited to, transcriptional activators,  
10 inducers, transcriptional suppressors, RNA polymerase inhibitors, and RNA binding compounds such as siRNA or ribozymes. Any of a variety of gene expression modulating compounds known in the art can be included in the combinations provided herein. Typically, the gene expression modulating compound included with a virus in the combinations provided herein will be a compound that can bind, inhibit,  
15 or react with one or more compounds, active in gene expression such as a transcription factor or RNA of the virus of the combination. A variety of other virus/expression modulator combinations known in the art can be included in the combinations provided herein.

In a further embodiment, combination can further contain nanoparticles.  
20 Nanoparticles can be designed such that they carry one or more therapeutic agents provided herein. Additionally, nanoparticles can be designed to carry a molecule that targets the nanoparticle to the tumor cells.

### 3. Kits

The viruses, cells, pharmaceutical compositions, or combinations provided  
25 herein can be packaged as kits. Kits can optionally include one or more components such as instructions for use, devices, and additional reagents, and components, such as tubes, containers and syringes for practice of the methods. Exemplary kits can include the viruses provided herein, and can optionally include instructions for use, a device for detecting a virus in a subject, a device for administering the virus to a  
30 subject, and a device for administering a compound to a subject.

In one example, a kit can contain instructions. Instructions typically include a tangible expression describing the virus and, optionally, other components included in

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the kit, and methods for administration, including methods for determining the proper state of the subject, the proper dosage amount, and the proper administration method, for administering the virus. Instructions can also include guidance for monitoring the subject over the duration of the treatment time.

5           In another example, a kit can contain a device for detecting a virus in a subject. Devices for detecting a virus in a subject can include a low light imaging device for detecting light, for example, emitted from luciferase, or fluoresced from fluorescent protein, such as a green or red fluorescent protein, a magnetic resonance measuring device such as an MRI or NMR device, a tomographic scanner, such as a  
10   PET, CT, CAT, SPECT or other related scanner, an ultrasound device, or other device that can be used to detect a protein expressed by the virus within the subject. Typically, the device of the kit will be able to detect one or more proteins expressed by the virus of the kit. Any of a variety of kits containing viruses and detection devices can be included in the kits provided herein, for example, a virus expressing  
15   luciferase and a low light imager, or a virus expressing fluorescent protein, such as a green or red fluorescent protein, and a low light imager.

Kits provided herein also can include a device for administering a virus to a subject. Any of a variety of devices known in the art for administering medications or vaccines can be included in the kits provided herein. Exemplary devices include, but  
20   are not limited to, a hypodermic needle, an intravenous needle, a catheter, a needle-less injection device, an inhaler, and a liquid dispenser, such as an eyedropper. Typically, the device for administering a virus of the kit will be compatible with the virus of the kit; for example, a needle-less injection device such as a high pressure injection device can be included in kits with viruses not damaged by high pressure  
25   injection, but is typically not included in kits with viruses damaged by high pressure injection.

Kits provided herein also can include a device for administering a compound to a subject. Any of a variety of devices known in the art for administering medications to a subject can be included in the kits provided herein. Exemplary  
30   devices include a hypodermic needle, an intravenous needle, a catheter, a needle-less injection, but are not limited to, a hypodermic needle, an intravenous needle, a catheter, a needle-less injection device, an inhaler, and a liquid dispenser such as an

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eyedropper. Typically the device for administering the compound of the kit will be compatible with the desired method of administration of the compound. For example, a compound to be delivered subcutaneously can be included in a kit with a hypodermic needle and syringe.

## 5 G. EXAMPLES

The following examples are offered for illustrative purposes only, and are not intended to limit the scope of the present invention in any way. Various modifications of the invention in addition to those shown and described herein will be apparent to those skilled in the art from the foregoing description.

10

### EXAMPLE 1

#### EFFECT OF GEMCITABINE ON ABILITY OF MODIFIED VACCINIA VIRUSES TO ARREST OR REVERSE *in vivo* LUNG TUMOR GROWTH

The *in vivo* effect of gemcitabine on tumor growth inhibition by modified vaccinia virus strain GLV-1h68 was evaluated using a mouse model of lung cancer. Tumors were established in nude mice by subcutaneously (s.c.) injecting A549 lung carcinoma cells into male nude mice [s.c. on right lateral thigh;  $5 \times 10^6$  cells; ATCC# CCL-185CRL]. Eight mice [Hsd:Athymic Nude-*Foxn1*<sup>nu</sup>; Harlan, Indianapolis, IN] were tested for each treatment. On day 23 after A549 cell implantation, viruses at a dose of  $5 \times 10^6$  PFU/mouse were injected intravenously (i.v.) into the femoral vein. At 7, 10, 13, 16, and 19 days after virus injection, Gemcitabine [Gemzar®, Eli Lilly and Company, at 50 mg/kg or 100 mg/kg] was injected intraperitoneally (i.p.). Median tumor volume (mm<sup>3</sup>) was measured at 22, 30, 37, 44, 51, 58, and 65 days post-tumor cell implantation. Results are provided in Table 1.

Gemcitabine alone at both 50 mg/kg and 100 mg/kg doses did not cause any inhibition of tumor growth in the mice. At both doses, the tumors actually exhibited increased size relative to the no treatment control group. In contrast, gemcitabine, when administered in combination with GLV-1h69, was able to enhance the slowing of tumor growth and tumor shrinkage effect of GLV-1h68 at earlier time points following administration of the virus (compare *e.g.*, day 37 post-tumor cell implantation onward). The combination of 100 mg/kg gemcitabine with GLV-1h68 was not as potent in enhancing slowing of tumor growth and tumor shrinkage



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compared to the combination of 50 mg/kg gemcitabine with GLV-1h68 (see, *e.g.*, data for day 37 to day 58 post-tumor cell implantation, demonstrating that the lower dose of gemcitabine exhibited a more potent effect in the combination therapy). This indicates that higher doses of gemcitabine can have an adverse effect on virus itself.

5 **Table 1. Effect of gemcitabine and/or GLV-1h68 virus on A459 tumor cell growth**

Days Post-implantation	Median tumor volume (mm <sup>3</sup> )					
	No treatment	GLV-1h68	Gemcitabine 50 mg/kg	GLV-1h68 + Gemcitabine 50 mg/kg	Gemcitabine 100 mg/kg	GLV-1h68 + Gemcitabine 100 mg/kg
22	226.5	303.8	245.6	234.0	228.1	251.9
30	477.4	677.2	579.8	565.7	487.4	599.1
37	557.1	1031.0	745.3	725.5	693.6	906.5
44	870.0	885.7	1023.9	544.4	1046.0	796.8
51	1442.7	902.0	1229.7	485.6	1580.2	616.3
58	1520.4	456.8	1619.0	336.9	2216.6	444.9
65	2168.7	262.1	2852.0	393.5	3413.4	424.1

#### EXAMPLE 2

#### EFFECT OF GEMCITABINE ON ABILITY OF MODIFIED VACCINIA VIRUSES TO ARREST OR REVERSE *in vivo* PANCREATIC TUMOR GROWTH

10 The *in vivo* effect of gemcitabine on tumor growth inhibition by modified vaccinia virus strain GLV-1h68 was evaluated using a mouse model of pancreatic cancer. Tumors were established in nude mice by subcutaneously (s.c.) injecting PANC-1 human pancreatic carcinoma cells into the right lateral thigh of male nude mice [ $5 \times 10^6$  cells; ATCC# CRL-1469; n=3-8 mice/group, Hsd:Athymic Nude-*Foxn1*<sup>nu</sup>; Harlan, Indianapolis, IN]. On day 28 after PANC-1 cell implantation, viruses at a dose of  $5 \times 10^6$  PFU/mouse were injected intravenously (i.v.) into the tail vein. At 7, 10, 13, 16, and 19 days after virus injection, Gemcitabine [Gemzar®, Eli Lilly and Company, at 50 mg/kg or 100 mg/kg] was injected intraperitoneally (i.p.).

15 Median tumor volume (mm<sup>3</sup>) was measured at 28, 35, 42, 50, 56, 63, 71 and 79 days post-tumor cell implantation. Results are provided in Table 2.

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Gemcitabine alone was observed to decrease tumor growth in the mice at both 50 mg/kg and 100 mg/kg doses to some extent relative to the no treatment control. By contrast, gemcitabine, when administered in combination with GLV-1h68, was able to enhance the slowing of tumor growth and tumor shrinkage of GLV-1h68 at earlier time points following administration of the virus (compare *e.g.*, day 37 post-tumor cell implantation onward). The combination of 100 mg/kg gemcitabine with GLV-1h68 was not as potent in enhancing slowing of tumor growth and tumor shrinkage compared to the combination of 50 mg/kg gemcitabine with GLV-1h68 (see, *e.g.*, data for day 42 to day 71 post-tumor cell implantation, demonstrating that the lower dose of gemcitabine exhibited a more potent effect in the combination therapy). This indicates that higher doses of gemcitabine can have an adverse effect on virus itself.

**Table 2. Effect of gemcitabine and/or GLV-1h68 virus on PANC-1 tumor cell growth**

Days Post-implantation	Median tumor volume (mm <sup>3</sup> )					
	No treatment	GLV-1h68	Gemcitabine 50 mg/kg	GLV-1h68 + Gemcitabine 50 mg/kg	Gemcitabine 100 mg/kg	GLV-1h68 + Gemcitabine 100 mg/kg
28	281.6	231.7	268.1	226.2	209.7	227.8
35	395.4	425.9	359.2	408.6	417.8	401.3
42	616.7	724.5	543.6	592.3	652.5	662.5
50	1114.6	845.1	584.8	513.2	810.3	569.7
56	1146.5	776.3	682.9	510.1	655.6	554.1
63	1446.1	547.9	654.7	372.5	407.3	508.8
71	2074.6	376.3	1006.2	257.9	789.1	281.6
79	2907.7	268.2	1534.1	257.7	1437.0	242.4

### EXAMPLE 3

#### EFFECT OF GEMCITABINE ON VACCINIA VIRUS REPLICATION IN BREAST TUMOR CELLS

A chemotherapeutic agent administered to a subject to whom a virus is administered for tumor treatment can have an effect on the virus itself. Therefore, the

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effect of the chemotherapeutic agent gemcitabine on virus yield of the recombinant vaccinia virus GLV-1h68 was assessed *in vitro* by infection of human breast tumor GI-101A cells (derived from GI-101, a human ductal adenocarcinoma cell line (Rathinavelu *et al.* (1999) *Cancer Biochem. Biophys* 17:133-146, which is incorporated herein by reference in its entirety). GI-101A cells were cultured in RPMI 1640 with 20% fetal bovine serum (FBS, Mediatech, Inc., Herndon, VA), 1% antibiotic-antimycotic solution, 10 mM HEPES, 1% sodium pyruvate, 5 ng/ml of  $\beta$ -estradiol (Sigma, St. Louis, MO), and 5 ng/ml of progesterone (Sigma, St. Louis, MO). African green monkey kidney fibroblast cells, CV-1 (CCL-70; ATCC, Manassas, VA), were used to titrate virus and were grown in DMEM (Mediatech, Inc., Herndon, VA) with 10% FBS (Mediatech, Inc., Herndon, VA). All cell lines were maintained at 37°C with 5% CO<sub>2</sub> in a humidified incubator.

GI-101A cells were plated in 6-well plates. The cells were then infected with GLV-1h68 at a multiplicity of infection (m.o.i.) of 0.01 for 1 hour at 37°C in the presence of gemcitabine [Gemzar®, Eli Lilly and Company] at the following concentrations: 0, 0.01, 0.1, 1, 10, 100 and 1000  $\mu$ M. The inoculum was removed by aspiration, and the cell monolayers were washed twice with 2 ml of DPBS (Mediatech, Inc., Herndon, VA). Two (2) ml of cell culture medium containing 2% FBS with corresponding amount of gemcitabine were added into each well. Three wells of each concentration were harvested at 48 hours post infection. The harvested cells were subjected to three cycles of freeze-thaw and sonicated three times for 1 minute at full power (Bronson sonicator) prior to titration. The virus was titrated in CV-1 cells in duplicate.

The number of plaque forming units (PFU) per 10<sup>6</sup> cells decreased with increasing gemcitabine concentration. At a concentration of 0.01  $\mu$ M, gemcitabine did not significantly affect GLV-1h68 growth in GI-101A cells. However, at a concentration of 0.1  $\mu$ M, gemcitabine significantly inhibited the virus growth. The growth of GLV-1h68 was completely inhibited at concentration of 1.0  $\mu$ M and above. Gemcitabine thus appears to inhibit vaccinia viral replication in breast tumor cells.

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**Table 3. Effect of gemcitabine on viral replication in GI-101A breast cancer tumor cells**

Gemcitabine Concentration ( $\mu\text{M}$ )	Virus Titer
0	$8.02 \times 10^6 \pm 1.34 \times 10^6$
0.01	$7.38 \times 10^6 \pm 2.00 \times 10^6$
0.1	$7.12 \times 10^6 \pm 2.53 \times 10^5$
1	0
10	0
100	0
1000	0

**EXAMPLE 4**

5        **EFFECT OF IRINOTECAN ON THE ABILITY OF MODIFIED VACCINIA VIRUSES TO ARREST OR REVERSE *in vivo* BREAST TUMOR GROWTH**

The *in vivo* effect of irinotecan on tumor growth inhibition by modified vaccinia virus strain GLV-1h68 was evaluated using a mouse model of breast cancer. Tumors were established in nude mice by subcutaneously (s.c.) injecting GI-101A human breast carcinoma cells into four groups of female nude mice (Hsd:Athymic Nude-Foxn1<sup>nu</sup>; Harlan, Indianapolis, IN) (n = 6) [s.c. on the right lateral thigh;  $5 \times 10^6$  cells; GI-101A cells: Rumbaugh-Goodwin Institute for Cancer Research Inc. Plantation, FL; U.S. Pat. No. 5,693,533]. Twenty two days following tumor cell implantation, two groups of mice (n = 6) were injected intravenously [in 100  $\mu\text{l}$  of

10        PBS, through femoral vein under anesthesia] with  $5 \times 10^6$  PFU of GLV-1h68. Four

15        doses of irinotecan at 80mg/kg were administered by intraperitoneal route beginning 2 weeks after virus injection. The irinotecan doses were administered once weekly. Tumor volume ( $\text{mm}^3$ ) was measured at different time points post-cancer cell injection. Results of median tumor volume are provided in Table 4.

20        Irinotecan alone actually increased tumor growth in the mice. In contrast, irinotecan was able to enhance the slowing of tumor growth and tumor shrinkage effect of GLV-1h68 when administered in the combination with GLV-1h68 relative to administration of GLV-1h68 alone (compare *e.g.*, day 42 post-tumor cell implantation onward).

25        **Table 4. Effect of irinotecan on viral replication in GI-101A breast cancer tumor cells**

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Days post-implantation of tumor cells	Median tumor volume (mm <sup>3</sup> )			
	No Treatment	GLV-1h68	Irinotecan	GLV-1h68 + Irinotecan
22	244.5	166	184	219.45
32	594.9	604.3	458.45	546
36	695.85	649.3	546.2	734.55
42	951.55	1002	668.75	921.25
49	1261.05	1200.8	712.9	973.35
59	1844.7	1694	831.8	901.55
66	nd	2049.2	1011.8	1003.25
80	nd	2608.4	1502.15	817.45
86	nd	2296.8	1678.4	684.8
99	nd	1647.5	2712.55	526.15
108	nd	nd	nd	429.25
116	nd	nd	nd	337.65

## EXAMPLE 5

## EFFECT OF IRINOTECAN ON IMPROVING GENERAL HEALTH IN SUBJECTS TREATED BY MODIFIED VACCINIA VIRUS

5 Body weight can be used as an indicator of patient health. In mouse models of cancer, decreasing body weight is typically associated with stress and decline in health. The percent of body weight change following intravenous administration of modified vaccinia virus strain GLV-1h68 with and without irinotecan was examined to determine what effect co-administration of irinotecan with virus would have on the

10 mouse models of breast cancer (Example 4). Net body weight was calculated by subtracting the estimated tumor weight from gross body weight for each mouse. Results of net body weight change are provided in Table 5.

15 It was observed that mice treated with the combination of virus with irinotecan experienced a greater change in net body weight relative to those treated with virus alone. These results suggest that the combination of modified vaccinia virus with irinotecan imposes less physiological stress on the overall health of the mice compared to that imposed by the administration of virus alone. As a result, in addition to producing a more potent therapeutic effect, the combination of virus and

irinotecan can help minimize toxic side effects that can result from viral administration.

**Table 5. Net body weight of mice injected with in GI-101A breast cancer tumor cells during administration of cancer treatment in the absence and presence of GLV-1h68 virus and irinotecan.**

5

Days post-implantation of tumor cells	Net Median Body Weight Change (%)			
	No Treatment	GLV-1h68	Irinotecan	GLV-1h68 + Irinotecan
22	0	0	0	0
32	4.87	0.92	2.37	5.02
36	6.43	9.22	4.09	8.7
42	10.64	9.22	2.58	6.62
49	13.08	12.9	6.67	8.7
59	19.07	11.98	13.98	20.78
66	nd	12.9	12.69	17.35
80	nd	11.98	15.27	16.21
86	nd	14.75	16.77	15.07
99	nd	8.76	17.85	14.38
108	nd	nd	nd	16.44
116	nd	nd	nd	12.56

#### EXAMPLE 6

#### EFFECT OF IRINOTECAN ON VACCINIA VIRUS REPLICATION IN BREAST TUMOR CELLS

10 The effect of the chemotherapeutic agent irinotecan on virus yield of the recombinant vaccinia virus GLV-1h68 was assessed *in vitro* by infection of human breast tumor GI-101A cells. GI-101A cells were cultured as described in Example 3. African green monkey kidney fibroblast cells, CV-1 (CCL-70; ATCC, Manassas, VA), were used to titrate virus and were also grown as described in Example 3. All  
15 cell lines were maintained at 37°C with 5% CO<sub>2</sub> in a humidified incubator.

GI-101A cells in 6-well plates were infected with GLV-1h68 at a multiplicity of infection (m.o.i) of 0.01 for 1h at 37°C in presence of irinotecan at the following concentrations: 0, 0.01, 0.1, 1.0, 10, 100, and 1000 μM. The inoculum was aspirated and the cell monolayers were washed twice with 2 ml of DPBS (Mediatech, Inc.,

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Herndon, VA). Two ml of cell culture medium containing 2% FBS with corresponding amount of cisplatin were added into each well. Three wells of each concentration were harvested at 48 hours post infection. The harvested cells were subject to three cycles of freeze-thaw and were sonicated thrice for 1 minute at full power prior to titration. The virus was titrated in CV-1 cells in duplicate.

At the concentration of up to 10  $\mu\text{M}$ , irinotecan did not show any inhibitory effect on the growth of GLV-1h68 virus in GI-101A cells. However, the growth of GLV-1h68 was significantly inhibited at the concentration of 100  $\mu\text{M}$ , and completely inhibited at 1000  $\mu\text{M}$ . (See Table 6) The cytotoxic effect of irinotecan to GI-101A cells can contribute to the viral replication inhibition observed at higher concentrations. Nevertheless, the results indicate that irinotecan can inhibit vaccinia viral replication in breast tumor cells.

**Table 6. Effect of irinotecan on viral replication in GI-101A breast cancer tumor cells**

<b>Irinotecan Concentration (<math>\mu\text{M}</math>)</b>	<b>Virus Titer</b>
0	$2.03 \times 10^5 \pm 2.73 \times 10^4$
0.01	$3.95 \times 10^5 \pm 2.79 \times 10^5$
0.1	$5.50 \times 10^5 \pm 3.83 \times 10^5$
1	$3.18 \times 10^5 \pm 1.29 \times 10^5$
10	$4.00 \times 10^5 \pm 3.64 \times 10^5$
100	$5.31 \times 10^4 \pm 1.11 \times 10^4$
1000	$1.23 \times 10^2 \pm 43.7$

15

#### EXAMPLE 7

#### EFFECT OF IRINOTECAN ON PREVENTING SYSTEMIC TOXICITY INDUCED BY ADMINISTRATION OF MODIFIED VACCINIA VIRUSES FOR CANCER TREATMENT

Subjects treated with vaccinia viral therapy often suffer from adverse effects of viral therapy. Exemplary side effects include the formation of pocks in the tails, paws, face, ear tag wounds and other areas of the body surface in immunocompromised hosts, such as in nude mice. Pock formation may start any time from between one week to months after virus injection, and the timing of pock formation is dependent upon the dose of virus delivered, the delivery route, subject body temperature at the time of virus injection, and the immune status of the recipient.

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It was observed that when  $5 \times 10^6$  PFU of GLV-1h68 was delivered through femoral vein in mice injected subcutaneously with GI-101A tumor cells (n=8), 7 out of 8 animals developed pocks in tails, paws, face and/or other areas 80 days after virus injection. Variations in the timing of pock formation were observed in the group. In contrast, four doses of irinotecan (80mg/kg, by intraperitoneal route, beginning 2 weeks after virus injection, one week apart between each dose administered) were delivered to GLV-1h68 virus-treated animals (n=8), and no pocks were observed in 7 out of 8 animals on any part of the body 80 days after virus injection. The exception was in one animal with an ear tag wound.

Thus, irinotecan appears to prevent systemic toxicity (evaluated by pock formation of virus-infected subjects) of the intravenously injected vaccinia virus. In addition to the synergistic antitumor effect observed in Example 4, irinotecan also appears to provide an overall benefit in limiting symptoms associated with systemic toxicity of the virus.

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## EXAMPLE 8

## EFFECT OF DOXORUBICIN ON VACCINIA VIRUS REPLICATION IN BREAST TUMOR CELLS

The effect of the chemotherapeutic agent doxorubicin on virus yield of the recombinant vaccinia virus GLV-1h68 was assessed *in vitro* by infection of human breast tumor GI-101A cells. GI-101A cells were cultured as described in Example 3. African green monkey kidney fibroblast cells, CV-1 (CCL-70; ATCC, Manassas, VA), were used to titrate virus and were also grown as described in Example 3. All cell lines were maintained at 37°C with 5% CO<sub>2</sub> in a humidified incubator.

GI-101A cells in 6-well plates were infected with GLV-1h68 at a multiplicity of infection (m.o.i) of 0.01 for 1h at 37°C in presence of doxorubicin at the following concentrations: 0, 0.01, 0.1, 1.0, 10, 100, and 1000 μM. The inoculum was aspirated and the cell monolayers were washed twice with 2 ml of DPBS (Mediatech, Inc., Herndon, VA). Two ml of cell culture medium containing 2% FBS with corresponding amount of doxorubicin were added into each well. Three wells of each concentration were harvested at 48 hours post infection. The harvested cells were



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subject to three cycles of freeze-thaw and were sonicated thrice for 1 minute at full power prior to titration. The virus was titrated in CV-1 cells in duplicate.

At the concentration of 0.1  $\mu\text{M}$ , doxorubicin started to inhibit GLV-1h68 virus growth in GI-101A cells. The growth of GLV-1h68 was completely inhibited at the concentration of 1  $\mu\text{M}$  and above. (See Table 7.) The results indicate that doxorubicin can inhibit vaccinia viral replication in breast tumor cells.

**Table 7. Effect of doxorubicin on viral replication in GI-101A breast cancer tumor cells**

<b>Doxorubicin Concentration (<math>\mu\text{M}</math>)</b>	<b>Virus Titer</b>
0	$2.4 \times 10^6 \pm 6.9 \times 10^5$
0.01	$3.1 \times 10^6 \pm 1.1 \times 10^6$
0.1	$1.4 \times 10^6 \pm 9.4 \times 10^5$
1	0
10	0
100	0
1000	0

10

#### EXAMPLE 9

#### EFFECT OF CISPLATIN ON VACCINIA VIRUS REPLICATION IN BREAST TUMOR CELLS

The effect of the chemotherapeutic agent cisplatin on virus yield of the recombinant vaccinia virus GLV-1h68 was assessed *in vitro* by infection of human breast tumor GI-101A cells. GI-101A cells were cultured as described in Example 3. African green monkey kidney fibroblast cells, CV-1 (CCL-70; ATCC, Manassas, VA), were used to titrate virus and were also grown as described in Example 3. All cell lines were maintained at 37°C with 5% CO<sub>2</sub> in a humidified incubator.

GI-101A cells in 6-well plates were infected with GLV-1h68 at a multiplicity of infection (m.o.i) of 0.01 for 1h at 37°C in presence of cisplatin at the following concentrations: 0; 0.01, 0.1, 1.0, 10, 100, and 1000  $\mu\text{M}$ . The inoculum was aspirated and the cell monolayers were washed twice with 2 ml of DPBS (Mediatech, Inc., Herndon, VA). Two ml of cell culture medium containing 2% FBS with corresponding amount of cisplatin were added into each well. Three wells of each concentration were harvested at 48 hours post infection. The harvested cells were

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subject to three cycles of freeze-thaw and were sonicated thrice for 1 minute at full power prior to titration. The virus was titrated in CV-1 cells in duplicate.

At a concentration of 1  $\mu\text{M}$ , cisplatin started to inhibit GLV-1h68 growth in GI-101A cells. At a concentration of 10  $\mu\text{M}$ , cisplatin significantly inhibited the virus growth. The growth of GLV-1h68 was completely inhibited at the concentration of 100  $\mu\text{M}$  and above. (See Table 8.) The cytotoxic effect of cisplatin to GI-101A cells can contribute to the viral replication inhibition at higher concentrations. Nevertheless, the results indicate that cisplatin can inhibit vaccinia viral replication in breast tumor cells.

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**Table 8. Effect of cisplatin on viral replication in GI-101A breast cancer tumor cells**

<b>Cisplatin Concentration (<math>\mu\text{M}</math>)</b>	<b>Virus Titer</b>
0	$9.1 \times 10^6 \pm 5.5 \times 10^6$
0.01	$7.6 \times 10^6 \pm 3.6 \times 10^6$
0.1	$1.1 \times 10^7 \pm 6.1 \times 10^6$
1	$3.4 \times 10^6 \pm 2.2 \times 10^6$
10	$1.6 \times 10^5 \pm 1.6 \times 10^5$
100	0
1000	0

#### EXAMPLE 10

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#### EFFECT OF GEMCITABINE ON VIRAL LOAD IN A PATIENT

The chemotherapeutic agent gemcitabine is administered to a subject to whom a modified vaccinia virus, such as, for example, GLV-1h68, is administered for tumor treatment. The patient is injected with a virus at a level effective for arrest and/or shrinkage of tumor growth. Gemcitabine is subsequently administered by intravenous infusion once a week for up to seven weeks to the patient at a dose of 8.1 mg/kg (conversion calculated according to FDA's Guidance for Industry and Reviewers: "Estimating the Maximum Safe Starting Dose in Initial Clinical Trials for Therapeutics in Adult Healthy Volunteers", U.S. Department of Health and Human Services, Food and Drug Administration (FDA), Center for Drug Evaluation and Research (CDER), July 6, 2005). Viral load in the bloodstream is measured intermittently over the period of time that gemcitabine is administered and for 7

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weeks afterwards. It is expected that the viral load in the bloodstream increases to a lesser extent relative to that of a subject which does not receive gemcitabine. In addition, viral load decreases more quickly during over the 14 week period relative to that of a control subject which does not receive gemcitabine.

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## EXAMPLE 11

## EFFECT OF IRINOTECAN ON VIRAL LOAD IN A PATIENT

The chemotherapeutic agent irinotecan is administered to a subject to whom a modified vaccinia virus, such as, for example, GLV-1h68, is administered for tumor treatment. The patient is injected with a virus at a level effective for arrest and/or shrinkage of tumor growth. Irinotecan is subsequently administered by intravenous infusion once a week for up to four weeks to the patient at a dose of  $125 \text{ mg/m}^2$ , followed by a two-week rest period. The administration of irinotecan is optionally repeated over a 6-week cycle as described. Viral load in the bloodstream is measured intermittently over the period of time that irinotecan is administered and for 7 weeks afterwards. It is expected that the viral load in the bloodstream increases to a lesser extent relative to that of a subject which does not receive irinotecan. In addition, viral load decreases more quickly during the entire observation period relative to that of a control subject which does not receive irinotecan.

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## EXAMPLE 12

## EFFECT OF DOXORUBICIN ON VIRAL LOAD IN A PATIENT

The chemotherapeutic agent doxorubicin is administered to a subject to whom a modified vaccinia virus, such as, for example, GLV-1h68, is administered for tumor treatment. The patient is injected with a virus at a level effective for arrest and/or shrinkage of tumor growth. Doxorubicin is subsequently administered by intravenous infusion once every three weeks per cycle at a dose of  $60 \text{ mg/m}^2$ . The administration of doxorubicin is optionally repeated for additional cycles as described. Viral load in the bloodstream is measured intermittently over the period of time that doxorubicin is administered and for 7 weeks afterwards. It is expected that the viral load in the bloodstream increases to a lesser extent relative to that of a subject which does not receive doxorubicin. In addition, viral load decreases more quickly during the entire

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observation period relative to that of a control subject which does not receive doxorubicin.

### EXAMPLE 13

#### EFFECT OF CISPLATIN ON VIRAL LOAD IN A PATIENT

5           The chemotherapeutic agent cisplatin is administered to a subject to whom a modified vaccinia virus, such as, for example, GLV-1h68, is administered for tumor treatment. The patient is injected with a virus at a level effective for arrest and/or shrinkage of tumor growth. Cisplatin is subsequently administered by intravenous infusion once every four weeks per cycle at a dose of  $75 \text{ mg/m}^2$ . The administration  
10 of cisplatin is optionally repeated for additional cycles as described. Viral load in the bloodstream is measured intermittently over the period of time that cisplatin is administered and for 7 weeks afterwards. It is expected that the viral load in the bloodstream increases to a lesser extent relative to that of a subject which does not receive cisplatin. In addition, viral load decreases more quickly during the entire  
15 observation period relative to that of a control subject which does not receive cisplatin.

### EXAMPLE 14

#### USE OF GEMCITABINE TO REDUCE SIDE EFFECTS OF VACCINIA VIRUS POST-VACCINATION

20           The chemotherapeutic agent gemcitabine is administered to a subject to whom a modified vaccinia virus, such as, for example, GLV-1h68, is administered for tumor treatment. The patient is initially injected with a dose of virus effective for arrest and/or shrinkage of tumor growth. The patient begins to experience side effects related to use of the vaccinia virus, such as pock formation, weight loss, fever,  
25 abdominal pain, aches or pains in muscles, cough, diarrhea, or general feeling of discomfort or illness. Gemcitabine is subsequently administered by intravenous injection once a week for up to seven weeks to the patient at a dose of 15 mg/kg, 20 mg/kg or 30 mg/kg. Viral load in the bloodstream is measured intermittently over the period of time that gemcitabine is administered and for 7 weeks afterwards. It is  
30 expected that body weight of the patient is improved and any pock formation dissipates relative to that of a control subject which does not receive gemcitabine.

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Furthermore, it is expected that the viral load in the bloodstream decreases over the period of time after gemcitabine is administered, and the patient's symptoms subside after gemcitabine treatment is initiated.

## EXAMPLE 15

5 USE OF IRINOTECAN TO REDUCE SIDE EFFECTS OF VIRUS POST-  
VACCINATION

The chemotherapeutic agent irinotecan is administered to a subject to whom a modified vaccinia virus, such as, for example, GLV-1h68, is administered for tumor treatment. The patient is initially injected with a dose of virus effective for arrest  
10 and/or shrinkage of tumor growth. The patient begins to experience side effects related to use of the vaccinia virus, such as pock formation, weight loss, fever, abdominal pain, aches or pains in muscles, cough, diarrhea, or general feeling of discomfort or illness. Irinotecan is subsequently administered by intravenous injection once a week for up to four weeks to the patient at a dose of between 100 to  
15 150 mg/m<sup>2</sup>, followed by a two-week rest period. The administration of irinotecan is optionally repeated over a 6-week cycle as described. Viral load in the bloodstream is measured intermittently over the period of time that irinotecan is administered and for 7 weeks afterwards. It is expected that body weight of the patient is improved and any pock formation dissipates relative to that of a control subject which does not  
20 receive irinotecan. Furthermore, it is expected that the viral load in the bloodstream of the patient treated with irinotecan decreases over the period of time after irinotecan is administered, and the patient's symptoms subside after irinotecan treatment is initiated.

## EXAMPLE 16

25 USE OF DOXORUBICIN TO REDUCE SIDE EFFECTS OF VIRUS POST-  
VACCINATION

The chemotherapeutic agent doxorubicin is administered to a subject to whom a modified vaccinia virus, such as, for example, GLV-1h68, is administered for tumor treatment. The patient is initially injected with a dose of virus effective for arrest  
30 and/or shrinkage of tumor growth. The patient begins to experience side effects related to use of the viral vaccine, such as pock formation, weight loss, fever,

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abdominal pain, aches or pains in muscles, cough, diarrhea, or general feeling of discomfort or illness. Doxorubicin is subsequently administered by intravenous injection once every four weeks per cycle to the patient at a dose of between 60 to 75 mg/m<sup>2</sup>. The administration of doxorubicin is optionally repeated for additional cycles as described. Viral load in the bloodstream is measured intermittently over the period of time that doxorubicin is administered and for 7 weeks afterwards. It is expected that body weight of the patient is improved and any pock formation dissipates relative to that of a control subject which does not receive doxorubicin. Furthermore, it is expected that the viral load in the bloodstream of the patient treated with doxorubicin decreases over the period of time after doxorubicin is administered, and the patient's symptoms subside after doxorubicin treatment is initiated.

## EXAMPLE 17

## USE OF CISPLATIN TO REDUCE SIDE EFFECTS OF VIRUS POST-VACCINATION

The chemotherapeutic agent cisplatin is administered to a subject to whom a modified vaccinia virus, such as, for example, GLV-1h68, is administered for tumor treatment. The patient is initially injected with a dose of virus effective for arrest and/or shrinkage of tumor growth. The patient begins to experience side effects related to use of the viral vaccine, such as pock formation, weight loss, fever, abdominal pain, aches or pains in muscles, cough, diarrhea, or general feeling of discomfort or illness. Cisplatin is subsequently administered by intravenous injection once every three weeks per cycle to the patient at a dose of between 50 to 75 mg/m<sup>2</sup>. The administration of cisplatin is optionally repeated for additional cycles as described. Viral load in the bloodstream is measured intermittently over the period of time that cisplatin is administered and for 7 weeks afterwards. It is expected that body weight of the patient is improved and any pock formation dissipates relative to that of a control subject which does not receive cisplatin. Furthermore, it is expected that the viral load in the bloodstream of the patient treated with cisplatin decreases over the period of time after cisplatin is administered, and the patient's symptoms subside after cisplatin treatment is initiated.

## EXAMPLE 18

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SIMULTANEOUS ADMINISTRATION OF GEMCITABINE WITH  
ADMINISTRATION OF VIRUS TO REDUCE SIDE EFFECTS OF VIRUS

The chemotherapeutic agent gemcitabine is administered to a subject to whom a modified vaccinia virus, such as, for example, GLV-1h68, is administered for tumor  
5 treatment. The patient is injected with a dose of virus effective for arrest and/or shrinkage of tumor growth. The patient simultaneously is administered gemcitabine by intravenous infusion at a dose of 1000 mg/m<sup>2</sup> or 1500 mg/m<sup>2</sup> once a week for up to seven weeks. It is expected that tumor growth is arrested or decreases post-injection of virus. It is also expected that the patient suffers fewer side effects from the virus  
10 compared to a control patient which does not receive simultaneous administration of gemcitabine with the virus.

EXAMPLE 19

SIMULTANEOUS ADMINISTRATION OF IRINOTECAN WITH  
ADMINISTRATION OF VIRUS TO REDUCE SIDE EFFECTS OF VIRUS

The chemotherapeutic agent irinotecan is administered to a subject to whom a  
15 modified vaccinia virus, such as, for example, GLV-1h68, is administered for tumor treatment. The patient is injected with a dose of virus effective for arrest and/or shrinkage of tumor growth. The patient simultaneously is administered irinotecan by intravenous infusion at a dose of 100 to 150 mg/m<sup>2</sup> once a week for up to four weeks,  
20 followed by a two-week rest period. The administration of irinotecan is optionally repeated over a 6-week cycle as described. It is expected that tumor growth is arrested or decreases post-injection of virus. It also is expected that the patient suffers fewer side effects from the virus (e.g., pock formation, fever, abdominal pain, aches or pains in muscles, cough, diarrhea, or general feeling of discomfort or illness) and  
25 exhibits better general health (e.g., maintenance of body weight) compared to a control patient which does not receive simultaneous administration of irinotecan with the virus.

EXAMPLE 20

SIMULTANEOUS ADMINISTRATION OF DOXORUBICIN WITH  
30 ADMINISTRATION OF VIRUS TO REDUCE SIDE EFFECTS OF VIRUS

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The chemotherapeutic agent doxorubicin is administered to a subject to whom a modified vaccinia virus, such as, for example, GLV-1h68, is administered for tumor treatment. The patient is injected with a dose of virus effective for arrest and/or shrinkage of tumor growth. The patient simultaneously is administered doxorubicin by intravenous infusion at a dose of 60 to 75 mg/m<sup>2</sup> once every four weeks per cycle. The administration of doxorubicin is optionally repeated for additional cycles as described. It also is expected that the patient suffers fewer side effects from the virus (e.g., pock formation, fever, abdominal pain, aches or pains in muscles, cough, diarrhea, or general feeling of discomfort or illness) and exhibits better general health (e.g., maintenance of body weight) compared to a control patient which does not receive simultaneous administration of doxorubicin with the virus.

## EXAMPLE 21

SIMULTANEOUS ADMINISTRATION OF CISPLATIN WITH  
ADMINISTRATION OF VIRUS TO REDUCE SIDE EFFECTS OF VIRUS

The chemotherapeutic agent cisplatin is administered to a subject to whom a modified vaccinia virus, such as, for example, GLV-1h68, is administered for tumor treatment. The patient is injected with a dose of virus effective for arrest and/or shrinkage of tumor growth. The patient simultaneously is administered cisplatin by intravenous infusion at a dose of 50 to 75 mg/m<sup>2</sup> once every three weeks per cycle. The administration of cisplatin is optionally repeated for additional cycles as described. It also is expected that the patient suffers fewer side effects from the virus (e.g., pock formation, fever, abdominal pain, aches or pains in muscles, cough, diarrhea, or general feeling of discomfort or illness) and exhibits better general health (e.g., maintenance of body weight) compared to a control patient which does not receive simultaneous administration of cisplatin with the virus.

## EXAMPLE 22

ADMINISTRATION OF GEMCITABINE PRIOR TO ADMINISTRATION OF  
VIRUS TO REDUCE SIDE EFFECTS OF VIRUS

The chemotherapeutic agent gemcitabine is administered to a subject to whom a modified vaccinia virus, such as, for example, GLV-1h68, is administered for tumor treatment. The patient begins chemotherapy treatment with gemcitabine prior to



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being injected with virus. Gemcitabine is administered to the patient by intravenous infusion at a dose of 8 mg/kg once a week for up to four weeks. The patient is then injected a dose of virus effective for arrest and/or shrinkage of tumor growth.

Gemcitabine is subsequently administered post-viral injection by intravenous infusion  
5 at a dose of 8 mg/kg once a week for up to seven weeks. It is expected that tumor growth is arrested or decreases post-injection of virus. It also is expected that the patient suffers fewer side effects from the virus (e.g., pock formation, fever, abdominal pain, aches or pains in muscles, cough, diarrhea, or general feeling of discomfort or illness) and exhibits better general health (e.g., maintenance of body  
10 weight) compared to a patient who does not receive administration of gemcitabine both prior to and subsequent to administration of the virus.

#### EXAMPLE 23

##### ADMINISTRATION OF IRINOTECAN PRIOR TO ADMINISTRATION OF VIRUS TO REDUCE SIDE EFFECTS OF VIRUS

15 The chemotherapeutic agent irinotecan is administered to a subject to whom a modified vaccinia virus, such as, for example, GLV-1h68, is administered for tumor treatment. The patient begins chemotherapy treatment with irinotecan prior to being injected with virus. Irinotecan is administered to the patient by intravenous infusion at a dose of between 100 to 150 mg/m<sup>2</sup> once a week for up to four weeks, followed by  
20 a two-week rest period. The administration of irinotecan is optionally repeated over a 6-week cycle as described. The patient is then injected a dose of virus effective for arrest and/or shrinkage of tumor growth. Irinotecan is subsequently administered post-viral injection by intravenous infusion at a dose of between 100 to 150 mg/m<sup>2</sup> once a week for up to four weeks, again followed by a two-week rest period and  
25 optionally including a repeated administration of irinotecan over a 6-week cycle. It is expected that tumor growth is arrested or decreases post-injection of virus. It also is expected that the patient suffers fewer side effects from the virus (e.g., pock formation, fever, abdominal pain, aches or pains in muscles, cough, diarrhea, or general feeling of discomfort or illness) and exhibits better general health (e.g.,  
30 maintenance of body weight) compared to a control patient which does not receive administration of irinotecan both prior to and after administration of the virus.

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## EXAMPLE 24

ADMINISTRATION OF DOXORUBICIN PRIOR TO ADMINISTRATION OF  
VIRUS TO REDUCE SIDE EFFECTS OF VIRUS

The chemotherapeutic agent doxorubicin is administered to a subject to whom  
5 a modified vaccinia virus, such as, for example, GLV-1h68, is administered for tumor  
treatment. The patient begins chemotherapy treatment with irinotecan prior to being  
injected with virus. Doxorubicin is administered to the patient by intravenous  
infusion at a dose of between 60 to 75 mg/m<sup>2</sup> once every four weeks per cycle. The  
administration of doxorubicin is optionally repeated for additional cycles as  
10 described. The patient is then injected a dose of virus effective for arrest and/or  
shrinkage of tumor growth. Doxorubicin is subsequently administered post-viral  
injection by intravenous infusion at a dose of between 60 to 75 mg/m<sup>2</sup> per four-week  
cycle, optionally including additional cycles of doxorubicin administration as needed.  
It is expected that tumor growth is arrested or decreases post-injection of virus. It also  
15 is expected that the patient suffers fewer side effects from the virus (e.g., pock  
formation, fever, abdominal pain, aches or pains in muscles, cough, diarrhea, or  
general feeling of discomfort or illness) and exhibits better general health (e.g.,  
maintenance of body weight) compared to a control patient which does not receive  
administration of doxorubicin both prior to and after administration of the virus.

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## EXAMPLE 25

ADMINISTRATION OF CISPLATIN PRIOR TO ADMINISTRATION OF VIRUS  
TO REDUCE SIDE EFFECTS OF VIRUS

The chemotherapeutic agent cisplatin is administered to a subject to whom a  
modified vaccinia virus, such as, for example, GLV-1h68, is administered for tumor  
25 treatment. The patient begins chemotherapy treatment with cisplatin prior to being  
injected with virus. Cisplatin is administered to the patient by intravenous infusion at  
a dose of between 50 to 75 mg/m<sup>2</sup> once every three weeks per cycle. The  
administration of cisplatin is optionally repeated for additional cycles as described.  
The patient is then injected a dose of virus effective for arrest and/or shrinkage of  
30 tumor growth. Cisplatin is subsequently administered post-viral injection by  
intravenous infusion at a dose of between 50 to 75 mg/m<sup>2</sup> per three-week cycle,

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optionally including additional cycles of cisplatin administration as needed. It is expected that tumor growth is arrested or decreases post-injection of virus. It also is expected that the patient suffers fewer side effects from the virus (e.g., pock formation, fever, abdominal pain, aches or pains in muscles, cough, diarrhea, or  
5 general feeling of discomfort or illness) and exhibits better general health (e.g., maintenance of body weight) compared to a control patient which does not receive administration of cisplatin both prior to and after administration of the virus.

## EXAMPLE 26

## EFFECT OF GEMCITABINE ON VIRAL LOAD IN A PATIENT

10 The chemotherapeutic agent gemcitabine is administered to a subject to whom a modified vaccinia virus, such as, for example, GLV-1h68, is administered for tumor treatment. The patient is injected with a virus at a level effective for arrest and/or shrinkage of tumor growth. Gemcitabine is subsequently administered by intravenous infusion once a week for up to seven weeks to the patient at a dose of 9 mg/kg  
15 (conversion calculated according to FDA's Guidance for Industry and Reviewers: "Estimating the Maximum Safe Starting Dose in Initial Clinical Trials for Therapeutics in Adult Healthy Volunteers", U.S. Department of Health and Human Services, Food and Drug Administration (FDA), Center for Drug Evaluation and Research (CDER), July 6, 2005). Viral load in the bloodstream is measured  
20 intermittently over the period of time that gemcitabine is administered and for 7 weeks afterwards. It is expected that the viral load in the bloodstream is maintained or increases before subsequently decreasing over the 14 week period.

## EXAMPLE 27

## EFFECT OF IRINOTECAN ON VIRAL LOAD IN A PATIENT

25 The chemotherapeutic agent irinotecan is administered to a subject to whom a modified vaccinia virus, such as, for example, GLV-1h68, is administered for tumor treatment. The patient is injected with a virus at a level effective for arrest and/or shrinkage of tumor growth. Irinotecan is subsequently administered by intravenous infusion once a week for up to four weeks to the patient at a dose of between 100 to  
30 150 mg/m<sup>2</sup>, followed by a two-week rest period. The administration of irinotecan is optionally repeated over a 6-week cycle as described. Viral load in the bloodstream is

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measured intermittently over the period of time that gemcitabine is administered and for 7 weeks afterwards. It is expected that the viral load in the bloodstream is maintained or increases before subsequently decreasing over the observation period.

## EXAMPLE 28

## 5 EFFECT OF DOXORUBICIN ON VIRAL LOAD IN A PATIENT

The chemotherapeutic agent doxorubicin is administered to a subject to whom a modified vaccinia virus, such as, for example, GLV-1h68, is administered for tumor treatment. The patient is injected with a virus at a level effective for arrest and/or shrinkage of tumor growth. Doxorubicin is subsequently administered by intravenous  
10 infusion once every four weeks to the patient at a dose of between 60 to 75 mg/m<sup>2</sup>, and administration of doxorubicin is optionally repeated for additional cycles as described. Viral load in the bloodstream is measured intermittently over the period of time that doxorubicin is administered and for 7 weeks afterwards. It is expected that the viral load in the bloodstream is maintained or increases before subsequently  
15 decreasing over the observation period.

## EXAMPLE 29

## EFFECT OF CISPLATIN ON VIRAL LOAD IN A PATIENT

The chemotherapeutic agent cisplatin is administered to a subject to whom a modified vaccinia virus, such as, for example, GLV-1h68, is administered for tumor  
20 treatment. The patient is injected with a virus at a level effective for arrest and/or shrinkage of tumor growth. Cisplatin is subsequently administered by intravenous infusion once every three weeks to the patient at a dose of between 50 to 75 mg/m<sup>2</sup>, and administration of cisplatin is optionally repeated for additional cycles as described. Viral load in the bloodstream is measured intermittently over the period of  
25 time that cisplatin is administered and for 7 weeks afterwards. It is expected that the viral load in the bloodstream is maintained or increases before subsequently decreasing over the observation period.

## EXAMPLE 30

EFFECT OF SUSTAINED RELEASE OF A COMBINATION OF VIRUS AND  
30 GEMCITABINE ON VIRAL LOAD IN A PATIENT

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A composition comprising a modified vaccinia virus and the chemotherapeutic agent gemcitabine is implanted near the site of a tumor in a subject. The composition provides sustained release of an antigen expressed by the virus and of gemcitabine, wherein the antigen is provided to induce the subject's immune system to target the tumor. Sustained release of the antigen and gemcitabine takes place over a period of up to 8 weeks or longer. Viral load in the bloodstream is measured intermittently after implantation of the composition. It is expected that the viral load in the bloodstream is increases to a lesser extent than in a subject to which a composition comprising vaccinia virus without gemcitabine is administered. In addition, viral load in the subject decreases more rapidly over the observation period than does that of the subject in which gemcitabine is not sustainably released.

#### EXAMPLE 31

##### EFFECT OF SUSTAINED RELEASE OF A COMBINATION OF VIRUS AND IRINOTECAN ON VIRAL LOAD IN A PATIENT

A composition comprising a modified vaccinia virus and the chemotherapeutic agent irinotecan is implanted near the site of a tumor in a subject. The composition provides sustained release of an antigen expressed by the virus and of irinotecan, wherein the antigen is provided to induce the subject's immune system to target the tumor. Sustained release of the antigen and irinotecan takes place over a period of up to 8 weeks or longer. Viral load in the bloodstream is measured intermittently after implantation of the composition. It is expected that the viral load in the bloodstream is increased to a lesser extent than in a control subject to which a composition comprising vaccinia virus without irinotecan is administered. In addition, viral load in the subject decreases more rapidly over the observation period than does that of the subject in which irinotecan is not sustainably released.

#### EXAMPLE 32

##### EFFECT OF SUSTAINED RELEASE OF A COMBINATION OF VIRUS AND DOXORUBICIN ON VIRAL LOAD IN A PATIENT

A composition comprising a modified vaccinia virus and the chemotherapeutic agent doxorubicin is implanted near the site of a tumor in a subject. The composition provides sustained release of an antigen expressed by the virus and of doxorubicin,

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wherein the antigen is provided to induce the subject's immune system to target the tumor. Sustained release of the antigen and doxorubicin takes place over a period of up to 8 weeks or longer. Viral load in the bloodstream is measured intermittently after implantation of the composition. It is expected that the viral load in the  
5 bloodstream is increased to a lesser extent than in a control subject to which a composition comprising vaccinia virus without doxorubicin is administered. In addition, viral load in the subject decreases more rapidly over the observation period than does that of the subject in which doxorubicin is not sustainably released.

## EXAMPLE 33

10 EFFECT OF SUSTAINED RELEASE OF A COMBINATION OF VIRUS AND  
CISPLATIN ON VIRAL LOAD IN A PATIENT

A composition comprising a modified vaccinia virus and the chemotherapeutic agent cisplatin is implanted near the site of a tumor in a subject. The composition provides sustained release of an antigen expressed by the virus and of cisplatin,  
15 wherein the antigen is provided to induce the subject's immune system to target the tumor. Sustained release of the antigen and cisplatin takes place over a period of up to 8 weeks or longer. Viral load in the bloodstream is measured intermittently after implantation of the composition. It is expected that the viral load in the bloodstream is increased to a lesser extent than in a control subject to which a composition  
20 comprising vaccinia virus without cisplatin is administered. In addition, viral load in the subject decreases more rapidly over the observation period than does that of the subject in which cisplatin is not sustainably released.

## EXAMPLE 34

25 EFFECT OF SUSTAINED RELEASE OF A COMBINATION OF VIRUS AND  
GEMCITABINE ON VIRUS-INDUCED SYMPTOMS IN A PATIENT

A composition comprising a modified vaccinia virus and the chemotherapeutic agent gemcitabine is implanted near the site of a tumor in a subject. The composition provides sustained release of an antigen expressed by the virus and of gemcitabine,  
30 wherein the antigen is provided to induce the subject's immune system to target the tumor. Sustained release of the antigen and gemcitabine takes place over a period of up to 8 weeks. Fewer virus-associated side effects (*e.g.*, pock formation, weight loss,

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fever, abdominal pain, aches or pains in muscles, cough, diarrhea, or general feeling of discomfort or illness) are expected in the subject than in a subject in which a composition comprising virus without gemcitabine is provided.

## EXAMPLE 35

5 EFFECT OF SUSTAINED RELEASE OF A COMBINATION OF VIRUS AND  
IRINOTECAN ON VIRUS-INDUCED SYMPTOMS IN A PATIENT

A composition comprising a modified vaccinia virus and the chemotherapeutic agent irinotecan is implanted near the site of a tumor in a subject. The composition provides sustained release of an antigen expressed by the virus and of irinotecan,  
10 wherein the antigen is provided to induce the subject's immune system to target the tumor. Sustained release of the antigen and irinotecan takes place over a period of up to 8 weeks. Fewer virus-associated side effects (*e.g.*, pock formation, weight loss, fever, abdominal pain, aches or pains in muscles, cough, diarrhea, or general feeling of discomfort or illness) are expected in the subject than in a control subject in which  
15 a composition comprising virus without irinotecan is provided.

## EXAMPLE 36

EFFECT OF SUSTAINED RELEASE OF A COMBINATION OF VIRUS AND  
DOXORUBICIN ON VIRUS-INDUCED SYMPTOMS IN A PATIENT

A composition comprising a modified vaccinia virus and the chemotherapeutic  
20 agent doxorubicin is implanted near the site of a tumor in a subject. The composition provides sustained release of an antigen expressed by the virus and of doxorubicin, wherein the antigen is provided to induce the subject's immune system to target the tumor. Sustained release of the antigen and doxorubicin takes place over a period of up to 8 weeks. Fewer virus-associated side effects (*e.g.*, pock formation, weight loss,  
25 fever, abdominal pain, aches or pains in muscles, cough, diarrhea, or general feeling of discomfort or illness) are expected in the subject than in a control subject in which a composition comprising virus without doxorubicin is provided.

## EXAMPLE 37

EFFECT OF SUSTAINED RELEASE OF A COMBINATION OF VIRUS AND  
30 CISPLATIN ON VIRUS-INDUCED SYMPTOMS IN A PATIENT

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A composition comprising a modified vaccinia virus and the chemotherapeutic agent cisplatin is implanted near the site of a tumor in a subject. The composition provides sustained release of an antigen expressed by the virus and of cisplatin, wherein the antigen is provided to induce the subject's immune system to target the tumor. Sustained release of the antigen and cisplatin takes place over a period of up to 8 weeks. Fewer virus-associated side effects (*e.g.*, pock formation, weight loss, fever, abdominal pain, aches or pains in muscles, cough, diarrhea, or general feeling of discomfort or illness) are expected in the subject than in a control subject in which a composition comprising virus without cisplatin is provided.

10

#### EQUIVALENTS

The foregoing written specification is considered to be sufficient to enable one skilled in the art to practice the invention. The foregoing description and Examples detail certain preferred embodiments of the invention and describes the best mode contemplated by the inventors. It will be appreciated, however, that no matter how detailed the foregoing may appear in text, the invention may be practiced in many ways and the invention should be construed in accordance with the appended claims and any equivalents thereof.

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**WHAT IS CLAIMED IS:**

1. Use of a chemotherapeutic agent in the preparation of a medicament for the treating an adverse side effect associated with viral treatment of cancer, wherein the chemotherapeutic agent is selected from among gemcitabine, irinotecan,  
5 doxorubicin and cisplatin.
2. A chemotherapeutic agent for use in ameliorating an adverse side effect associated with viral treatment of cancer, wherein the chemotherapeutic agent is selected from among gemcitabine, irinotecan, doxorubicin and cisplatin.
3. The use of claim 1 or 2, wherein the adverse side effect comprises one  
10 or more of pock formation, weight loss, fever, abdominal pain, aches or pains in muscles, cough, diarrhea, and feeling of discomfort or illness.
4. The use of any of claims 1-3, wherein the side effect is associated with treatment with a vaccinia virus.
5. The use of claim 4, wherein the virus is a Lister strain vaccinia virus.
- 15 6. The use of claim 5, wherein the virus strain is LIVP.
7. The use of claim 6, wherein the virus is selected from among GLV-1h68, GLV-1h70, GLV-1h71, GLV-1h72, GLV-1h73, GLV-1h74, GLV-1h81, GLV-1h82, GLV-1h83, GLV-1h84, GLV-1h85, GLV-1h86, GLV-1h90, GLV-1h91, GLV-1h92, GLV-1h96, GLV-1h97, GLV-1h98, GLV-1h99, GLV-1h100, GLV-1h101,  
20 GLV-1h104, GLV-1h105, GLV-1h106, GLV-1h107, GLV-1h108, GLV-1h109, GLV-1h139, GLV-1h146, GLV-1h150 GLV-1h151, GLV-1h152 and GLV-1h153.
8. The use of any of claims 1-7, wherein the cancer is a metastatic cancer, metastasis, a solid tumor.
9. A combination, comprising:  
25 a composition containing a therapeutic virus, wherein the virus is effective for treatment of cancer; and  
a composition containing a chemotherapeutic agent in an amount effective for clearing the virus from a subject, when the composition containing the chemotherapeutic agent is administered as a single dose.
- 30 10. The combination of claim 9, wherein the chemotherapeutic agent is selected from among gemcitabine, irinotecan, doxorubicin and cisplatin.

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11. The combination of claim 9 or claim 10, wherein the therapeutic virus is a vaccinia virus.
12. The combination of claim 11, wherein the virus is a Lister strain vaccinia virus.
- 5 13. The combination of claim 12, wherein the virus is LIVP.
14. The combination of claim 13, wherein the virus is selected from among GLV-1h68, GLV-1h70, GLV-1h71, GLV-1h72, GLV-1h73, GLV-1h74, GLV-1h81, GLV-1h82, GLV-1h83, GLV-1h84, GLV-1h85, GLV-1h86, GLV-1h90, GLV-1h91, GLV-1h92, GLV-1h96, GLV-1h97, GLV-1h98, GLV-1h99, GLV-1h100, GLV-10 1h101, GLV-1h104, GLV-1h105, GLV-1h106, GLV-1h107, GLV-1h108, GLV-1h109, GLV-1h139, GLV-1h146, GLV-1h150, GLV-1h151, GLV-1h152 and GLV-1h153.
15. The combination of any of claims 9-14, wherein the chemotherapeutic agent and virus are formulated as a single composition or separately in two 15 compositions.
16. A kit, comprising:  
the combination of any of claims 9-15; and  
optionally instructions for administration of the composition(s) and/or reagents for use with the combination.
- 20 17. A method for treating one or more adverse side effects associated with viral treatment, comprising administering a chemotherapeutic agent to a subject treated with a therapeutic virus, wherein:  
the subject exhibits one or more adverse effects following administration of the virus;  
25 the amount of chemotherapeutic agent administered is sufficient to control or reduce viral titer in the subject; and  
whereby an adverse side effect is treated.
18. A method for controlling viral load in a subject, comprising administering a chemotherapeutic agent to a subject treated with a therapeutic virus, 30 wherein:

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the subject exhibits a viral titer that is equal to or exceeds an amount that causes one or more adverse side effects in the subject during treatment with the virus;

the amount of chemotherapeutic agent administered is sufficient to  
5 control or reduce viral titer in the subject.

19. The method of claim 17 or claim 18, wherein the therapeutic virus is cleared from the subject.

20. The method of claim 18, wherein the amount of chemotherapeutic agent is sufficient to clear viral titer.

10 21. The method of any of claims 17-20, wherein the virus is an oncolytic virus.

22. The method of any of claims 17-21, wherein the virus is non-pathogenic, attenuated, replication competent or preferentially accumulates in tumors or metastases.

15 23. The method of any of claims 17-22, wherein the virus is a cytoplasmic virus.

24. The method of any of claims 17-23, wherein the virus is selected from among a poxvirus, adenovirus, adeno-associated virus, herpes simplex virus, Newcastle disease virus, vesicular stomatitis virus, mumps virus, influenza virus,  
20 measles virus, reovirus, human immunodeficiency virus (HIV), hanta virus, myxoma virus, cytomegalovirus (CMV), lentivirus and Sindbis virus.

25. The method of any of claims 17-24, wherein the virus is a vaccinia virus .

25 26. The method of claim 25, wherein the virus is a Lister strain vaccinia virus.

27. The method of claim 26, wherein the virus is an LIVP virus.

28. The method of claim 27, wherein the virus is selected from among GLV-1h68, GLV-1h70, GLV-1h71, GLV-1h72, GLV-1h73, GLV-1h74, GLV-1h81, GLV-1h82, GLV-1h83, GLV-1h84, GLV-1h85, GLV-1h86, GLV-1h90, GLV-1h91,  
30 GLV-1h92, GLV-1h96, GLV-1h97, GLV-1h98, GLV-1h99, GLV-1h100, GLV-1h101, GLV-1h104, GLV-1h105, GLV-1h106, GLV-1h107, GLV-

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1h109, GLV-1h139, GLV-1h146, GLV-1h150 GLV-1h151, GLV-1h152 and GLV-1h153.

29. A method to maintain or control numbers of a modified vaccinia virus delivered to a patient for treatment of cancer such that the patient suffers minimal  
5 adverse effects associated with the virus, comprising:

co-administration of the virus with a regimen of at least one chemotherapeutic agent selected from among gemcitabine, irinotecan, doxorubicin and cisplatin, wherein

10 the amount of gemcitabine, irinotecan, doxorubicin or cisplatin administered is sufficient to control or reduce viral titer in the subject.

30. The method of claim 29, wherein the virus is administered simultaneously, sequentially or intermittently with the chemotherapeutic agent.

31. The method of claim 29 or claim 30, wherein the virus is a Lister strain vaccinia virus.

15 32. The method of claim 31, wherein the virus is an LIVP virus.

33. The method of any of claims 17-32, further comprising monitoring viral titer in the subject.

34. The method of any of claims 17-33, wherein the chemotherapeutic agent decreases or inhibits viral replication.

20 35. The method of any of claims 17-28 and 31-34, wherein the chemotherapeutic agent is selected from among gemcitabine, irinotecan, doxorubicin and cisplatin.

25 36. The method of any of claims 17 and 19-35, wherein the adverse effect comprises one or more of pock formation, weight loss, fever, abdominal pain, aches or pains in muscles, cough, diarrhea, and feeling of discomfort or illness.

30 37. The method of any of claims 17-36, wherein the chemotherapeutic agent is administered systemically, intravenously, intraarterially, intratumorally, endoscopically, intralesionally, intramuscularly, intradermally, intraperitoneally, intravesicularly, intraarticularly, intrapleurally, percutaneously, subcutaneously, orally, parenterally, intranasally, intratracheally, by inhalation, intracranially, intraprostatically, intravitreally, topically, ocularly, vaginally, or rectally.

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38. The method of any of claims 17-37, wherein the chemotherapeutic agent is administered in a sustained release form.

39. The method of any claims 17-38, wherein the subject is one who is administered a therapeutic virus for the treatment of a tumor or metastasis.

5 40. The method of any claims 17-39, wherein the subject is treated for a tumor selected from among a bladder tumor, breast tumor, prostate tumor, carcinoma, basal cell carcinoma, biliary tract cancer, bladder cancer, bone cancer, brain cancer, CNS cancer, glioma tumor, cervical cancer, choriocarcinoma, colon and rectum cancer, connective tissue cancer, cancer of the digestive system, endometrial cancer, 10 esophageal cancer, eye cancer, cancer of the head and neck, gastric cancer, intra-epithelial neoplasm, kidney cancer, larynx cancer, leukemia, liver cancer, lung cancer, lymphoma, Hodgkin's lymphoma, Non-Hodgkin's lymphoma, melanoma, myeloma, neuroblastoma, oral cavity cancer, ovarian cancer, pancreatic cancer, retinoblastoma, rhabdomyosarcoma, rectal cancer, renal cancer, cancer of the respiratory system, 15 sarcoma, skin cancer, stomach cancer, testicular cancer, thyroid cancer, uterine cancer and cancer of the urinary system.

41. The method of claim 39 or 40, further comprising imaging the tumor or metastasis.

20 42. The method of any of claims 39-41, wherein the tumor is monitored by fluorescence imaging, magnetic resonance imaging (MRI), single-photon emission computed tomography (SPECT), positron emission tomography (PET), scintigraphy, gamma camera, a  $\beta^+$  detector, a  $\gamma$  detector or a combination thereof.

43. The method of any of claims 17-42, wherein the virus encodes a detectable gene product or gene product that induces a detectable signal.

25 44. The method of claim 43, wherein the gene product is a luciferase or a fluorescent protein

45. The method of any of claims 17-44, wherein the virus encodes a therapeutic gene product.

30 46. The method of any of claims 17-45, wherein the virus encodes an antigen.