

ENGINEERED CHIMERIC PEGYLATED ADI AND METHODS OF USE

CROSS-REFERENCE TO RELATED APPLICATIONS

5 This application claims priority under 35 U.S.C. § 119(e) to U.S. Application No. 61/954,929, filed on March 18, 2014, which is incorporated by reference in its entirety.

STATEMENT REGARDING SEQUENCE LISTING

The Sequence Listing associated with this application is provided in text format in lieu of a paper copy, and is hereby incorporated by reference into the specification.

10 The name of the text file containing the Sequence Listing is TDWG_002_02WO_ST25.txt. The text file is about 200 KB, was created on March 11, 2015, and is being submitted electronically via EFS-Web.

BACKGROUND

15 Technical Field

The present invention relates generally to engineered ADI, in particular recombinant chimeric ADI proteins engineered to reduce antigenicity. Such engineered chimeric ADI proteins are useful for treating arginine-dependent diseases such as cancer.

20 Description of the Related Art

Amino acid deprivation therapy can be an effective treatment of some forms of cancer. To date, there is one known clinical example relevant to this approach which utilizes asparaginase to lower circulating levels of asparagine and inhibit protein synthesis. This treatment is particularly effective for acute lymphoblastic leukemia (Avramis 2005, Viera

25 Pinheiro 2004). Acute lymphoblastic leukemia cells require the amino acid asparagine for growth and proliferation. In contrast, most normal human cells are capable of synthesizing asparagine and are unaffected by asparagine depletion. Therefore, decreasing serum asparagine with asparaginase can selectively kill the cancer cells without harming the normal cells, tissues, and host. An *E. coli* derived form of asparaginase has been approved

30 for human use. However, asparaginase is found only in microbes; which makes it highly immunogenic in humans and also has a short serum half-life following injection (Avramis 2005). To make asparaginase a more effective drug, these drawbacks were minimized by formulating the *E. coli* derived asparaginase with polyethylene glycol (PEG) to reduce the immunogenicity of this enzyme and the associated allergic reactions. In addition, PEG

35 greatly prolongs the circulating half-life of asparaginase, which reduces both the frequency of treatment and the total cost of the therapy. PEG formulated asparaginase is approved for

use and is marketed under the trade name Oncaspar® (Oncaspar® 2011, Avramis 2005, Viera Pinheiro 2004, Fu 2007, Zeidan 2008).

Arginine is another non-essential amino acid for humans and mice (for review see Rogers 1994). In humans, arginine can be synthesized from citrulline in two steps via the Krebs (urea) cycle enzymes argininosuccinate synthetase (ASS, L-citrulline:L-aspartate ligase [AMP-forming], EC 6.3.4.5) and argininosuccinate lyase (ASL, L-argininosuccinate arginine-lyase, EC 4.3.2.) (Haines 2011, Wu 2009, Morris 2006, Husson 2003, Tapiero 2002, Rogers 1994). ASS catalyzes the conversion of citrulline and aspartic acid to argininosuccinate, which is then converted to arginine and fumaric acid by ASL.

ADI-PEG 20 treatment requires multiple doses over a period of time. After a number of treatments, anti-ADI-PEG 20 antibodies can develop that may limit its continued effectiveness. Therefore, there is a need in the art for ADI that is engineered to improve and extend the efficacy of arginine depletion therapy.

References: Oncaspar FDA Label, Revised 7, 2006; downloaded from FDA website on April 5, 2011; Avramis VI, Panosyan EH. 2005. Clin Pharmacokinet 44:367-393; Fu CH, Sakamoto KM. 2007. Expert Opin Pharmacother 8:1977-1984; Haines RJ, et al. 2011. Int J Biochem Mol Biol 2:8-23; Husson A, et al. 2003. Eur J Biochem 270:1887-1899; Morris SM Jr. 2006. Am J Clin Nutr 83(Suppl):598S-512S; Viera Pinheiro JP, Boos J. 2004. Br J Haematol 125: 117-127; Wu G, et al. 2009. Amino Acids 37:153-168; Zeidan A, et al. 2008. Expert Opin Biol Ther 9:111-119; Rogers QR. Special Publication 86, Agriculture Experiment Station, University of Illinois, April 4-5, 1994:9-21; Tapiero H, Mathe G, Couvreur P, Tew KD (2002) I. Arginine. Biomed Pharmacother 56: 439-445; Wheatley DN (2004) Anticancer Drugs 15(9): 825-833; Feun LG, et al, British Journal of Cancer, 2012, 106, 1481-1485; Dillon BJ, et al, Cancer, 2004, 100(4), 826-33.

BRIEF SUMMARY

One aspect of the present invention provides a recombinant chimeric arginine deiminase (ADI) comprising a catalytic domain of an ADI protein derived from a first microorganism and an α -helical domain of an ADI protein derived from a second microorganism. In one embodiment, the first microorganism is selected from the genera *Mycoplasma*, *Clostridium*, *Bacillus*, *Borrelia*, *Enterococcus*, *Streptococcus*, *Lactobacillus*, and *Giardia*. In a further embodiment, the first microorganism is selected from the group consisting of *Mycoplasma pneumonia*, *Mycoplasma hominis*, *Mycoplasma arginini*, *Mycoplasma arthritidis*, *Streptococcus pyogenes*, *streptococcus pneumonia*, *Borrelia burgdorferi*, *Borrelia afzelii*, *Giardia intestinalis*, *Clostridium perfringens*, *Bacillus licheniformis*, and *Enterococcus faecalis*. In yet another embodiment, the first microorganism

is selected from the group consisting of *M. arginini*, *M. arthritidis*, *M. hominis*, *Mycoplasma pneumonia*, *Mycoplasma phocicerebrale*, *Mycoplasma orale*, *Mycoplasma gateae*, *Mycoplasma phocidae*, *Mycoplasma columbinum*, *Mycoplasma iowae*, *Mycoplasma crocodyli*, *Mycoplasma fermentans*, *Mycoplasma gallinarum*, *Mycoplasma iners*,

5 *Mycoplasma penetrans*, *Mycoplasma gallisepticum*, *Mycoplasma alligatoris*, *Mycoplasma mobile*, and *Mycoplasma capricolum*. In one embodiment, the second microorganism optionally differs from the first microorganism and is selected from the genera *Mycoplasma*, *Clostridium*, *Bacillus*, *Borrelia*, *Enterococcus*, *Streptococcus*, *Lactobacillus*, and *Giardia*. In another embodiment, the second microorganism optionally differs from the first

10 microorganism and is selected from the group consisting of *Mycoplasma pneumonia*, *Mycoplasma hominis*, *Mycoplasma arginini*, *Mycoplasma arthritidis*, *Streptococcus pyogenes*, *streptococcus pneumonia*, *Borrelia burgdorferi*, *Borrelia afzelii*, *Giardia intestinalis*, *Clostridium perfringens*, *Bacillus licheniformis*, and *Enterococcus faecalis*. In yet another embodiment, the second microorganism optionally differs from the first

15 microorganism and is selected from the group consisting of *M. arginini*, *M. arthritidis*, *M. hominis*, *Mycoplasma pneumonia*, *Mycoplasma phocicerebrale*, *Mycoplasma orale*, *Mycoplasma gateae*, *Mycoplasma phocidae*, *Mycoplasma columbinum*, *Mycoplasma iowae*, *Mycoplasma crocodyli*, *Mycoplasma fermentans*, *Mycoplasma gallinarum*, *Mycoplasma iners*, *Mycoplasma penetrans*, *Mycoplasma gallisepticum*, *Mycoplasma alligatoris*,

20 *Mycoplasma mobile*, and *Mycoplasma capricolum*.

In one embodiment, the first microorganism is selected from the group consisting of *Mycoplasma gallinarum*, *Mycoplasma iners*, and *Mycoplasma columbinum* and the second microorganism is selected from the group consisting of *Mycoplasma gallinarum*, *Mycoplasma iners*, and *Mycoplasma columbinum*, wherein the first and second

25 microorganism are optionally different microorganisms.

In a further embodiment, the first microorganism is *M. arginini* and the second microorganism is *M. arthritidis*, and in other specific embodiments, the first microorganism is *M. arginini* and the second microorganism is *M. hominis* or the first microorganism is *M. arthritidis* and the second microorganism is *M. arginini*. In certain embodiments, the first

30 microorganism is *M. gateae* and the second microorganism is *M. arthritidis*. In certain embodiments, the first microorganism is *M. gateae* and the second microorganism is *M. columbinum*. In some embodiments, the first microorganism is *M. gateae* and the second microorganism is *M. phocicerebrale*. In some embodiments, the first microorganism is *M. gateae* and the second microorganism is *M. phocidae*. In particular embodiments, the first

35 microorganism is *M. phocicerebrale* and the second microorganism is *M. arginini*. In certain embodiments, the first microorganism is *M. phocicerebrale* and the second microorganism is

M. gateae. In specific embodiments, the first microorganism is *M. phocicerebrale* and the second microorganism is *M. phocicerebrale*. In certain embodiments, the first microorganism is *M. phocidae* and the second microorganism is *M. arginini*. In some embodiments, the first microorganism is *M. phocidae* and the second microorganism is *M. arthritidis*. In certain
5 embodiments, the first microorganism is *M. phocidae* and the second microorganism is *M. columbinum*. In particular embodiments, the first microorganism is *M. phocidae* and the second microorganism is *M. gateae*. In certain embodiments, the first microorganism is *M. phocidae* and the second microorganism is *M. phocicerebrale*. In some embodiments, the first microorganism is *M. gallinarum* and the second microorganism is *M. columbinum*. In
10 certain embodiments, the first microorganism is *M. gallinarum* and the second microorganism is *M. iners*. In some embodiments, the first microorganism is *M. iners* and the second microorganism is *M. columbinum*. In certain embodiments, the first microorganism is *M. iners* and the second microorganism is *M. gallinarum*.

Illustrative recombinant chimeric ADI molecules comprise, consist, or consist
15 essentially of the amino acid sequence set forth in any one of SEQ ID NOs:4-13 or 22-59 or a variant thereof having at least 80% or 90% sequence identity to any of SEQ ID NOs:4-13 or 22-59.

In certain embodiments of the recombinant chimeric ADI described herein, the recombinant chimeric ADI has been modified to remove at least one pegylation site. In
20 another embodiment of the recombinant chimeric ADI described herein, at least one lysine residue has been modified by an amino acid substitution. In certain embodiments of the recombinant chimeric ADI described herein, at least 5 lysine residues have been modified by an amino acid substitution, at least 10 lysine residues have been modified by an amino acid substitution, at least 15 lysine residues have been modified by an amino acid substitution, or
25 at least 20 lysine residues have been modified by an amino acid substitution. Illustrative recombinant chimeric ADI molecules as described herein comprise the amino acid sequence set forth in any one of SEQ ID NOs:10-13.

In another embodiment of the recombinant chimeric ADI described herein, the ADI is covalently bonded via a biocompatible linker to polyethylene glycol. In this regard, the
30 arginine deiminase may be covalently bonded to more than one polyethylene glycol molecule and in certain embodiments may be covalently bonded to about 1 to about 10 polyethylene glycol molecules and in one specific embodiment, to 5±3 PEG molecules. The PEG molecules covalently bonded to the ADI as described herein may be straight chain or branch chain PEG molecules and may have a total weight average molecular weight of from
35 about 1,000 to about 40,000 and in one embodiment, from about 10,000 to about 30,000.

In certain embodiments of the recombinant chimeric ADI described herein, the biocompatible linker comprises a succinyl group, an amide group, an imide group, a carbamate group, an ester group, an epoxy group, a carboxyl group, a hydroxyl group, a carbohydrate, a tyrosine group, a cysteine group, a histidine group, a methylene group, or any combinations thereof. In one embodiment, the source of the succinyl group is succinimidyl succinate.

Other aspects of the invention provide a polynucleotide encoding the recombinant chimeric ADI described herein, vectors comprising the polynucleotide and isolated host cells comprising such vectors.

Suitable vectors can be chosen or constructed, containing appropriate regulatory sequences, including promoter sequences, terminator sequences, polyadenylation sequences, enhancer sequences, marker genes and other sequences as appropriate. Vectors may be plasmids, viral e.g. phage, or phagemid, as appropriate. For further details see, for example, *Molecular Cloning: a Laboratory Manual*: 2nd edition, Sambrook *et al.*, 1989, Cold Spring Harbor Laboratory Press. Many known techniques and protocols for manipulation of nucleic acid, for example in preparation of nucleic acid constructs, mutagenesis, sequencing, introduction of DNA into cells and gene expression, and analysis of proteins, are described in detail in *Current Protocols in Molecular Biology*, Second Edition, Ausubel *et al.* eds., John Wiley & Sons, 1992, or subsequent updates thereto.

As will be understood by those of skill in the art, it may be advantageous in some instances to produce polypeptide-encoding nucleotide sequences possessing non-naturally occurring codons. For example, codons preferred by a particular prokaryotic or eukaryotic host can be selected to increase the rate of protein expression or to produce a recombinant RNA transcript having desirable properties, such as a half-life which is longer than that of a transcript generated from the naturally occurring sequence. Such polynucleotides are commonly referred to as "codon-optimized." Any of the polynucleotides described herein may be utilized in a codon-optimized form. In certain embodiments, a polynucleotide can be codon optimized for use in specific bacteria such as *E. coli* or yeast such as *S. cerevisiae* (see, e.g., Burgess-Brown *et al.*, *Protein Expr Purif.* 59:94-102, 2008).

Systems for cloning and expression of a protein in a variety of different host cells are well known. Suitable host cells include mammalian cells, bacteria, yeast, and baculovirus systems. Mammalian cell lines available in the art for expression of a heterologous polypeptide include Chinese hamster ovary (CHO) cells, HeLa cells, baby hamster kidney cells, HEK-293 cells, human fibrosarcoma cell line HT-1080 (see, e.g., Moran, *Nat. Biotechnol.* 28:1139-40, 2010), NSO mouse melanoma cells and many others.

Additional examples of useful mammalian host cell lines include monkey kidney CV1 line transformed by SV40 (COS-7, ATCC CRL 1651); human embryonic kidney line (293 or 293 cells sub-cloned for growth in suspension culture, Graham *et al.*, *J. Gen Virol.* 36:59 (1977)); baby hamster kidney cells (BHK, ATCC CCL 10); mouse sertoli cells (TM4, Mather, *Biol. Reprod.* 23:243-251 (1980)); monkey kidney cells (CV1 ATCC CCL 70); African green monkey kidney cells (VERO-76, ATCC CRL-1587); human cervical carcinoma cells (HELA, ATCC CCL 2); canine kidney cells (MDCK, ATCC CCL 34); buffalo rat liver cells (BRL 3A, ATCC CRL 1442); human lung cells (W138, ATCC CCL 75); human liver cells (Hep G2, HB 8065); mouse mammary tumor (MMT 060562, ATCC CCL51); TR1 cells (Mather *et al.*, *Annals N.Y. Acad. Sci.* 383:44-68 (1982)); MRC 5 cells; FS4 cells; and a human hepatoma line (Hep G2). Other useful mammalian host cell lines include Chinese hamster ovary (CHO) cells, including DHFR-CHO cells (Urlaub *et al.*, *PNAS USA* 77:4216 (1980)); and myeloma cell lines such as NSO and Sp2/0. For a review of certain mammalian host cell lines suitable for polypeptide production, see, *e.g.*, Yazaki and Wu, *Methods in Molecular Biology*, Vol. 248 (B. K.C Lo, ed., Humana Press, Totowa, N.J., 2003), pp. 255-268. Certain preferred mammalian cell expression systems include CHO and HEK293-cell based expression systems. Mammalian expression systems can utilize attached cell lines, for example, in T-flasks, roller bottles, or cell factories, or suspension cultures, for example, in 1L and 5L spinners, 5L, 14L, 40L, 100L and 200L stir tank bioreactors, or 20/50L and 100/200L WAVE bioreactors, among others known in the art.

A common bacterial host is *E. coli*. The expression of proteins in prokaryotic cells such as *E. coli* is well established in the art. For a review, see for example Pluckthun, *A. Bio/Technology*. 9:545-551 (1991). Expression in eukaryotic cells in culture is also available to those skilled in the art as an option for recombinant production of polypeptides (see Ref, *Curr. Opinion Biotech.* 4:573-576, 1993; and Trill *et al.*, *Curr. Opinion Biotech.* 6:553-560, 1995). In specific embodiments, protein expression may be controlled by a T7 RNA polymerase (*e.g.*, pET vector series). These and related embodiments may utilize the expression host strain BL21(DE3), a λ DE3 lysogen of BL21 that supports T7-mediated expression and is deficient in lon and ompT proteases for improved target protein stability. Also included are expression host strains carrying plasmids encoding tRNAs rarely used in *E. coli*, such as Rosetta™ (DE3) and Rosetta 2 (DE3) strains. Cell lysis and sample handling may also be improved using reagents such as Benzonase® nuclease and BugBuster® Protein Extraction Reagent. For cell culture, auto-inducing media can improve the efficiency of many expression systems, including high-throughput expression systems. Media of this type (*e.g.*, Overnight Express™ Autoinduction System) gradually elicit protein expression through metabolic shift without the addition of artificial inducing agents such as IPTG.

Particular embodiments employ hexahistidine tags (such as His•Tag® fusions), followed by immobilized metal affinity chromatography (IMAC) purification, or related techniques. In certain aspects, however, clinical grade proteins can be isolated from *E. coli* inclusion bodies, with or without the use of affinity tags (see, e.g., Shimp *et al.*, *Protein Expr Purif.* 50:58-67, 2006). As a further example, certain embodiments may employ a cold-shock induced *E. coli* high-yield production system, because over-expression of proteins in *Escherichia coli* at low temperature improves their solubility and stability (see, e.g., Qing *et al.*, *Nature Biotechnology.* 22:877-882, 2004).

In addition, a host cell strain may be chosen for its ability to modulate the expression of the inserted sequences or to process the expressed protein in the desired fashion. Such modifications of the polypeptide include, but are not limited to, post-translational modifications such as acetylation, carboxylation, glycosylation, phosphorylation, lipidation, and acylation. Post-translational processing, which cleaves a "prepro" form of the protein may also be used to facilitate correct insertion, folding and/or function. Different host cells such as yeast, CHO, HeLa, MDCK, HEK293, and W138, in addition to bacterial cells, which have or even lack specific cellular machinery and characteristic mechanisms for such post-translational activities, may be chosen to ensure the correct modification and processing of the protein of interest.

For long-term, high-yield production of recombinant proteins, stable expression is generally preferred. For example, cell lines that stably express a polynucleotide of interest may be transformed using expression vectors which may contain viral origins of replication and/or endogenous expression elements and a selectable marker gene on the same or on a separate vector. Following the introduction of the vector, cells may be allowed to grow for about 1-2 days in an enriched media before they are switched to selective media. The purpose of the selectable marker is to confer resistance to selection, and its presence allows growth and recovery of cells which, successfully express the introduced sequences. Resistant clones of stably transformed cells may be proliferated using tissue culture techniques appropriate to the cell type. Transient production, such as by transient transfection or infection, can also be employed. Exemplary mammalian expression systems that are suitable for transient production include HEK293 and CHO-based systems.

Host cells transformed with a polynucleotide sequence of interest may be cultured under conditions suitable for the expression and recovery of the protein from cell culture. Certain specific embodiments utilize serum free cell expression systems. Examples include HEK293 cells and CHO cells that can grow on serum free medium (see, e.g., Rosser *et al.*, *Protein Expr. Purif.* 40:237-43, 2005; and U.S. Patent number 6,210,922).

The protein(s) produced by a recombinant cell can be purified and characterized according to a variety of techniques known in the art. Exemplary systems for performing protein purification and analyzing protein purity include fast protein liquid chromatography (FPLC) (e.g., AKTA and Bio-Rad FPLC systems), high-pressure liquid chromatography (HPLC) (e.g., Beckman and Waters HPLC). Exemplary chemistries for purification include ion exchange chromatography (e.g., Q, S), size exclusion chromatography, salt gradients, affinity purification (e.g., Ni, Co, FLAG, maltose, glutathione, protein A/G), gel filtration, reverse-phase, ceramic HyperD® ion exchange chromatography, and hydrophobic interaction columns (HIC), among others known in the art. Also included are analytical methods such as SDS-PAGE (e.g., coomassie, silver stain), immunoblot, Bradford, and ELISA, which may be utilized during any step of the production or purification process, typically to measure the purity of the protein composition.

Also included are methods of concentrating recombinantly produced proteins, e.g., chimeric ADI proteins. Examples include lyophilization, which is typically employed when the solution contains few soluble components other than the protein of interest. Lyophilization is often performed after HPLC run, and can remove most or all volatile components from the mixture. Also included are ultrafiltration techniques, which typically employ one or more selective permeable membranes to concentrate a protein solution. The membrane allows water and small molecules to pass through and retains the protein; the solution can be forced against the membrane by mechanical pump, gas pressure, or centrifugation, among other techniques.

In certain embodiments, the chimeric ADI proteins have a purity of at least about 90%, as measured according to routine techniques in the art. In certain embodiments, such as diagnostic compositions or certain therapeutic compositions, the chimeric ADI proteins have a purity of at least about 95%. In specific embodiments, such as therapeutic or pharmaceutical compositions, the chimeric ADI proteins have a purity of at least about 97% or 98% or 99%. In other embodiments, such as when being used as reference or research reagents, proteins can be of lesser purity, and may have a purity of at least about 50%, 60%, 70%, or 80%. Purity can be measured overall or in relation to selected components, such as other proteins, e.g., purity on a protein basis.

In certain embodiments, the compositions described here are about substantially endotoxin free, including, for example, about 95% endotoxin free, preferably about 99% endotoxin free, and more preferably about 99.99% endotoxin free. The presence of endotoxins can be detected according to routine techniques in the art, as described herein. In specific embodiments, the chimeric ADI proteins are made from a eukaryotic cell such as a mammalian or human cell in substantially serum free media.

Another aspect of the invention provides a composition comprising one or more of the recombinant chimeric ADI described herein and a physiologically acceptable carrier. In one embodiment, the composition may further comprise an autophagy modulator. Autophagy modulators include, but are not limited to chloroquine, 3-methyladenine, hydroxychloroquine, bafilomycin A1, 5-amino-4-imidazole carboxamide riboside (AICAR), okadaic acid, N6-mercaptopurine riboside, vinblastine, wortmannin, rapamycin, everolimus, metformin, perifosine, resveratrol, and tamoxifen. In another embodiment, the compositions comprising the recombinant chimeric ADI described herein may further comprise a chemotherapeutic agent, such as but not limited to docetaxel, carboplatin, cyclophosphamide, gemcitabine, cisplatin, sorafenib, sunitinib or everolimus, or combinations thereof.

Yet another aspect of the present invention provides a method of treating, ameliorating the symptoms of, or inhibiting the progression of a cancer comprising administering to a patient in need thereof a therapeutically effective amount of a composition comprising one or more of the recombinant chimeric ADI described herein and a physiologically acceptable carrier, thereby treating, ameliorating the symptoms of, or inhibiting the progression of the cancer. In this regard, the cancer can include, but is not limited to melanoma, pancreatic cancer, prostate cancer, small cell lung cancer, mesothelioma, lymphocytic leukemia, chronic myelogenous leukemia, lymphoma, hepatoma, sarcoma, leukemia, acute myeloid leukemia, relapsed acute myeloid leukemia, breast cancer, ovarian cancer, colorectal cancer, gastric cancer, glioma, glioblastoma multiforme, non-small cell lung cancer (NSCLC), kidney cancer, bladder cancer, uterine cancer, esophageal cancer, brain cancer, head and neck cancers, cervical cancer, testicular cancer, and stomach cancer.

BRIEF DESCRIPTION OF THE SEQUENCES

SEQ ID NO:1 is the amino acid sequence of wild type *M. hominis* ADI.

SEQ ID NO:2 is the amino acid sequence of wild type *M. arginini* ADI.

SEQ ID NO:3 is the amino acid sequence of wild type *M. arthritidis* ADI.

SEQ ID NO:4 is the amino acid sequence of the DS1 recombinant chimeric ADI protein.

SEQ ID NO:5 is the amino acid sequence of the DS2 recombinant chimeric ADI protein.

SEQ ID NO:6 is the amino acid sequence of the DS3 recombinant chimeric ADI protein.

SEQ ID NO:7 is the amino acid sequence of the DS4 recombinant chimeric ADI protein.

SEQ ID NO:8 is the amino acid sequence of a recombinant chimeric ADI derived from *M. hominis* Phoenix (see SEQ ID NO:14; plus lysine substitutions) (catalytic domain) and *M. arginini* (α -helical domain).

SEQ ID NO:9 is the amino acid sequence of a recombinant chimeric ADI derived from *M. hominis* Phoenix (see SEQ ID NO:14) (catalytic domain) and *M. arthritidis* (α -helical domain).

SEQ ID NO:10 is the amino acid sequence of the DS1-1 lysine reduction mutant of the recombinant chimeric ADI protein (see Table E3).

SEQ ID NO:11 is the amino acid sequence of the DS1-2 lysine reduction mutant of the recombinant chimeric ADI protein (see Table E3).

SEQ ID NO:12 is the amino acid sequence of the DS1-3 lysine reduction mutant of the recombinant chimeric ADI protein (see Table E3).

SEQ ID NO:13 is the amino acid sequence of the DS1-4 lysine reduction mutant of the recombinant chimeric ADI protein (see Table E3).

SEQ ID NO:14 is the amino acid sequence of the ADI Phoenix sequence. This ADI sequence is identical to *M. hominis* ADI except for K112E and P210S substitutions.

SEQ ID NO:15 is the amino acid sequence of *M. alligatoris* ADI.

SEQ ID NO:16 is the amino acid sequence of *M. colombinum* ADI.

SEQ ID NO:17 is the amino acid sequence of *M. gallinarum* ADI.

SEQ ID NO:18 is the amino acid sequence of *M. gatea* ADI.

SEQ ID NO:19 is the amino acid sequence of *M. iners* ADI.

SEQ ID NO:20 is the amino acid sequence of *M. phocicerabrae* ADI.

SEQ ID NO:21 is the amino acid sequence of *M. phocidae* ADI.

SEQ ID NOs:22-59 are the amino acid sequences of chimeric ADI proteins.

DETAILED DESCRIPTION

The present invention relates generally to chimeric ADI proteins, e.g., engineered to have reduced antigenicity as compared with corresponding wild type ADI molecules. The present invention also relates to methods of treating cancer and other disorders with chimeric ADI, and in particular chimeric ADI-PEG 20.

Normal cells do not require arginine for growth, since they can synthesize arginine from citrulline in a two-step process catalyzed by ASS and ASL. In contrast, certain cancers do not express ASS. Certain cancers do not express ASL, and other cancers may have diminished expression of, or may not express ASS and/or ASL. Therefore, these

cancers are auxotrophic for arginine. This metabolic difference may be capitalized upon to develop a safe and effective therapy to treat these forms of cancer. ADI catalyzes the conversion of arginine to citrulline via the arginine dihydrolase pathway, and may thus be used to eliminate arginine.

5 The practice of the present invention will employ, unless indicated specifically to the contrary, conventional methods of virology, immunology, microbiology, molecular biology and recombinant DNA techniques within the skill of the art, many of which are described below for the purpose of illustration. Such techniques are explained fully in the literature. See, e.g., *Current Protocols in Protein Science*, *Current Protocols in Molecular*
10 *Biology* or *Current Protocols in Immunology*, John Wiley & Sons, New York, N.Y.(2009); Ausubel *et al.*, *Short Protocols in Molecular Biology*, 3rd ed., Wiley & Sons, 1995; Sambrook and Russell, *Molecular Cloning: A Laboratory Manual* (3rd Edition, 2001); Maniatis *et al.* *Molecular Cloning: A Laboratory Manual* (1982); *DNA Cloning: A Practical Approach*, vol. I & II (D. Glover, ed.); *Oligonucleotide Synthesis* (N. Gait, ed., 1984); *Nucleic Acid Hybridization*
15 (B. Hames & S. Higgins, eds., 1985); *Transcription and Translation* (B. Hames & S. Higgins, eds., 1984); *Animal Cell Culture* (R. Freshney, ed., 1986); Perbal, *A Practical Guide to Molecular Cloning* (1984) and other like references.

As used in this specification and the appended claims, the singular forms "a," "an" and "the" include plural references unless the content clearly dictates otherwise.

20 Throughout this specification, unless the context requires otherwise, the word "comprise", or variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated element or integer or group of elements or integers but not the exclusion of any other element or integer or group of elements or integers.

By "about" is meant a quantity, level, value, number, frequency, percentage,
25 dimension, size, amount, weight or length that varies by as much as 30, 25, 20, 15, 10, 9, 8, 7, 6, 5, 4, 3, 2 or 1% to a reference quantity, level, value, number, frequency, percentage, dimension, size, amount, weight or length.

By "statistically significant," it is meant that the result was unlikely to have occurred by chance. Statistical significance can be determined by any method known in the
30 art. Commonly used measures of significance include the p-value, which is the frequency or probability with which the observed event would occur, if the null hypothesis were true. If the obtained p-value is smaller than the significance level, then the null hypothesis is rejected. In simple cases, the significance level is defined at a p-value of 0.05 or less.

Each embodiment in this specification is to be applied *mutatis mutandis* to
35 every other embodiment unless expressly stated otherwise.

Standard techniques may be used for recombinant DNA, oligonucleotide synthesis, and tissue culture and transformation (e.g., electroporation, lipofection). Enzymatic reactions and purification techniques may be performed according to manufacturer's specifications or as commonly accomplished in the art or as described herein. These and related techniques and procedures may be generally performed according to conventional methods well known in the art and as described in various general and more specific references that are cited and discussed throughout the present specification. Unless specific definitions are provided, the nomenclature utilized in connection with, and the laboratory procedures and techniques of, molecular biology, analytical chemistry, synthetic organic chemistry, and medicinal and pharmaceutical chemistry described herein are those well-known and commonly used in the art. Standard techniques may be used for recombinant technology, molecular biological, microbiological, chemical syntheses, chemical analyses, pharmaceutical preparation, formulation, and delivery, and treatment of patients.

"Patient" refers to an animal, in certain embodiments a mammal, and in a specific embodiment, a human.

"Biocompatible" refers to materials or compounds which are generally not injurious to biological functions and which will not result in any degree of unacceptable toxicity, including allergenic and disease states.

The term "reference sequence" refers generally to a nucleic acid coding sequence, or amino acid sequence, to which another sequence is being compared. All polypeptide and polynucleotide sequences described herein are included as reference sequences, including those described by name and those described in the Tables and the Sequence Listing.

Throughout the present disclosure, the following abbreviations may be used: PEG, polyethylene glycol; ADI, arginine deiminase; SS, succinimidyl succinate; SSA, succinimidyl succinimide; SPA, succinimidyl propionate; NHS, N-hydroxy-succinimide; ASS1 or ASS, argininosuccinate synthetase; ASL, argininosuccinate lyase.

In certain embodiments, the chimeric ADI enzymes as described herein are compared to the benchmark ADI-PEG 20 molecule derived from *M. hominis*. As used herein, "ADI-PEG 20" refers to the ADI molecule known in the art and described for example in US6183738; US6635462; Ascierto PA, *et al.* (2005) Pegylated arginine deiminase treatment of patients with metastatic melanoma: results from phase I and II studies. *J Clin Oncol* 23(30): 7660–7668; Izzo F, *et al.* (2004) Pegylated arginine deiminase treatment of patients with unresectable hepatocellular carcinoma: results from phase I/II studies. *J Clin Oncol* 22(10): 1815–1822; Holtsberg FW, *et al.* (2002), Poly(ethylene glycol) (PEG) conjugated

arginine deiminase: effects of PEG formulations on its pharmacological properties. J Control Release 80(1– 3): 259–271; Kelly *et al.*, (2012) British Journal of Cancer 106, 324 – 332.

As would be recognized by the skilled artisan, this molecule is a pegylated (PEG 20,000) ADI enzyme derived from *M. hominis*, and has two substitutions (K112E; P210S) relative to the wild type *M. hominis* ADI enzyme.

The terms "polypeptide," "protein" and "peptide" and "enzyme" are used interchangeably and mean a polymer of amino acids not limited to any particular length. The terms do not exclude modifications such as myristoylation, sulfation, glycosylation, phosphorylation and addition or deletion of signal sequences. The terms "polypeptide" or "protein" or "enzyme" mean one or more chains of amino acids, wherein each chain comprises amino acids covalently linked by peptide bonds, and wherein said polypeptide or protein can comprise a plurality of chains non-covalently and/or covalently linked together by peptide bonds, having the sequence of native proteins, that is, proteins produced by naturally-occurring and specifically non-recombinant cells, or genetically-engineered or recombinant cells, and comprise molecules having the amino acid sequence of the native protein, or molecules having deletions from, additions to, and/or substitutions of one or more amino acids of the native sequence. The terms "polypeptide" and "protein" specifically encompass the chimeric ADI enzymes of the present disclosure, or sequences that have deletions from, additions to, and/or substitutions of one or more amino acid of the chimeric ADI enzymes. In certain embodiments, the polypeptide is a "recombinant" polypeptide, produced by recombinant cell that comprises one or more recombinant DNA molecules, which are typically made of heterologous polynucleotide sequences or combinations of polynucleotide sequences that would not otherwise be found in the cell.

The term "isolated protein" referred to herein means that a subject protein (1) is free of at least some other proteins with which it would typically be found in nature, (2) is essentially free of other proteins from the same source, e.g., from the same species, (3) is expressed by a cell from a different species, (4) has been separated from at least about 50 percent of polynucleotides, lipids, carbohydrates, or other materials with which it is associated in nature, (5) is not associated (by covalent or noncovalent interaction) with portions of a protein with which the "isolated protein" is associated in nature, (6) is operably associated (by covalent or noncovalent interaction) with a polypeptide with which it is not associated in nature, or (7) does not occur in nature. Such an isolated protein can be encoded by genomic DNA, cDNA, mRNA or other RNA, or may be of synthetic origin, or any combination thereof. In certain embodiments, the isolated protein is substantially free from proteins or polypeptides or other contaminants that are found in its natural environment that would interfere with its use (therapeutic, diagnostic, prophylactic, research or otherwise).

In the present invention, a chimeric ADI or a polynucleotide encoding a chimeric ADI may be derived, cloned or produced from any source, including, for example, microorganisms, recombinant biotechnology or any combination thereof. For example, arginine deiminase may be cloned from microorganisms of the genera *Mycoplasma*, *Clostridium*, *Bacillus*, *Borrelia*, *Enterococcus*, *Streptococcus*, *Lactobacillus*, *Giardia*. In certain embodiments, arginine deiminase is cloned from *Mycoplasma pneumoniae*, *Mycoplasma hominis*, *Mycoplasma arginini*, *Mycoplasma arthritidis*, *Mycoplasma phocicerebrale*, *Mycoplasma orale*, *Mycoplasma gateae*, *Mycoplasma phocidae*, *Mycoplasma columbinum*, *Mycoplasma iowae*, *Mycoplasma crocodyli*, *Mycoplasma fermentans*, *Mycoplasma penetrans*, *Mycoplasma gallisepticum*, *Mycoplasma gallinarum*, *Mycoplasma iners*, *Mycoplasma alligatoris*, *Mycoplasma mobile*, and *Mycoplasma capricolum*, *Streptococcus pyogenes*, *Streptococcus pneumoniae*, *Borrelia burgdorferi*, *Borrelia afzelii*, *Giardia intestinalis*, *Clostridium perfringens*, *Bacillus licheniformis*, *Enterococcus faecalis*, *Lactobacillus sake*, or any combination thereof. The amino acid sequences of certain of these arginine deiminases is provided in **Table A1** below.

Table A1. Exemplary ADI sequences for cloning of chimeric ADI		
Source	Sequence	SEQ ID NO:
M. hominis	MSVFDSKFNHGIHVYSEIGELETVLVHEPGREIDYITPARLDELLFSAI LESHDARKEHQSFVKIMKDRGINVVELTDLVAETYDLASKAAKEEFIE TFLEETVPVLTEANKEAVRAFLLSKPTHEMVEFMMSGITKYELGVESE NELIVDPMPNLYFTTRDPFASVGNVGTIHFMYIVRRRETFLFARFVRN HPKLVKTPWYYDPAMKMSIEGGDVFIYNNETLVVGVSSERTDLDTITLL AKNIKANKEVEFKRIVAINVPKWTNLMHLDTWLTMLDKNKFLYSPIAN DVFKFWDYDLVNGGAEPQPQLNGLPLDKLLASIIINKEPVLPIPIGGAGA TEMEIARETNFDGTNYLAIKPGLVIGYDRNEKTNAALKAAGITVLPFH GNQLSLGGMGNARCMSPSLSRKDVKW	1
M. arginini	MSVFDSKFKGIHVYSEIGELESVLVHEPGREIDYITPARLDELLFSAI LESHDARKEHKQFVAELKANDINVVELIDLVAETYDLASQEAADKLIE EFLEDSEPVLSSEHKVVVRNFKAKKTSRELVEIMMAGITKYDLGIEA DHELIVDPMPNLYFTTRDPFASVGNVGTIHYMYKVRQRETFLSRFVFS NHPKLINTPWYYDPSLKLSEIEGGDVFIYNNETLVVGVSSERTDLQTVTL LAKNIVANKESEFKRIVAINVPKWTNLMHLDTWLTMLDKDKFLYSPIA NDVFKFWDYDLVNGGAEPQPVENGLPLEGLLQSIINKKPVLPIPIAGEG ASQMEIERETHFDGTNYLAIRPGVVIGYSRNEKTNAALEAAGIKVLPF HGNQLSLGGMGNARCMSPSLSRKDVKW	2
M. arthritidis	msvfdsfkfkihvseigeletvlvhepgkeidyitparldellfsai leshdarkehkefvaelkkrginvvelvdlivetydlaskeakeklle eflddsvpvlsdehrtvkkflqsqkstrslveyimiagitkhdhkies dlelivdpmpnlyfttrdpfasvngvgtihymrykvrqretflsrfvfs nhpklvntpwyydpaegitieggdvfiyndtlvvgvsertdlqtitl laknikankesefkrivainvpkwtnlmhltdwtlmldkdkflyspia ndvfkfwdydlvnggdapqpvdnglpledllksiigkkptliapiagag asqidierethfdgtnylavapgivigyarnektnaaleaagitvlpf rgnqlslgmggnarcmssmplsrkdvw	3
M. alligatoris	MSKINVYSEVGRLEKVLVHTPGDEIRRISPTRLEELLFSAILEPDTAI EEHKRFLNVLEKNGIKAIQLDELVAQTYDQVDQKIKDEFIDQWLQEA PVLNDQLKKLVKNYLLKSQKEFSTKKMVRIMMAGIDKKEINIDLDRDL	15

	VVDPMPLNYFTRDPFASVGNISLHNMKYQTRKRETIFAQFIFKYNKD YKTPHWFDRFDHGSIEGGDVVFYTKDTLVIGISERTTKEAVLNIACK IKANTDSKFKKIVAINVPPMPNLMHLDTWITMVDHDKFLYSPNMKSL KFWLIDLSKEIKMVELEESLSNMLEAIIIGKKPILIPiAGKNASQLDID IETHFDGTNYLTIAPGVVVGYSRNKLTQKALEDAGVKVLSFDGNQLSL MGSAARCMSMPLVREDIK	
M. colombinum	MSKINVYSEIGELKEVLVHTPGDEIRRISSPSRLDELLFSAILEPNEAI KEHKGFLKILQDKGIKVIQSLDLVAETTYTYHATQKEREAFIEKWLDEA EPALTKDLRAKVSYVLSKEGTPVAMVRTMMAGVSKQELNVESETELV VDPMPNLYFTRDPFASAGNGISLNNMKYVTRKRETIFAEIFATHPDY KTPHWFDRDLDEGNIIEGGDVFIYNKDTLVIGVSERTNKEAIIITIAKKI KNNKEAKFKKIVAINVPPMPNLMHLDTWLTMVDKDKFLYSPNMLSVLK VWEIDLSKEIEMVETNKPLADVLESIIGVKPVLIPiAGKGATQLDIDI ETHFDGTNYLTIAPGVVVGYSRNKTEAALRAAGVTVLSFEGNQLSLG MGSARCMSMPLVREDVK	16
M. gallinarum	MSKIRVYSEIGNLKKVLVHTPGDEIRRISSPSRLEELLFSAVLEPNAAI EEHKRFVKLLEDGRGIIQAIQSLDLVAETTYVKYATAEQKAAFIKYLDEA TPALSAENRERAKKYILSLEMOPVKMIRTMAGLSKYELNVESNIELI IDPMPNLYFTRDPFASAGNGISLNNMKYVVRKRETIFAEIFAIHPEY KETPHWFDRDLHGSIEGGDVVFYNKDTLVIGVSERTNKEAIIITIAKHI QDNKEAEFKKIVAINVPPMPNLMHLDTWLTMVDKNKFIYSPNMLSVLK IWEIDLAKPIEMVESNKSLETVLESIIGEKPILIPiAGEGASQLDIDI ETHFDGTNYLTIAPGVVVGYSRNEKTEKALKAAGITVLSFEGNQLSLG MGSARCMSMPLVREDVK	17
M. gatea	MSVFDSKFNGIHVYSEIGELESVLVHEPGREIDYITPARLDELLFSAI LESHDARKEHKLFLVSELKANDINVVELTDLVTETDYLASQEAKNLIE EFLEDSEPVLTTELKSVVRTYLSIKSTRELIQMMAGITKYDLGIEA DHELIVDPMPLNYFTRDPFASVGNVGTIHYMRYKVRQRETLSRFVFS NHPKLVNTPWYYDPSLKLSIEGGDVFIYNNNTLVVGVSERTDLETITL LAKNIVANKECEFKRIVAINVPKWTNLMHLDTWLTMVDKDKFLYSPiA NDVFKFWDYDLVNGGEEFPQPVENGLPLEGLLESIIINKKPILIPiAGEG ASQIDIERETHFDGTNYLAIRPGVVIGYSRNEKTNAALEAAGIKVLPF HGNQLSLGMGNARCMSMPLSRKDVKW	18
M. iners	MSKINVYSEIGVLKEVLVHTPGDEIRRIAPSRLDELLFSAILEPSAAI QEHSFLKILQDRGIKTIQSLDLVAETTYKHYASEAEKEAFIEKYLDEA TPVLSKDMRAKVKNYILSMQGEPPVKMVRTMMAGVSKQELNVESEVELI VDPMPNLYFTRDPFASAGNGISLNNMKYVVRKRETIFAEIFSIHPEY KKTPHWFDRDLNGSIEGGDVFIYNKDTLVIGVSERTNKEAIIITIAKHI QDNKEAQFKKIVAINVPPMPNLMHLDTWLTMVDKNKFLYSPNMLSVLK VWEIDLSKPIEMVETNKPLAEVLESIIGEKPILIPiAGKDATQLDIDI ETHFDGTNYLTIAPGVVVGYSRNVKTEAALRAAGVTVLSFEGNQLSLG MGSARCMSMPLVREDVK	19
M. phocicerabrales	MSVFDSKFNGIHVYSEIGELETVLVHEPGREIDYITPARLDELLFSAI LESHDARKEHQSFVKQLKDNGINVVELTDLVAETFDLASKEEQEKLIE EFLEDSEPVLSAEHKTAVRKFLTSRKSTREMFVMMAGITKYDLGIEA DHELIVDPMPLNYFTRDPFASVGNVGTIHYMRYKVRQRETLSRFVFS NHPKLVKTPWYYDPAMKMSIEGGDVFIYNNNTLVVGVSERTDLETITL LAKNIKANKEVEFKRIVAINVPKWTNLMHLDTWLTMVDKDKFLYSPiA NDVFKFWDYDLVNGGAEPQPKENGLPLEGLLQSIINKKPVLIPiAGNN ASHIDIERETHFDGTNYLAIRPGVVIGYARNEKTNAALAAAGIKVLPF HGNQLSLGMGNARCMSMPLSRKDVKW	20
M. phocidae	MSVFDSKFNGIHVYSEIGELQTVLVHEPGREIEYITPARLDELLFSAI LESHDARKEHQEFVAELKNNINNVVELTDLVSETYDMVSKEKQEKLIE EFLEDSEPVLSSEHKGVLVRKFLKSLKSSKELIQYMMAGITKHDLNIEA DHELIVDPMPLNYFTRDPFASVGNVGTIHYMRYKVRQRETLSRFIFA NHPKLMNTPLYNPDMLKLSIEGGDVFIYNNNTLVVGVSERTDLDITL LAKNIKANKEREVEFKRIVAINVPKWTNLMHLDTWLTMVDKDKFLYSPiA NDVFKFWDYDLVNGGDEPQPKVNGLPLEKLLESIIINKKPILIPiAGTS ASNIDVERETHFDGTNYLAIRPGVVIGYSRNVKTNEALEAAGIKVLPF KGNQLSLGMGNARCMSMPLSRKDVKW	21

Thus, in some embodiments, the ADI used in a chimeric ADI may comprise the amino acid sequence from Table A1 (any one of SEQ ID NOs: 1-3 or 15-21), or a variant thereof having ADI activity (e.g., able to metabolize arginine into citrulline and ammonia) or a fragment thereof having ADI activity, or engineered chimeras thereof having ADI activity.

The sequences of exemplary chimeric ADI are provided in **Table A2** below.

Table A2. Chimeric ADI		
Name	Sequence	SEQ ID NO:
DS1	MSVFDSKFKGIHVYSEIGELESVLVHEPGREIDYITPARLDELLEFSAILESH DARKEHKQFVAELKANDINVVELVDLIVETYDLASKEAKEKLLEEFLLDDSV VLSDEHRATVKKFLQSQKSTRSLVEYMIAGITKHDLEKIESDLELIVDPMPL YFTRDPFASVGNVGTIHYMRYKVRQRETLSRFVFSNHPKLINTPWYYDPSL KLSIEGGDVFIYNNDTLVVGVSERTDLQTVTLLAKNIVANKESEFKRIVAIN VPKWTNLMHLDTWLTMLDKDKFLYSPIANDVFKFWDYDLVNGGAEPQPVENG LPLEGLLQSI INKKPVLIPIAGEGASQMEIERETHFDGTNYLAIRPGVVIGY SRNEKTNAALEAAGIKVLPFHGNQLSLGMGNARCMSPLSRKDVKW	4
DS2	MSVFDSKFKGIHVYSEIGELESVLVHEPGREIDYITPARLDELLEFSAILESH DARKEHKQFVAELKANDINVVELTDLVAETYDLASRAAKEEFLETFTLEETVP VLTEANREAVRAFLLSKPTHEMVEFMMSGITKYLGVESSENELIVDPMPL YFTRDPFASVGNVGTIHYMRYKVRQRETLSRFVFSNHPKLINTPWYYDPSL LSIEGGDVFIYNNDTLVVGVSERTDLQTVTLLAKNIVANKESEFKRIVAIN VPKWTNLMHLDTWLTMLDKDKFLYSPIANDVFKFWDYDLVNGGAEPQPVENG LPLEGLLQSI INKKPVLIPIAGEGASQMEIERETHFDGTNYLAIRPGVVIGY SRNEKTNAALEAAGIKVLPFHGNQLSLGMGNARCMSPLSRKDVKW	5
DS3	MSVFDSKFKGIHVYSEIGELETVLVHEPGKEIDYITPARLDELLEFSAILESH DARKEHKEFVAELKKRGINVVELIDLVAETYDLASQEAQKLEEFLEDEP VLSEEHKVVVRNFLKAKKTSRELVEIMMAGITKYDLGIEADHELIVDPMPL YFTRDPFASVGNVGTIHYMRYKVRQRETLSRFVFSNHPKLINTPWYYDPAE GLTIEGGDVFIYNNDTLVVGVSERTDLQTVTLLAKNIKANKESEFKRIVAIN VPKWTNLMHLDTWLTMLDKDKFLYSPIANDVFKFWDYDLVNGGDAPQPVENG LPLEDLLKSI IGKKPTLIPIAGAGASQIDIERETHFDGTNYLAVAPGIVIGY ARNEKTNAALEAAGITVLPFRGNQLSLGMGNARCMSPLSRKDVKW	6
DS4	MSVFDSKFKGIHVYSEIGELETVLVHEPGKEIDYITPARLDELLEFSAILESH DARKEHKEFVAELKKRGINVVELTDLVAETYDLASRAAKEEFLETFTLEETVP VLTEANREAVRAFLLSKPTHEMVEFMMSGITKYLGVESSENELIVDPMPL YFTRDPFASVGNVGTIHYMRYKVRQRETLSRFVFSNHPKLINTPWYYDPAE GLTIEGGDVFIYNNDTLVVGVSERTDLQTVTLLAKNIKANKESEFKRIVAIN VPKWTNLMHLDTWLTMLDKDKFLYSPIANDVFKFWDYDLVNGGDAPQPVENG LPLEDLLKSI IGKKPTLIPIAGAGASQIDIERETHFDGTNYLAVAPGIVIGY ARNEKTNAALEAAGITVLPFRGNQLSLGMGNARCMSPLSRKDVKW	7
C2DS1	MSVFDSKFKGIHVYSEIGELESVLVHEPGREIDYITPARLDELLEFSAILESH DARKEHKQFVAELKANDINVVELDELVAQTYDQVDQKIKDEFIDQWLQEA KPVINDQLKKLVKNYLLKSQKEFSTKKMVRIMMAGIDKKEINIDLDRDLV VDPMPNLYFTRDPFASVGNVGTIHYMRYKVRQRETLSRFVFSNHPKLINT PWYYDPSLKLSIEGGDVFIYNNDTLVVGVSERTDLQTVTLLAKNIVANKE SEFKRIVAINVPKWTNLMHLDTWLTMLDKDKFLYSPIANDVFKFWDYDLV NGGAEPQPVENGPLEGLLQSI INKKPVLIPIAGEGASQMEIERETHFDGT NYLAIRPGVVIGYSRNEKTNAALEAAGIKVLPFHGNQLSLGMGNARCMSP LSRKDVKW	22
C2DS3	MSVFDSKFKGIHVYSEIGELESVLVHEPGREIDYITPARLDELLEFSAILESH DARKEHKQFVAELKANDINVVELVDLIVETYDLASKEAKEKLLEEFLLDDSV VLSDEHRATVKKFLQSQKSTRSLVEYMIAGITKHDLEKIESDLELIVDPMPL YFTRDPFASVGNVGTIHYMRYKVRQRETLSRFVFSNHPKLINTPWYYDPSL KLSIEGGDVFIYNNDTLVVGVSERTDLQTVTLLAKNIVANKESEFKRIVAIN VPKWTNLMHLDTWLTMLDKDKFLYSPIANDVFKFWDYDLVNGGAEPQPVENG LPLEGLLQSI INKKPVLIPIAGEGASQMEIERETHFDGTNYLAIRPGVVIGY SRNEKTNAALEAAGIKVLPFHGNQLSLGMGNARCMSPLSRKDVKW	23

	NNDTLVVGVSERTDLQTVTLLAKNIVANKESEFKRIVAINVFKWTNLMHLDTWLT MLDKDKFLYSPIANDVFKFWDYDLVNGGAEPQPVENGLPLEGLLQSI INKKPVLI PIAGEGASQMEIERETHFDGTNYLAIRPGVVIGYSRNEKTNAALEAAGIKVLPFH GNQLSLGGMGNARCMSPLSRKDVKW	
C2DS4	MSVFDSKFKGIHVYSEIGELESVLVHEPGREIDYITPARLDELLFSAILES HDAR KEHKQFVAELKANDINVVELSDLVAETYTYHATQKEREAFIEKWLDEAEPAITKD LRKVKSVYLSKEGTPVAMVRTMMAGVSKQELNVESETELVDMPNLYFTRDPF ASVGNVGTIHYMRYKVRQRETLSRFVFSNHPKLINTPWYYDPSLKLSIEGGDVFIY IYNNDTLVVGVSERTDLQTVTLLAKNIVANKESEFKRIVAINVFKWTNLMHLDTW LTMLDKDKFLYSPIANDVFKFWDYDLVNGGAEPQPVENGLPLEGLLQSI INKKPV LIPIAGEGASQMEIERETHFDGTNYLAIRPGVVIGYSRNEKTNAALEAAGIKVLP FHGNQLSLGGMGNARCMSPLSRKDVKW	24
C2DS5	MSVFDSKFKGIHVYSEIGELESVLVHEPGREIDYITPARLDELLFSAILES HDAR KEHKQFVAELKANDINVVELTDLVTETYDLASQEAKNLIEEFLEDSEPVLTEEL KSVVRTYLKSIKSTRELIQMMAGITKYDLGIEADHELIVDMPNLYFTRDPFAS VGNGVGTIHYMRYKVRQRETLSRFVFSNHPKLINTPWYYDPSLKLSIEGGDVFIY NNDTLVVGVSERTDLQTVTLLAKNIVANKESEFKRIVAINVFKWTNLMHLDTWLT MLDKDKFLYSPIANDVFKFWDYDLVNGGAEPQPVENGLPLEGLLQSI INKKPVLI PIAGEGASQMEIERETHFDGTNYLAIRPGVVIGYSRNEKTNAALEAAGIKVLPFH GNQLSLGGMGNARCMSPLSRKDVKW	25
C2DS6	MSVFDSKFKGIHVYSEIGELESVLVHEPGREIDYITPARLDELLFSAILES HDAR KEHKQFVAELKANDINVVELTDLVAETFDLASKEEQEKLIEEFLEDSEPVLSEAH KTAVRKFLT SRKSTREMVEFMAGITKYDLGIEADHELIVDMPNLYFTRDPFAS VGNGVGTIHYMRYKVRQRETLSRFVFSNHPKLINTPWYYDPSLKLSIEGGDVFIY NNDTLVVGVSERTDLQTVTLLAKNIVANKESEFKRIVAINVFKWTNLMHLDTWLT MLDKDKFLYSPIANDVFKFWDYDLVNGGAEPQPVENGLPLEGLLQSI INKKPVLI PIAGEGASQMEIERETHFDGTNYLAIRPGVVIGYSRNEKTNAALEAAGIKVLPFH GNQLSLGGMGNARCMSPLSRKDVKW	26
C2DS7	MSVFDSKFKGIHVYSEIGELESVLVHEPGREIDYITPARLDELLFSAILES HDAR KEHKQFVAELKANDINVVELTDLVSETYDMVSKEKQEKLIEEFLEDSEPVLSEEH KGLVRKFLKSLKSSKELIQYMMAGITKHDLNIEADHELIVDMPNLYFTRDPFAS VGNGVGTIHYMRYKVRQRETLSRFVFSNHPKLINTPWYYDPSLKLSIEGGDVFIY NNDTLVVGVSERTDLQTVTLLAKNIVANKESEFKRIVAINVFKWTNLMHLDTWLT MLDKDKFLYSPIANDVFKFWDYDLVNGGAEPQPVENGLPLEGLLQSI INKKPVLI PIAGEGASQMEIERETHFDGTNYLAIRPGVVIGYSRNEKTNAALEAAGIKVLPFH GNQLSLGGMGNARCMSPLSRKDVKW	27
C4DS1	MSKINVYSEIGELKEVLVHTPGDEIRRISPSRLDELLFSAILEPNEAIKEHKGFL KILQDKGIKVIQLDELVAQTYDQVDQKIKDEFIDQWLQEAQPVNDQLKKLVKNY LLKSQKEFSTKKMVRIMMAGIDKKEINIDLDRDLVVDMPNLYFTRDPFASAGNG ISLNNMKYVTRKRETI FAEFIFATHPDYKTTPHWFDRLDEGNI EGGDVFIYNKDT LVIGV SERTNKEAILTI AKKIKNNKEAKFKKIVAINVPPMPNLMHLDTWLTMVDK DKFLYSPNMLSVLKVWEIDLSKEIEMVETNKPLADVLESIIIGVKPVLIPIAGKGA TQLDIDIETHFDGTNYLTIAPGVVVGYSRNIKTEAALRAAGVTVLSFEGNQLSLG MGSARCMSPMLVREDVK	28
C4DS2	MSKINVYSEIGELKEVLVHTPGDEIRRISPSRLDELLFSAILEPNEAIKEHKGFL KILQDKGIKVIQLIDLVAETYDLASQEAQKDLIEEFLEDSEPVLSEEHKVVVRNF LKAKKTSRELVEIMMAGITKYDLGIEADHELIVDMPNLYFTRDPFASAGNGISL NNMKYVTRKRETI FAEFIFATHPDYKTTPHWFDRLDEGNI EGGDVFIYNKDTLVI GV SERTNKEAILTI AKKIKNNKEAKFKKIVAINVPPMPNLMHLDTWLTMVDKDKF LYSPNMLSVLKVWEIDLSKEIEMVETNKPLADVLESIIIGVKPVLIPIAGKGATQL DIDIETHFDGTNYLTIAPGVVVGYSRNIKTEAALRAAGVTVLSFEGNQLSLGMS ARCMSPMLVREDVK	29
C4DS3	MSKINVYSEIGELKEVLVHTPGDEIRRISPSRLDELLFSAILEPNEAIKEHKGFL KILQDKGIKVIQLVDLIVETYDLASKEAKEKLLEEFLLDSDVPVLSDEHRATVKKF LQSQKSTRSLVEYMIAGITKHDLKIESDLELIVDMPNLYFTRDPFASAGNGISL NNMKYVTRKRETI FAEFIFATHPDYKTTPHWFDRLDEGNI EGGDVFIYNKDTLVI GV SERTNKEAILTI AKKIKNNKEAKFKKIVAINVPPMPNLMHLDTWLTMVDKDKF LYSPNMLSVLKVWEIDLSKEIEMVETNKPLADVLESIIIGVKPVLIPIAGKGATQL DIDIETHFDGTNYLTIAPGVVVGYSRNIKTEAALRAAGVTVLSFEGNQLSLGMS ARCMSPMLVREDVK	30

C4DS5	MSKINVYSEIGELKEVLVHTPGDEIRRISPSRLDELLFSAILEPNEAIKEHKGFL KILQDKGIKVIQLTDLVTETYDLASQEAKDNLEEFLEDSEPVLTEELKSVVRTY LKS IKSTRELIQMMAGITKYDLGIEADHELIVDPMPNLYFTRDPFASAGNGISL NNMKYVTRKRETI FAEFIFATHPDYKTTPHWFDRLEDEGNIEGGDVFIYNKDTLVI GV SERTNKEAILTI AKKIKNNKEAKFKKIVAINVPPMPNLMHLDTWLTMVDKDKF LYSPNMLSVLKVWEIDL SKEIEMVETNKPLADVLESIIIGVKPVLIPIAGKGATQL DIDIETHFDGTNYLTIAPGVVVGYSRNIKTEAALRAAGVTVLSFEGNQSLGMS ARCMSMPLVREDVK	31
C4DS6	MSKINVYSEIGELKEVLVHTPGDEIRRISPSRLDELLFSAILEPNEAIKEHKGFL KILQDKGIKVIQLTDLVAETFDLASKEEQEKLIEEFLEDSEPVLS EAHKTAVRKF LTSRKSTREMEVFMMAGITKYDLGIEADHELIVDPMPNLYFTRDPFASAGNGISL NNMKYVTRKRETI FAEFIFATHPDYKTTPHWFDRLEDEGNIEGGDVFIYNKDTLVI GV SERTNKEAILTI AKKIKNNKEAKFKKIVAINVPPMPNLMHLDTWLTMVDKDKF LYSPNMLSVLKVWEIDL SKEIEMVETNKPLADVLESIIIGVKPVLIPIAGKGATQL DIDIETHFDGTNYLTIAPGVVVGYSRNIKTEAALRAAGVTVLSFEGNQSLGMS ARCMSMPLVREDVK	32
C4DS7	MSKINVYSEIGELKEVLVHTPGDEIRRISPSRLDELLFSAILEPNEAIKEHKGFL KILQDKGIKVIQLTDLVSETYDMVSKEKQEKLEEFLEDSEPVLS EEHKGLVRKF LKS LKSSKELIQYMMAGITKHDLNIEADHELIVDPMPNLYFTRDPFASAGNGISL NNMKYVTRKRETI FAEFIFATHPDYKTTPHWFDRLEDEGNIEGGDVFIYNKDTLVI GV SERTNKEAILTI AKKIKNNKEAKFKKIVAINVPPMPNLMHLDTWLTMVDKDKF LYSPNMLSVLKVWEIDL SKEIEMVETNKPLADVLESIIIGVKPVLIPIAGKGATQL DIDIETHFDGTNYLTIAPGVVVGYSRNIKTEAALRAAGVTVLSFEGNQSLGMS ARCMSMPLVREDVK	33
C4DS8	MSKINVYSEIGELKEVLVHTPGDEIRRISPSRLDELLFSAILEPNEAIKEHKGFL KILQDKGIKVIQLSDLVAETVVKYATAEQKAFFIEKYLDEATPALS AENRERAKK YILSLEMOPVKMIRTMAGLSKYELNVESENIELIIDPMPNLYFTRDPFASAGNGI SLNNMKYVTRKRETI FAEFIFATHPDYKTTPHWFDRLEDEGNIEGGDVFIYNKDTL VIGV SERTNKEAILTI AKKIKNNKEAKFKKIVAINVPPMPNLMHLDTWLTMVDKD KFLYSPNMLSVLKVWEIDL SKEIEMVETNKPLADVLESIIIGVKPVLIPIAGKGAT QLDIDIETHFDGTNYLTIAPGVVVGYSRNIKTEAALRAAGVTVLSFEGNQSLGMS GSARCMSMPLVREDVK	34
C4DS9	MSKINVYSEIGELKEVLVHTPGDEIRRISPSRLDELLFSAILEPNEAIKEHKGFL KILQDKGIKVIQLSDLVAETVKKHYASEAEKEAFIEKYLDEATPVLSKDMRAKVKN YILSMQGEVPVKMVRTMMAGVSKQELNVESEVELIVDPMPNLYFTRDPFASAGNGI SLNNMKYVTRKRETI FAEFIFATHPDYKTTPHWFDRLEDEGNIEGGDVFIYNKDTL VIGV SERTNKEAILTI AKKIKNNKEAKFKKIVAINVPPMPNLMHLDTWLTMVDKD KFLYSPNMLSVLKVWEIDL SKEIEMVETNKPLADVLESIIIGVKPVLIPIAGKGAT QLDIDIETHFDGTNYLTIAPGVVVGYSRNIKTEAALRAAGVTVLSFEGNQSLGMS GSARCMSMPLVREDVK	35
C5DS1	MSVFDSKFNGIHVYSEIGELESVLVHEPGREIDYITPARLDELLFSAILES HDAR KEHKLFVSELKANDINVVELDELVAQTYDQVDQKIKDEFIDQWLQEAKPVLNDQL KKLVKNYLLKSQKEFSTKKMVRIMMAGIDKKEINIDLDRLVVDMPNLYFTRDP FASVGNVGTIHYMRYKVRQRETLSRFVFSNHPKLVNTPWYYDPSLKLSIEGGDV FIYNNNTLVVGVSERTDLETVTLLAKNIVANKECEFKRIVAINVPKWTNLMHLD WLTMLDKDKFLYSPIANVDVFKFWDYDLVNGGEEFPQPVENGLPLEGLLESII INKKP ILIP IAGEGASQIDIERETHFDGTNYLAIRPGVVIGYSRNEKTNAALEAAGIKVL PFHGNQSLGMSGNARCMSMPLSRKDVKW	36
C5DS2	MSVFDSKFNGIHVYSEIGELESVLVHEPGREIDYITPARLDELLFSAILES HDAR KEHKLFVSELKANDINVVELIDLVAETYDLASQEAKDKLIEEFLEDSEPVLS EEH KVVRNFKLAKKTSRELVEIMMAGITKYDLGIEADHELIVDPMPNLYFTRDPFAS VGNVGTIHYMRYKVRQRETLSRFVFSNHPKLVNTPWYYDPSLKLSIEGGDVFIY NNNTLVVGVSERTDLETVTLLAKNIVANKECEFKRIVAINVPKWTNLMHLDTWLT MLDKDKFLYSPIANVDVFKFWDYDLVNGGEEFPQPVENGLPLEGLLESII INKKPIL PIAGEGASQIDIERETHFDGTNYLAIRPGVVIGYSRNEKTNAALEAAGIKVLPFH GNQSLGMSGNARCMSMPLSRKDVKW	37
C5DS3	MSVFDSKFNGIHVYSEIGELESVLVHEPGREIDYITPARLDELLFSAILES HDAR KEHKLFVSELKANDINVVELVDLIVETYDLASKEAKEKLLEEFLLDSVPVLSDEH RATVKKFLQSQKSTRSLVEYMIAGITKHDLKIESDLELIVDPMPNLYFTRDPFAS VGNVGTIHYMRYKVRQRETLSRFVFSNHPKLVNTPWYYDPSLKLSIEGGDVFIY	38

	NNNTLVVGVSSERTDLETVTLLAKNIVANKECEFKRIVAINVPKWTNLMHLDTWLT MLDKDKFLYSPIANDVFKFWDYDLVNGGEEPQPVENGLPLEGLLES I INKKPILI PIAGEGASQIDIERETHFDGTNYLAIRPGVVIGYSRNEKTNAALEAAGIKVLPFH GNQLSLGGMGNARCMSMPLSRKDVKW	
C5DS4	MSVFDSKFNGIHVYSEIGELESVLVHEPGREIDYITPARLDELLFSAILESH DAR KEHKLFVSELKANDINVVELSDLVAETYTYHATQKEREAFIEKWLDEAEPALTKD LRKVKSYVLSKEGTPVAMVRTMMAGVSKQELNVESETELVVDMPNLYFTRDPF ASVGNVGTIHYMRYKVRQRETLSRFVFSNHPKLVNTPWYYDPSLKLSIEGGDV F IYNNNTLVVGVSSERTDLETVTLLAKNIVANKECEFKRIVAINVPKWTNLMHLD TW LTMLDKDKFLYSPIANDVFKFWDYDLVNGGEEPQPVENGLPLEGLLES I INKKP I LIPIAGEGASQIDIERETHFDGTNYLAIRPGVVIGYSRNEKTNAALEAAGIKVLP FHGNQLSLGGMGNARCMSMPLSRKDVKW	39
C5DS6	MSVFDSKFNGIHVYSEIGELESVLVHEPGREIDYITPARLDELLFSAILESH DAR KEHKLFVSELKANDINVVELTDLVAETFDLASKEEQEKLIEEFLEDSEPVLSEAH KTAVRKFLT SRKSTREMVEFMMAGITKYDLGIEADHELIVDMPNLYFTRDPFAS VGNGVGTIHYMRYKVRQRETLSRFVFSNHPKLVNTPWYYDPSLKLSIEGGDVFIY NNNTLVVGVSSERTDLETVTLLAKNIVANKECEFKRIVAINVPKWTNLMHLDTWLT MLDKDKFLYSPIANDVFKFWDYDLVNGGEEPQPVENGLPLEGLLES I INKKPILI PIAGEGASQIDIERETHFDGTNYLAIRPGVVIGYSRNEKTNAALEAAGIKVLPFH GNQLSLGGMGNARCMSMPLSRKDVKW	40
C5DS7	MSVFDSKFNGIHVYSEIGELESVLVHEPGREIDYITPARLDELLFSAILESH DAR KEHKLFVSELKANDINVVELTDLVSETYDMVSKEKQEKLIEEFLEDSEPVLSEEH KGLVRKFLSKLSSKELIQYMMAGITKHDLNIEADHELIVDMPNLYFTRDPFAS VGNGVGTIHYMRYKVRQRETLSRFVFSNHPKLVNTPWYYDPSLKLSIEGGDVFIY NNNTLVVGVSSERTDLETVTLLAKNIVANKECEFKRIVAINVPKWTNLMHLDTWLT MLDKDKFLYSPIANDVFKFWDYDLVNGGEEPQPVENGLPLEGLLES I INKKPILI PIAGEGASQIDIERETHFDGTNYLAIRPGVVIGYSRNEKTNAALEAAGIKVLPFH GNQLSLGGMGNARCMSMPLSRKDVKW	41
C6DS1	MSVFDSKFNGIHVYSEIGELETVLVHEPGREIDYITPARLDELLFSAILESH DAR KEHQSFVKQLKDNGINVVELDELVAQTYDQVDQKIDDEFIDQWLQEA KPVLNDQ L KKLVKNYLLKSQKEFSTKKMVRIMMAGIDKKEINIDLDRDLVVDMPNLYFTRDP FASVGNGVGTIHYMRYKVRQRETLSRFVFSNHPKLVKTPWYYDPAMKMSIEGGDV FIYNNNDTLVGVSSERTDLETITLLAKNIKANKEVEFKRIVAINVPKWTNLMHLD T WLTMLDKDKFLYSPIANDVFKFWDYDLVNGGAEPQPKENGLPLEGLLQSI INKKP VLIPIAGNNASHIDIERETHFDGTNYLAIKPGVVIGYARNEKTNAALAAAGIKVL PFHGNQLSLGGMGNARCMSMPLSRKDVKW	42
C6DS2	MSVFDSKFNGIHVYSEIGELETVLVHEPGREIDYITPARLDELLFSAILESH DAR KEHQSFVKQLKDNGINVVELIDLVAETYDLASQEAKEKLIEEFLEDSEPVLSEEH KVVVRNFLKAKKTSRELVEIMMAGITKYDLGIEADHELIVDMPNLYFTRDPFAS VGNGVGTIHYMRYKVRQRETLSRFVFSNHPKLVKTPWYYDPAMKMSIEGGDVFIY NNDTLVGVSSERTDLETITLLAKNIKANKEVEFKRIVAINVPKWTNLMHLDTWLT MLDKDKFLYSPIANDVFKFWDYDLVNGGAEPQPKENGLPLEGLLQSI INKKPVLI PIAGNNASHIDIERETHFDGTNYLAIKPGVVIGYARNEKTNAALAAAGIKVLPFH GNQLSLGGMGNARCMSMPLSRKDVKW	43
C6DS3	MSVFDSKFNGIHVYSEIGELETVLVHEPGREIDYITPARLDELLFSAILESH DAR KEHQSFVKQLKDNGINVVELVDLIVETYDLASKEAKEKLLEEFLLDDSVFVLSDEH RATVKKFLQSQKSTRSLVEYMIAGITKHDLKIESDLELIVDMPNLYFTRDPFAS VGNGVGTIHYMRYKVRQRETLSRFVFSNHPKLVKTPWYYDPAMKMSIEGGDVFIY NNDTLVGVSSERTDLETITLLAKNIKANKEVEFKRIVAINVPKWTNLMHLDTWLT MLDKDKFLYSPIANDVFKFWDYDLVNGGAEPQPKENGLPLEGLLQSI INKKPVLI PIAGNNASHIDIERETHFDGTNYLAIKPGVVIGYARNEKTNAALAAAGIKVLPFH GNQLSLGGMGNARCMSMPLSRKDVKW	44
C6DS4	MSVFDSKFNGIHVYSEIGELETVLVHEPGREIDYITPARLDELLFSAILESH DAR KEHQSFVKQLKDNGINVVELSDLVAETYTYHATQKEREAFIEKWLDEAEPALTKD LRKVKSYVLSKEGTPVAMVRTMMAGVSKQELNVESETELVVDMPNLYFTRDPF ASVGNVGTIHYMRYKVRQRETLSRFVFSNHPKLVKTPWYYDPAMKMSIEGGDV F IYNNNDTLVGVSSERTDLETITLLAKNIKANKEVEFKRIVAINVPKWTNLMHLD TW LTMLDKDKFLYSPIANDVFKFWDYDLVNGGAEPQPKENGLPLEGLLQSI INKKPV LIPIAGNNASHIDIERETHFDGTNYLAIKPGVVIGYARNEKTNAALAAAGIKVLP FHGNQLSLGGMGNARCMSMPLSRKDVKW	45

C6DS5	MSVFDSKFNGIHVYSEIGELETVLVHEPGREIDYITPARLDELLFSAILES HDAR KEHQSFVKQLKDNGINVVELTDLVTETYDLASQEAKDNLIEEFLEDSEPVLTEEL KSVVRTYLKS IKSTRELIQMMAGITKYDLGIEADHELIVDPMPNLYFTRDPFAS VGNGVTIHYMRYKVRQRETFLSRFVFSNHPKLVKTPWYYDPAMKMSIEGGDVFIY NNDTLVVGVSERTDLETITLLAKNIKANKEVEFKRIVAINVPKWTNLMHLDTWLT MLDKDKFLYSPIANDVFKFWDYDLVNGGAEPQPKENGLPLEGLLQSI INKKPVLI PIAGNNASHIDIERETHFDGTNYLAIKPGVVIGYARNEKTNAALAAAGIKVLPFH GNQLSLGMGNARCMSMPLSRKDVKW	46
C6DS7	MSVFDSKFNGIHVYSEIGELETVLVHEPGREIDYITPARLDELLFSAILES HDAR KEHQSFVKQLKDNGINVVELTDLVSETYDMVSKEKQEKLIEEFLEDSEPVLSEEH KGLVRKFLKSLKSSKELIQYMMAGITKHDNLIEADHELIVDPMPNLYFTRDPFAS VGNGVTIHYMRYKVRQRETFLSRFVFSNHPKLVKTPWYYDPAMKMSIEGGDVFIY NNDTLVVGVSERTDLETITLLAKNIKANKEVEFKRIVAINVPKWTNLMHLDTWLT MLDKDKFLYSPIANDVFKFWDYDLVNGGAEPQPKENGLPLEGLLQSI INKKPVLI PIAGNNASHIDIERETHFDGTNYLAIKPGVVIGYARNEKTNAALAAAGIKVLPFH GNQLSLGMGNARCMSMPLSRKDVKW	47
C7DS1	MSVFDSKFNGIHVYSEIGELQTVLVHEPGREIEYITPARLDELLFSAILES HDAR KEHQEFVAELKKNININVVELDELVAQTYDQVDQKIKDEFIDQWLQEAQPVNDQL KKLVKNYLLKSQKEFSTKKMVRIMMAGIDKKEINIDLDRDLVDPMPNLYFTRDP FASVGNGVTIHYMRYKVRQRETFLSRFIFANHPKLMNTPLYNPD MKLSIEGGDV FVYNNETLVVGVSERTDLDTITLLAKNIKANKEVEFKRIVAINVPKWTNLMHLD WLTMLDKDKFLYSPIANDVFKFWDYDLVNGGDEPQPKVNGLPLEKLLES I INKKP ILIPIAGTSASNIDVERETHFDGTNYLAIA PGVVIGYSRNVKTNEALEAAGIKVL PFKGNQLSLGMGNARCMSMPLSRKDVKW	48
C7DS2	MSVFDSKFNGIHVYSEIGELQTVLVHEPGREIEYITPARLDELLFSAILES HDAR KEHQEFVAELKKNININVVELIDLVAETYDLASQEAKDKLIEEFLEDSEPVLSEEH KVVVRNFLKAKKTSRELVEIMMAGITKYDLGIEADHELIVDPMPNLYFTRDPFAS VGNGVTIHYMRYKVRQRETFLSRFIFANHPKLMNTPLYNPD MKLSIEGGDV FVY NNETLVVGVSERTDLDTITLLAKNIKANKEVEFKRIVAINVPKWTNLMHLDTWLT MLDKDKFLYSPIANDVFKFWDYDLVNGGDEPQPKVNGLPLEKLLES I INKKPILI PIAGTSASNIDVERETHFDGTNYLAIA PGVVIGYSRNVKTNEALEAAGIKVLPFK GNQLSLGMGNARCMSMPLSRKDVKW	49
C7DS3	MSVFDSKFNGIHVYSEIGELQTVLVHEPGREIEYITPARLDELLFSAILES HDAR KEHQEFVAELKKNININVVELVDLIVETYDLASKEAKEKLLEEFLLDSDVPVLSDEH RATVKKFLQSQKSTRSLVEYMIAGITKHDLKIESDLELIVDPMPNLYFTRDPFAS VGNGVTIHYMRYKVRQRETFLSRFIFANHPKLMNTPLYNPD MKLSIEGGDV FVY NNETLVVGVSERTDLDTITLLAKNIKANKEVEFKRIVAINVPKWTNLMHLDTWLT MLDKDKFLYSPIANDVFKFWDYDLVNGGDEPQPKVNGLPLEKLLES I INKKPILI PIAGTSASNIDVERETHFDGTNYLAIA PGVVIGYSRNVKTNEALEAAGIKVLPFK GNQLSLGMGNARCMSMPLSRKDVKW	50
C7DS4	MSVFDSKFNGIHVYSEIGELQTVLVHEPGREIEYITPARLDELLFSAILES HDAR KEHQEFVAELKKNININVVELSDLVAETTYTHATQKEREAFIEKWLDEAEPALTKD LRKVKSYVLSKEGTPVAMVRTMMAGVSKQELNVESETELVDMPMPNLYFTRDPF ASVGNGVTIHYMRYKVRQRETFLSRFIFANHPKLMNTPLYNPD MKLSIEGGDV F VYNNETLVVGVSERTDLDTITLLAKNIKANKEVEFKRIVAINVPKWTNLMHLDTW LTMLDKDKFLYSPIANDVFKFWDYDLVNGGDEPQPKVNGLPLEKLLES I INKKPILI PIAGTSASNIDVERETHFDGTNYLAIA PGVVIGYSRNVKTNEALEAAGIKVLP FKGNQLSLGMGNARCMSMPLSRKDVKW	51
C7DS5	MSVFDSKFNGIHVYSEIGELQTVLVHEPGREIEYITPARLDELLFSAILES HDAR KEHQEFVAELKKNININVVELTDLVTETYDLASQEAKDNLIEEFLEDSEPVLTEEL KSVVRTYLKS IKSTRELIQMMAGITKYDLGIEADHELIVDPMPNLYFTRDPFAS VGNGVTIHYMRYKVRQRETFLSRFIFANHPKLMNTPLYNPD MKLSIEGGDV FVY NNETLVVGVSERTDLDTITLLAKNIKANKEVEFKRIVAINVPKWTNLMHLDTWLT MLDKDKFLYSPIANDVFKFWDYDLVNGGDEPQPKVNGLPLEKLLES I INKKPILI PIAGTSASNIDVERETHFDGTNYLAIA PGVVIGYSRNVKTNEALEAAGIKVLPFK GNQLSLGMGNARCMSMPLSRKDVKW	52
C7DS6	MSVFDSKFNGIHVYSEIGELQTVLVHEPGREIEYITPARLDELLFSAILES HDAR KEHQEFVAELKKNININVVELTDLVAETFDLASKEEQEKLIEEFLEDSEPVLSEAH KTAVRKFLTSRKSTREMFMMAGITKYDLGIEADHELIVDPMPNLYFTRDPFAS VGNGVTIHYMRYKVRQRETFLSRFIFANHPKLMNTPLYNPD MKLSIEGGDV FVY	53

	NNETLVVGVSERTDLDITITLLAKNIKANKEREFFKRIVAINVFKWTNLMHLDTWLT MLDKDKFLYSPIANDVFKFWDYDLVNGGDEPQPKVNGLPLEKLLESIIINKKPILI PIAGTSASNIDVERETHFDGTNYLAIAPGVVIGYSRNVKTNEALEAAGIKVLPFK GNQLSLGMGNARCMSMPLSRKDVKW	
C8DS3	MSKIRVYSEIGNLKKVLVHTPGDEIRRIISPSRLEELLFSAVLEPNAAIEEHKRFV KLEEDRGIQAIQLVDLIVETYDLASKEAKEKLLEEFLLDSDVPVLSDEHRATVKKF LQSQKSTRSLVEYMIAGITKHDLKIESDLELIVDPMPNLYFTRDPFASAGNGISL NNMKYVVRKRETIFAEFIFAIHPEYKETPHWFDRDLHGSIIEGGDVVYNKDTLVI GVSSERTNKEAIIITIAKHIQDNKEAEFFKIVAINVPPMPNLMHLDTWLTMVDKNKF IYSPNMLSVLKIWEIDLAKPIEMVESNKSLETVLESIIIEKPIILIPiAGEGASQL DIDIETHFDGTNYLTIAPGVVVGYSRNEKTEKALKAAGITVLSFEGNQSLGMSG ARCMSMPLVREDVK	54
C8DS4	MSKIRVYSEIGNLKKVLVHTPGDEIRRIISPSRLEELLFSAVLEPNAAIEEHKRFV KLEEDRGIQAIQLSDLVAETTYTYHATQKEREAFIEKWLDEAEPALTKDLRAKVKS YVLSKEGTFVAMVRTMMAGVSKQELNVESETELVDMPNLYFTRDPFASAGNGI SLNNMKYVVRKRETIFAEFIFAIHPEYKETPHWFDRDLHGSIIEGGDVVYNKDTL VIGVSERTNKEAIIITIAKHIQDNKEAEFFKIVAINVPPMPNLMHLDTWLTMVDKN KFIYSPNMLSVLKIWEIDLAKPIEMVESNKSLETVLESIIIEKPIILIPiAGEGAS QLDIDIETHFDGTNYLTIAPGVVVGYSRNEKTEKALKAAGITVLSFEGNQSLGMSG GSARCMSMPLVREDVK	55
C8DS9	MSKIRVYSEIGNLKKVLVHTPGDEIRRIISPSRLEELLFSAVLEPNAAIEEHKRFV KLEEDRGIQAIQLSDLVAETYYHYASEAEKEAFIEKYLDEATPVLSKDMRAKVKN YILSMQGEPPVKMVRTMMAGVSKQELNVESEVELIVDPMPNLYFTRDPFASAGNGI SLNNMKYVVRKRETIFAEFIFAIHPEYKETPHWFDRDLHGSIIEGGDVVYNKDTL VIGVSERTNKEAIIITIAKHIQDNKEAEFFKIVAINVPPMPNLMHLDTWLTMVDKN KFIYSPNMLSVLKIWEIDLAKPIEMVESNKSLETVLESIIIEKPIILIPiAGEGAS QLDIDIETHFDGTNYLTIAPGVVVGYSRNEKTEKALKAAGITVLSFEGNQSLGMSG GSARCMSMPLVREDVK	56
C9DS3	MSKINVYSEIGVLKEVLVHTPGDEIRRIAPSRLDELLFSAILEPSAAIQEHKSFL KILQDRGIKTIQLVDLIVETYDLASKEAKEKLLEEFLLDSDVPVLSDEHRATVKKF LQSQKSTRSLVEYMIAGITKHDLKIESDLELIVDPMPNLYFTRDPFASAGNGISL NNMKYVVRKRETIFAEFIFSIHPEYKKTPHWFDRDLNGSIIEGGDVFIYNKDTLVI GVSSERTNKEAIIITIAKHIQDNKEAQFKKIVAINVPPMPNLMHLDTWLTMVDKNKF LYSPNMLSVLKVWEIDLKPIEMVETNKPLAEVLESIIIEKPIILIPiAGKDATQL DIDIETHFDGTNYLTIAPGVVVGYSRNVKTEAALRAAGVTVLSFEGNQSLGMSG ARCMSMPLVREDVK	57
C9DS4	MSKINVYSEIGVLKEVLVHTPGDEIRRIAPSRLDELLFSAILEPSAAIQEHKSFL KILQDRGIKTIQLSDLVAETTYTYHATQKEREAFIEKWLDEAEPALTKDLRAKVKS YVLSKEGTFVAMVRTMMAGVSKQELNVESETELVDMPNLYFTRDPFASAGNGI SLNNMKYVVRKRETIFAEFIFSIHPEYKKTPHWFDRDLNGSIIEGGDVFIYNKDTL VIGVSERTNKEAIIITIAKHIQDNKEAQFKKIVAINVPPMPNLMHLDTWLTMVDKN KFLYSPNMLSVLKVWEIDLKPIEMVETNKPLAEVLESIIIEKPIILIPiAGKDAT QLDIDIETHFDGTNYLTIAPGVVVGYSRNVKTEAALRAAGVTVLSFEGNQSLGMSG GSARCMSMPLVREDVK	58
C9DS8	mskinvyseigvlkevlvhtpgdeirriapsrldellfsailepsaaigehksfl kilqdrigiktqilsdlvaetyvkyataeqkaafiekyldeatpalsaenrerakk yilslemqpvkmirtmmaglskyelnvesnieliidpmpnlyftrdpfasagngi slnnmkyvvrkretifaefifsihpeykktphwfdrlngsieggdvfiynkdtl vigvsertnkeaiitiakhiqdnkeaqfkkivainvppmpnlnmhltdwltmvdkn kflyspnmlsvlkvweidlskpiemvetnkplaevlesiiegekpilipiagkdat qldidiethfdgtnyltiapgvvvgyssrnnvkteaalraagvtvlsfegnqslsgm gsarcmsmplvredvk	59

Hence, in some embodiments, the chimeric ADI comprises, consists, or consists essentially of an illustrative chimeric sequence from Table A2 (SEQ ID NOs:4-13 or 22-59), or a variant or fragment thereof having ADI activity.

Certain embodiments include variants of the reference ADI polypeptide sequences described herein, whether described by name or by reference to a sequence identifier (e.g., Tables A1-A2). A "variant" sequence, as the term is used herein, refers to a polypeptide or polynucleotide sequence that differs from a reference sequence disclosed
5 herein by one or more substitutions, deletions (e.g., truncations), additions, and/or insertions. Certain variants thus include fragments of a reference sequence described herein. Variant polypeptides are biologically active, that is, they continue to possess the enzymatic or binding activity of a reference polypeptide. Such variants may result from, for example, genetic polymorphism and/or from human manipulation.

10 In many instances, a biologically active variant will contain one or more conservative substitutions. A "conservative substitution" is one in which an amino acid is substituted for another amino acid that has similar properties, such that one skilled in the art of peptide chemistry would expect the secondary structure and hydrophobic nature of the polypeptide to be substantially unchanged. As described above, modifications may be made
15 in the structure of the polynucleotides and polypeptides of the present invention and still obtain a functional molecule that encodes a variant or derivative polypeptide with desirable characteristics. When it is desired to alter the amino acid sequence of a polypeptide to create an equivalent, or even an improved, variant or portion of a polypeptide of the invention, one skilled in the art will typically change one or more of the codons of the
20 encoding DNA sequence.

For example, certain amino acids may be substituted for other amino acids in a protein structure without appreciable loss of interactive binding capacity with structures such as, for example, antigen-binding regions of antibodies or binding sites on substrate molecules. Since it is the interactive capacity and nature of a protein that defines that
25 protein's biological functional activity, certain amino acid sequence substitutions can be made in a protein sequence, and, of course, its underlying DNA coding sequence, and nevertheless obtain a protein with like properties. It is thus contemplated that various changes may be made in the peptide sequences of the disclosed compositions, or corresponding DNA sequences which encode said peptides without appreciable loss of their
30 utility.

In making such changes, the hydrophobic index of amino acids may be considered. The importance of the hydrophobic amino acid index in conferring interactive biologic function on a protein is generally understood in the art (Kyte & Doolittle, 1982, incorporated herein by reference). It is accepted that the relative hydrophobic character of the
35 amino acid contributes to the secondary structure of the resultant protein, which in turn defines the interaction of the protein with other molecules, for example, enzymes,

substrates, receptors, DNA, antibodies, antigens, and the like. Each amino acid has been assigned a hydropathic index on the basis of its hydrophobicity and charge characteristics (Kyte & Doolittle, 1982). These values are: isoleucine (+4.5); valine (+4.2); leucine (+3.8); phenylalanine (+2.8); cysteine (+2.5); methionine (+1.9); alanine (+1.8); glycine (−0.4);
5 threonine (−0.7); serine (−0.8); tryptophan (−0.9); tyrosine (−1.3); proline (−1.6); histidine (−3.2); glutamate (−3.5); glutamine (−3.5); aspartate (−3.5); asparagine (−3.5); lysine (−3.9); and arginine (−4.5). It is known in the art that certain amino acids may be substituted by other amino acids having a similar hydropathic index or score and still result in a protein with similar biological activity, *i.e.*, still obtain a biological functionally equivalent protein. In
10 making such changes, the substitution of amino acids whose hydropathic indices are within ± 2 is preferred, those within ± 1 are particularly preferred, and those within ± 0.5 are even more particularly preferred.

It is also understood in the art that the substitution of like amino acids can be made effectively on the basis of hydrophilicity. U.S. Patent 4,554,101 (specifically
15 incorporated herein by reference in its entirety), states that the greatest local average hydrophilicity of a protein, as governed by the hydrophilicity of its adjacent amino acids, correlates with a biological property of the protein. As detailed in U. S. Patent 4,554,101, the following hydrophilicity values have been assigned to amino acid residues: arginine (+3.0); lysine (+3.0); aspartate ($+3.0 \pm 1$); glutamate ($+3.0 \pm 1$); serine (+0.3); asparagine (+0.2);
20 glutamine (+0.2); glycine (0); threonine (−0.4); proline (-0.5 ± 1); alanine (−0.5); histidine (−0.5); cysteine (−1.0); methionine (−1.3); valine (−1.5); leucine (−1.8); isoleucine (−1.8); tyrosine (−2.3); phenylalanine (−2.5); tryptophan (−3.4). It is understood that an amino acid can be substituted for another having a similar hydrophilicity value and still obtain a biologically equivalent, and in particular, an immunologically equivalent protein. In such
25 changes, the substitution of amino acids whose hydrophilicity values are within ± 2 is preferred, those within ± 1 are particularly preferred, and those within ± 0.5 are even more particularly preferred.

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

Amino acid substitutions may further be made on the basis of similarity in
35 polarity, charge, solubility, hydrophobicity, hydrophilicity and/or the amphipathic nature of the residues. For example, negatively charged amino acids include aspartic acid and glutamic

acid; positively charged amino acids include lysine and arginine; and amino acids with uncharged polar head groups having similar hydrophilicity values include leucine, isoleucine and valine; glycine and alanine; asparagine and glutamine; and serine, threonine, phenylalanine and tyrosine. Other groups of amino acids that may represent conservative changes include: (1) ala, pro, gly, glu, asp, gln, asn, ser, thr; (2) cys, ser, tyr, thr; (3) val, ile, leu, met, ala, phe; (4) lys, arg, his; and (5) phe, tyr, trp, his.

A variant may also, or alternatively, contain non-conservative changes. In a preferred embodiment, variant polypeptides differ from a native or reference sequence by substitution, deletion or addition of fewer than about 10, 9, 8, 7, 6, 5, 4, 3, 2 amino acids, or even 1 amino acid. Variants may also (or alternatively) be modified by, for example, the deletion or addition of amino acids that have minimal influence on the immunogenicity, secondary structure, enzymatic activity, and/or hydrophobic nature of the polypeptide.

In certain embodiments, a polypeptide sequence is about, at least about, or up to about 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100, 110, 120, 130, 140, 150, 160, 170, 180, 190, 200, 210, 220, 230, 240, 250, 260, 270, 280, 290, 300, 310, 320, 330, 340, 350, 360, 370, 380, 390, 400, 410, 420, 430, 440, 450, 460, 470, 480, 490, 500, 510, 520, 530, 540, 550, 560, 570, 580, 590, 600, 610, 620, 630, 640, 650, 660, 670, 680, 690, 700, 710, 720, 730, 740, 750, 760, 770, 780, 790, 800, 810, 820, 830, 840, 850, 860, 870, 880, 890, 900, 910, 920, 930, 940, 950, 960, 970, 980, 990, 1000 or more contiguous amino acids in length, including all integers in between, and which may comprise all or a portion of a reference sequence (see, e.g., Sequence Listing).

In other specific embodiments, a polypeptide sequence consists of about or no more than about 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100, 110, 120, 130, 140, 150, 160, 170, 180, 190, 200, 210, 220, 230, 240, 250, 260, 270, 280, 290, 300, 310, 320, 330, 340, 350, 360, 370, 380, 390, 400, 410, 420, 430, 440, 450, 460, 470, 480, 490, 500, 510, 520, 530, 540, 550, 560, 570, 580, 590, 600, 610, 620, 630, 640, 650, 660, 670, 680, 690, 700, 710, 720, 730, 740, 750, 760, 770, 780, 790, 800, 810, 820, 830, 840, 850, 860, 870, 880, 890, 900, 910, 920, 930, 940, 950, 960, 970, 980, 990, 1000 or more contiguous amino acids, including all integers in between, and which may comprise all or a portion of a reference sequence (see, e.g., Sequence Listing).

In still other specific embodiments, a polypeptide sequence is about 10-1000, 10-900, 10-800, 10-700, 10-600, 10-500, 10-400, 10-300, 10-200, 10-100, 10-50, 10-40, 10-

30, 10-20, 20-1000, 20-900, 20-800, 20-700, 20-600, 20-500, 20-400, 20-300, 20-200, 20-100, 20-50, 20-40, 20-30, 50-1000, 50-900, 50-800, 50-700, 50-600, 50-500, 50-400, 50-300, 50-200, 50-100, 100-1000, 100-900, 100-800, 100-700, 100-600, 100-500, 100-400, 100-300, 100-200, 200-1000, 200-900, 200-800, 200-700, 200-600, 200-500, 200-400, or
 5 200-300 contiguous amino acids, including all ranges in between, and comprises all or a portion of a reference sequence. In certain embodiments, the C-terminal or N-terminal region of any reference polypeptide may be truncated by about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150, 160, 170, 180, 190, 200, 250, 300, 350, 400, 450, 500, 550, 600, 650, 700, 750, or 800 or more amino acids, or by
 10 about 10-50, 20-50, 50-100, 100-150, 150-200, 200-250, 250-300, 300-350, 350-400, 400-450, 450-500, 500-550, 550-600, 600-650, 650-700, 700-750, 750-800 or more amino acids, including all integers and ranges in between (e.g., 101, 102, 103, 104, 105), so long as the truncated polypeptide retains the binding properties and/or activity of the reference polypeptide. Typically, the biologically-active fragment has no less than about 1%, about 5%,
 15 about 10%, about 25%, or about 50% of an activity of the biologically-active reference polypeptide from which it is derived.

In general, variants will display at least about 30%, 40%, 50%, 55%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99% similarity or sequence identity or sequence homology to a reference polypeptide sequence.
 20 Moreover, sequences differing from the native or parent sequences by the addition (e.g., C-terminal addition, N-terminal addition, both), deletion, truncation, insertion, or substitution (e.g., conservative substitution) of about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, or 100 amino acids
 25 (including all integers and ranges in between) but which retain the properties or activities of a parent or reference polypeptide sequence are contemplated.

In some embodiments, variant polypeptides differ from reference sequence by at least one but by less than 50, 40, 30, 20, 15, 10, 8, 6, 5, 4, 3 or 2 amino acid residue(s). In other embodiments, variant polypeptides differ from a reference sequence by
 30 at least 1% but less than 20%, 15%, 10% or 5% of the residues. (If this comparison requires alignment, the sequences should be aligned for maximum similarity. "Looped" out sequences from deletions or insertions, or mismatches, are considered differences.)

Calculations of sequence similarity or sequence identity between sequences (the terms are used interchangeably herein) are performed as follows. To determine the
 35 percent identity of two amino acid sequences, or of two nucleic acid sequences, the sequences are aligned for optimal comparison purposes (e.g., gaps can be introduced in

one or both of a first and a second amino acid or nucleic acid sequence for optimal alignment and non-homologous sequences can be disregarded for comparison purposes). In certain embodiments, the length of a reference sequence aligned for comparison purposes is at least 30%, preferably at least 40%, more preferably at least 50%, 60%, and even more preferably at least 70%, 80%, 90%, 100% of the length of the reference sequence. The amino acid residues or nucleotides at corresponding amino acid positions or nucleotide positions are then compared. When a position in the first sequence is occupied by the same amino acid residue or nucleotide as the corresponding position in the second sequence, then the molecules are identical at that position.

The percent identity between the two sequences is a function of the number of identical positions shared by the sequences, taking into account the number of gaps, and the length of each gap, which need to be introduced for optimal alignment of the two sequences.

The comparison of sequences and determination of percent identity between two sequences can be accomplished using a mathematical algorithm. In a preferred embodiment, the percent identity between two amino acid sequences is determined using the Needleman and Wunsch, (*J. Mol. Biol.* 48: 444-453, 1970) algorithm which has been incorporated into the GAP program in the GCG software package, using either a Blossum 62 matrix or a PAM250 matrix, and a gap weight of 16, 14, 12, 10, 8, 6, or 4 and a length weight of 1, 2, 3, 4, 5, or 6. In yet another preferred embodiment, the percent identity between two nucleotide sequences is determined using the GAP program in the GCG software package, using a NWSgapdna.CMP matrix and a gap weight of 40, 50, 60, 70, or 80 and a length weight of 1, 2, 3, 4, 5, or 6. A particularly preferred set of parameters (and the one that should be used unless otherwise specified) are a Blossum 62 scoring matrix with a gap penalty of 12, a gap extend penalty of 4, and a frameshift gap penalty of 5.

The percent identity between two amino acid or nucleotide sequences can be determined using the algorithm of E. Meyers and W. Miller (*Cabios.* 4:11-17, 1989) which has been incorporated into the ALIGN program (version 2.0), using a PAM120 weight residue table, a gap length penalty of 12 and a gap penalty of 4.

The nucleic acid and protein sequences described herein can be used as a "query sequence" to perform a search against public databases to, for example, identify other family members or related sequences. Such searches can be performed using the NBLAST and XBLAST programs (version 2.0) of Altschul, *et al.*, (1990, *J. Mol. Biol.* 215: 403-10). BLAST nucleotide searches can be performed with the NBLAST program, score = 100, wordlength = 12 to obtain nucleotide sequences homologous to nucleic acid molecules of the invention. BLAST protein searches can be performed with the XBLAST program,

score = 50, wordlength = 3 to obtain amino acid sequences homologous to protein molecules of the invention. To obtain gapped alignments for comparison purposes, Gapped BLAST can be utilized as described in Altschul *et al.*, (*Nucleic Acids Res.* 25: 3389-3402, 1997). When utilizing BLAST and Gapped BLAST programs, the default parameters of the
5 respective programs (e.g., XBLAST and NBLAST) can be used.

In one embodiment, as noted above, polynucleotides and/or polypeptides can be evaluated using a BLAST alignment tool. A local alignment consists simply of a pair of sequence segments, one from each of the sequences being compared. A modification of Smith-Waterman or Sellers algorithms will find all segment pairs whose scores cannot be
10 improved by extension or trimming, called high-scoring segment pairs (HSPs). The results of the BLAST alignments include statistical measures to indicate the likelihood that the BLAST score can be expected from chance alone.

The raw score, S , is calculated from the number of gaps and substitutions associated with each aligned sequence wherein higher similarity scores indicate a more
15 significant alignment. Substitution scores are given by a look-up table (see PAM, BLOSUM).

Gap scores are typically calculated as the sum of G , the gap opening penalty and L , the gap extension penalty. For a gap of length n , the gap cost would be $G + Ln$. The choice of gap costs, G and L is empirical, but it is customary to choose a high value for G (10-15), e.g., 11, and a low value for L (1-2) e.g., 1.

The bit score, S' , is derived from the raw alignment score S in which the statistical properties of the scoring system used have been taken into account. Bit scores are normalized with respect to the scoring system, therefore they can be used to compare alignment scores from different searches. The terms "bit score" and "similarity score" are used interchangeably. The bit score gives an indication of how good the alignment is; the
20 higher the score, the better the alignment.

The E-Value, or expected value, describes the likelihood that a sequence with a similar score will occur in the database by chance. It is a prediction of the number of different alignments with scores equivalent to or better than S that are expected to occur in a database search by chance. The smaller the E-Value, the more significant the alignment.

30 For example, an alignment having an E value of e^{-117} means that a sequence with a similar score is very unlikely to occur simply by chance. Additionally, the expected score for aligning a random pair of amino acids is required to be negative, otherwise long alignments would tend to have high score independently of whether the segments aligned were related. Additionally, the BLAST algorithm uses an appropriate substitution matrix, nucleotide or
35 amino acid and for gapped alignments uses gap creation and extension penalties. For example, BLAST alignment and comparison of polypeptide sequences are typically done

using the BLOSUM62 matrix, a gap existence penalty of 11 and a gap extension penalty of 1.

In one embodiment, sequence similarity scores are reported from BLAST analyses done using the BLOSUM62 matrix, a gap existence penalty of 11 and a gap extension penalty of 1.

In a particular embodiment, sequence identity/similarity scores provided herein refer to the value obtained using GAP Version 10 (GCG, Accelrys, San Diego, Calif.) using the following parameters: % identity and % similarity for a nucleotide sequence using GAP Weight of 50 and Length Weight of 3, and the nwsgapdna.cmp scoring matrix; % identity and % similarity for an amino acid sequence using GAP Weight of 8 and Length Weight of 2, and the BLOSUM62 scoring matrix (Henikoff and Henikoff, *PNAS USA*. 89:10915-10919, 1992). GAP uses the algorithm of Needleman and Wunsch (*J Mol Biol.* 48:443-453, 1970) to find the alignment of two complete sequences that maximizes the number of matches and minimizes the number of gaps.

In one particular embodiment, the variant polypeptide comprises an amino acid sequence that can be optimally aligned with a reference polypeptide sequence (see, e.g., Sequence Listing) to generate a BLAST bit scores or sequence similarity scores of at least about 50, 60, 70, 80, 90, 100, 100, 110, 120, 130, 140, 150, 160, 170, 180, 190, 200, 210, 220, 230, 240, 250, 260, 270, 280, 290, 300, 310, 320, 330, 340, 350, 360, 370, 380, 390, 400, 410, 420, 430, 440, 450, 460, 470, 480, 490, 500, 510, 520, 530, 540, 550, 560, 570, 580, 590, 600, 610, 620, 630, 640, 650, 660, 670, 680, 690, 700, 710, 720, 730, 740, 750, 760, 770, 780, 790, 800, 810, 820, 830, 840, 850, 860, 870, 880, 890, 900, 910, 920, 930, 940, 950, 960, 970, 980, 990, 1000, or more, including all integers and ranges in between, wherein the BLAST alignment used the BLOSUM62 matrix, a gap existence penalty of 11, and a gap extension penalty of 1.

As noted above, a reference polypeptide may be altered in various ways including amino acid substitutions, deletions, truncations, additions, and insertions. Methods for such manipulations are generally known in the art. For example, amino acid sequence variants of a reference polypeptide can be prepared by mutations in the DNA. Methods for mutagenesis and nucleotide sequence alterations are well known in the art. See, for example, Kunkel (*PNAS USA*. 82: 488-492, 1985); Kunkel *et al.*, (*Methods in Enzymol.* 154: 367-382, 1987), U.S. Pat. No. 4,873,192, Watson, J. D. *et al.*, ("Molecular Biology of the Gene," Fourth Edition, Benjamin/Cummings, Menlo Park, Calif., 1987) and the references cited therein. Guidance as to appropriate amino acid substitutions that do not affect biological activity of the protein of interest may be found in the model of Dayhoff *et al.*,

(1978) Atlas of Protein Sequence and Structure (Natl. Biomed. Res. Found., Washington, D.C.).

Methods for screening gene products of combinatorial libraries made by such modifications, and for screening cDNA libraries for gene products having a selected property are known in the art. Such methods are adaptable for rapid screening of the gene libraries generated by combinatorial mutagenesis of reference polypeptides. As one example, recursive ensemble mutagenesis (REM), a technique which enhances the frequency of functional mutants in the libraries, can be used in combination with the screening assays to identify polypeptide variants (Arkin and Yourvan, *PNAS USA* 89: 7811-7815, 1992; Delgrave *et al.*, *Protein Engineering*. 6: 327-331, 1993).

Native ADI may be found in microorganisms and is immunogenic and rapidly cleared from circulation in a patient. These problems may be overcome by engineering ADI to reduce its antigenicity, such as by engineering chimeric ADI molecules. In one embodiment, chimeric ADI are constructed by combining different domains (e.g. catalytic domain and α -helical domains) from different ADI proteins using standard molecular biological, or protein synthesis techniques. In one embodiment, the catalytic domain from *M. arginini* or *M. arthritidis* is combined with the α -helical domain of *M. hominis*. In another embodiment, the catalytic domain of *M. arginini* is combined with the α -helical domain of *M. arthritidis*. In a further embodiment, the catalytic domain of *M. arthritidis* is combined with the α -helical domain of *M. arginini*. As would be recognized by the skilled person, other combinations of catalytic and α -helical domains can be constructed from ADI proteins derived from other species, such as from *Mycoplasma pneumoniae*, *Streptococcus pyogenes*, *Streptococcus pneumoniae*, *Borrelia burgdorferi*, *Borrelia afzelii*, *Giardia intestinalis*, *Clostridium perfringens*, *Bacillus licheniformis*, *Enterococcus faecalis*, and *Lactobacillus sake*.

Antigenicity problems may also be overcome by modifying chimeric ADI. Thus, the present disclosure provides chimeric ADI modified by a modifying agent, including, but not limited to macromolecule polymers, proteins, peptides, polysaccharides, or other compounds. Arginine deiminase or chimeras thereof as described herein and the modifying agent may be linked by either covalent bonds or non-covalent interaction to form a stable conjugate or a stable composition to achieve a desired effect. In certain embodiments, the modified chimeric ADI retains the biological activity of an unmodified chimeric ADI and has a longer half-life *in vivo* and lower antigenicity than the unmodified, chimeric ADI. In certain embodiments, the modified chimeric ADI retains at least 20%, 25%, 30%, 35%, 40%, 45%, 50%, 55%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or more of the biological activity of unmodified chimeric ADI.

In one embodiment, a modifying agent can be a polymer or a protein or a fragment thereof that is biocompatible and can increase the half-life of chimeric ADI in blood. The modifying agent can be either chemically coupled to chimeric ADI or where applicable, linked to the chimeric ADI via fusion protein expression.

5 Macromolecule polymers may include a non-peptide macromolecule polymer, which in certain embodiments, may have its own bioactivity. Suitable polymers include, but are not limited to, polyenol compounds, polyether compounds, polyvinylpyrrolidone, poly amino acids, copolymer of divinyl ether and maleic anhydride, N-(2-hydroxypropyl)-methacrylamide, polysaccharide, polyoxyethylated polyol, heparin or its fragment, poly-alkyl-
10 ethylene glycol and its derivatives, copolymers of poly-alkyl-ethylene glycol and its derivatives, poly(vinyl ethyl ether), a,P-Poly[(2-hydroxyethyl)-DL-aspartamide], polycarboxylates, poly oxyethylene-oxymethylenes, polyacryloyl morpholines, copolymer of amino compounds and oxyolefin, poly hyaluronic acid, polyoxiranes, copolymer of ethanedioic acid and malonic acid, poly (1,3-dioxolane), ethylene and maleic hydrazide
15 copolymer, poly sialic acid, cyclodextrin, etc. In certain embodiments, the polymer is polyethylene glycol.

 The polyenol compounds as used herein include, but are not limited to, polyethylene glycol (including monomethoxy polyethylene glycol, monohydroxyl polyethylene glycol), polyvinyl alcohol, polyallyl alcohol, polybutenol and the like, and their derivatives,
20 such as lipids.

 The polyether compounds include, but are not limited to poly alkylene glycol ($\text{HO}((\text{CH}_2)_x\text{O})_n\text{H}$), polypropylene glycol, polyoxyrehylene ($\text{HO}((\text{CH}_2)_2\text{O})_n\text{H}$), polyvinyl alcohol ($((\text{CH}_2\text{CHOH})_n)$).

 Poly amino acids include, but are not limited to, polymers of one type of
25 amino acid or copolymers of two or more types of amino acids, for example, polyalanine or polylysine, or block co-polymers thereof.

 Polysaccharides include but are not limited to, glucosan and its derivatives, for example dextran sulfate, cellulose and its derivatives (including methyl cellulose and carboxymethyl cellulose), starch and its derivatives, polysucrose, etc.

30 In one specific embodiment of the present invention, chimeric ADI is modified by coupling with proteins or peptides, wherein one or more proteins or peptides are directly or indirectly linked to chimeric ADI. The proteins can either be naturally existing proteins or their fragments, including but not limited to naturally existing human serum proteins or their fragments, such as thyroxine-binding protein, transthyretin, a1-acid glycoprotein, transferrin,
35 fibrinogen, immunoglobulin, Ig Fc regions, albumin, and fragments thereof. By "fragment" is meant any portion of a protein that is smaller than the whole protein but which retains the

desired function of the protein. Engineered chimeric ADI may be directly or indirectly linked to a protein via a covalent bond. Direct linking means that one amino acid of chimeric ADI is directly linked to one amino acid of the modifying protein, via a peptide bond or a disulfide bridge. Indirect linking refers to the linkages between a chimeric ADI and a modifying protein, via originally existing chemical groups there between or specific chemical groups added through biological or chemical means, or the combination of the above-mentioned linkages.

In one particular embodiment, chimeric ADI is modified by covalent attachment with PEG. Chimeric ADI covalently modified with PEG (with or without a linker) may be hereinafter referred to as chimeric "ADI-PEG." When compared to unmodified chimeric ADI, chimeric ADI-PEG retains most of its enzymatic activity, is far less antigenic, has a greatly extended circulating half-life, and is much more efficacious in the treatment of tumors.

"Polyethylene glycol" or "PEG" refers to mixtures of condensation polymers of ethylene oxide and water, in a branched or straight chain, represented by the general formula $H(OCH_2CH_2)_nOH$, wherein n is at least 4. "Polyethylene glycol" or "PEG" is used in combination with a numeric suffix to indicate the approximate weight average molecular weight thereof. For example, PEG5,000 refers to PEG having a total weight average molecular weight of about 5,000; PEG12,000 refers to PEG having a total weight average molecular weight of about 12,000; and PEG20,000 refers to PEG having a total weight average molecular weight of about 20,000.

In one embodiment of the present invention, the PEG has a total weight average molecular weight of about 1,000 to about 50,000; in one embodiment from about 3,000 to about 40,000, and in another embodiment from about 5,000 to about 30,000; in certain embodiments from about 8,000 to about 30,000; in other embodiments from about 11,000 to about 30,000; in additional embodiments, from about 12,000 to about 28,000; in still other embodiments, from about 16,000 to about 24,000; and in other embodiments, about 18,000 to about 22,000; in another embodiment, from 19,000 to about 21,000, and in one embodiment, the PEG has a total weight average molecular weight of about 20,000.

Generally, PEG with a molecular weight of 30,000 or more is difficult to dissolve, and yields of the formulated product may be reduced. The PEG may be a branched or straight chain. Generally, increasing the molecular weight of the PEG decreases the antigenicity of the ADI or chimeric ADI. The PEG having a molecular weight described in this embodiment may be used in conjunction with chimeric ADI, and, optionally, a biocompatible linker, to treat cancer, including, for example, acute myeloid leukemia, such as relapsed acute myeloid leukemia, breast cancer, ovarian cancer, colorectal cancer, gastric cancer, glioma, glioblastoma

multiforme, non-small cell lung cancer (NSCLC), kidney cancer, bladder cancer, uterine cancer, esophageal cancer, brain cancer, head and neck cancers, cervical cancer, testicular cancer, stomach cancer and esophageal cancer.

In another embodiment of the present invention, the PEG has a total weight average molecular weight of about 1,000 to about 50,000; in certain embodiments about 3,000 to about 30,000; in other embodiments from about 3,000 to about 20,000; in one embodiment from about 4,000 to about 12,000; in still other embodiments from about 4,000 to about 10,000; in additional embodiments from about 4,000 to about 8,000; still further embodiments from about 4,000 to about 6,000; and about 5,000 in another embodiment.

The PEG may be a branched or straight chain, and in certain embodiments is a straight chain. The PEG having a molecular weight described in this embodiment may be used in conjunction with chimeric ADI, and optionally, a biocompatible linker, to treat graft versus host disease (GVHD) or cancer.

While chimeric ADI-PEG is the illustrative modified chimeric ADI described herein, as would be recognized by the skilled person chimeric ADI may be modified with other polymers or appropriate molecules for the desired effect, in particular reducing antigenicity and increasing serum half-life.

Chimeric ADI may be covalently bonded to a modifying agent, such as PEG, with or without a linker, although a preferred embodiment utilizes a linker.

The linker used to covalently attach chimeric ADI to a modifying agent, e.g. PEG, may be any biocompatible linker. As discussed above, "biocompatible" indicates that the compound or group is non-toxic and may be utilized in vitro or in vivo without causing injury, sickness, disease, or death. A modifying agent, such as PEG, can be bonded to the linker, for example, via an ether bond, a thiol bond, or an amide bond. The linker group includes, for example, a succinyl group, an amide group, an imide group, a carbamate group, an ester group, an epoxy group, a carboxyl group, a hydroxyl group, a carbohydrate, a tyrosine group, a cysteine group, a histidine group, a methylene group, and combinations thereof. In one embodiment, the source of the biocompatible linker is succinimidyl succinate (SS). Other suitable sources of linker may include an oxycarbonylimidazole group (including, for example, carbonylimidazole (CDI)), a nitro phenyl group (including, for example, nitrophenyl carbonate (NCP) or trichlorophenyl carbonate (TCP)), a trysylate group, an aldehyde group, an isocyanate group, a vinylsulfone group, or a primary amine. In another embodiment, the linker is derived from SS, SPA, SCM, or NHS; in certain embodiments, SS, SPA, or NHS are used, and in other embodiments, SS or SPA are used. Thus, in certain embodiments, potential linkers can be formed from methoxy-PEG succinimidyl succinate(SS), methoxy-PEG succinimidyl glutarate(SG), methoxy-PEG succinimidyl

carbonate (SC), methoxy-PEG succinimidyl carboxymethyl ester (SCM), methoxy-PEG2 N-hydroxy succinimide (NHS), methoxy-PEG succinimidyl butanoate (SBA), methoxy-PEG succinimidyl propionate (SPA), methoxy-PEG succinimidyl glutaramide, and methoxy-PEG succinimidyl succinimide.

Alternatively, chimeric ADI may be coupled directly to a modifying agent, such as PEG (*i.e.*, without a linker) through an amino group, a sulfhydryl group, a hydroxyl group or a carboxyl group.

Chimeric ADI may be covalently bonded to PEG, via a biocompatible linker, using methods known in the art, as described, for example, by Park et al, *Anticancer Res.*, 1:373-376 (1981); and Zaplipsky and Lee, *Polyethylene Glycol Chemistry: Biotechnical and Biomedical Applications*, J. M. Harris, ed., Plenum Press, NY, Chapter 21 (1992), the disclosures of which are hereby incorporated by reference herein in their entirety.

The attachment of PEG to chimeric ADI increases the circulating half-life of chimeric ADI. Generally, PEG is attached to a primary amine of chimeric ADI. Selection of the attachment site of PEG, or other modifying agent, on the chimeric ADI is determined by the role of each of the sites within the active domain of the protein, as would be known to the skilled artisan. PEG may be attached to the primary amines of chimeric ADI without substantial loss of enzymatic activity. For example, ADI cloned from *Mycoplasma arginini*, *Mycoplasma arthritidis* and *Mycoplasma hominis* has a number of lysine residues that may be modified by this procedure. In other words, one or more or all of the lysines are possible points at which ADI and chimeric forms of ADI as described herein can be attached to PEG via a biocompatible linker, such as SS, SPA, SCM, SSA and/or NHS. PEG may also be attached to other sites on ADI and chimeric forms of ADI as described herein, as would be apparent to one skilled in the art in view of the present disclosure.

From 1 to about 30 PEG molecules may be covalently bonded to chimeric ADI. In certain embodiments, chimeric ADI is modified with one PEG molecule. In other embodiments, chimeric ADI is modified with more than one PEG molecule. In one embodiment, chimeric ADI is modified with about 1 to about 10 PEG molecules, in one embodiment from about 2 to about 8 PEG molecules and in another embodiment, from about 9 to about 12 PEG molecules. In another embodiment, the chimeric ADI is modified with 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, or 12 PEG molecules. In one specific embodiment, chimeric ADI is modified with 4.5 – 5.5 PEG molecules per ADI. In another embodiment, chimeric ADI is modified with 5 ± 1.5 PEG molecules.

In another embodiment, about 15% to about 70% of the primary amino groups in chimeric ADI are modified with PEG, in one embodiment about 20% to about 65%, about 25% to about 60%, or in certain embodiments about 30% to about 55%, or 45% to

about 50%, and in other embodiments about 20% or 30% or 40% or 50% of the primary amino groups in arginine deiminase are modified with PEG. As would be understood by the skilled artisan, the range of primary amino groups depends upon how many lysines are successfully removed. In certain embodiments, all of the lysines may be removed and the N-terminus of the molecule is PEGylated. When PEG is covalently bonded to the end terminus of chimeric ADI, it may be desirable to have only 1 PEG molecule utilized. Increasing the number of PEG units on chimeric ADI increases the circulating half-life of the enzyme. However, increasing the number of PEG units on chimeric ADI decreases the specific activity of the enzyme. Thus, a balance needs to be achieved between the two, as would be apparent to one skilled in the art in view of the present disclosure.

In the present invention, a common feature of biocompatible linker is that they attach to a primary amine of arginine deiminase via a succinyl group. Once coupled with chimeric ADI, SS-PEG has an ester linkage next to the PEG, which may render this site sensitive to serum esterase, which may release PEG from chimeric ADI in the body. SPA-PEG and PEG2-NHS do not have an ester linkage, so they are not sensitive to serum esterase.

In certain embodiments, a biocompatible linker is used in the present invention. PEG which is attached to the protein may be either a straight chain, as with SS-PEG, SPA-PEG and SC-PEG, or a branched chain of PEG may be used, as with PEG2-NHS.

In certain embodiments, the chimeric ADI of the present disclosure may be modified as described in US Patent No. 6,635,462. In particular, modifications of one or more of the naturally occurring amino acid residues of ADI and chimeric molecules of ADI, in particular derived from *Mycoplasma hominis*, *M. arthritis* and *M. arginini*, can provide for an enzyme that is more easily renatured and formulated thereby improving existing techniques for the manufacture of chimeric ADI and therapeutic compositions comprising the same. In one embodiment, the chimeric ADI of the present disclosure is modified to remove one or more lysine residues (*e.g.*, the lysine can be substituted with another amino acid or analogues thereof, or a non-natural amino acid). In particular, in one embodiment, the chimeric ADI is modified to be free of the lysine at position 112, 374, 405 or 408 of SEQ ID NO:1 (*M. hominis* ADI), or a combination of one or more of these positions. In a further embodiment, the chimeric ADI is modified to be free of one or more lysines, for example, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, or more lysine residues, should they be present, can be substituted with another amino acid or analogues thereof, or a nonnatural amino acid. In one embodiment, a chimeric ADI has 5 lysines substituted, for example, at position 7, 88, 137, 209, and 380 of SEQ ID NO: 4. In another embodiment, a

chimeric ADI has 10 lysines substituted, for example, at positions 7, 9, 59, 88, 115, 116, 137, 178, 209, and 380 of SEQ ID NO: 4. In yet another embodiment, a chimeric ADI has 15 lysines substituted, for example, at positions 7, 9, 59, 66, 88, 91, 93, 115, 116, 137, 141, 178, 209, 279, and at position 380 of SEQ ID NO: 4. In one embodiment, a chimeric ADI comprises 21 lysines substituted, for example, at positions 7, 9, 56, 59, 66, 88, 91, 93, 96, 115, 116, 137, 141, 178, 209, 254, 279, 325, 326, 380, and 406 of SEQ ID NO: 4. Illustrative chimeric ADI molecules having lysine substitutions are set forth in SEQ ID NOs: 10-13.

In certain embodiments, pegylation sites associated with ADI located at or adjacent to the catalytic region of the enzyme are modified. For purposes of the present invention, the phrase "pegylation site" may be defined as any site or position of ADI or a chimeric ADI that may be covalently modified with polyethylene glycol. A "pegylation site" can be considered located at or adjacent to the catalytic region of the enzyme where pegylation of the site results in a significant reduction in catalytic activity of the enzyme. The pegylation of such sites has traditionally resulted in the inactivation of the enzyme. For example, ADI from *Mycoplasma hominis* has a lysine at the 112 position which can be considered to be at or adjacent the catalytic region of the enzyme. The attachment of PEG to this lysine at the 112 position can inactivate the enzyme. In addition, ADI from *Mycoplasma hominis* has a cysteine at the 397 position which can be considered to be at or adjacent the catalytic region of the enzyme. The amino acid substitutions for cysteine at the 397 position can inactivate the enzyme. In particular, substituting alanine, histidine, arginine, serine, lysine or tyrosine for cysteine at the 397 position can result in a loss of all detectable enzyme activity. ADI from *Mycoplasma hominis* also has three lysines located near this conserved cysteine, in particular Lys374, Lys405 and Lys408. The attachment of PEG to Lys374, Lys405, Lys408 or combinations thereof can inactivate the enzyme.

It is to be understood that ADI derived from other organisms may also have pegylation sites corresponding to 112 position of ADI from *Mycoplasma hominis*. For example, ADI from *Streptococcus pyrogenes* has lysine at the 104 position, ADI from *Mycoplasma pneumoniae* has lysine at the 106 position, and ADI from *Giardia intestinalis* has lysine at the 114 position. In addition, ADI from some organisms may have lysines corresponding to the same general location as the 112 position of ADI from *Mycoplasma hominis*. The location of lysine in ADI from such organisms are known to the skilled person and are described in US Patent No. 6,635,462.

Thus, in one embodiment, the present invention provides for certain amino acid substitutions in the polypeptide chain of ADI. These amino acid substitutions provide for modified ADI that loses less activity when modified by a modifying agent, e.g., upon

pegylation. By eliminating pegylation sites, or other known modification sites, at or adjacent to the catalytic region of enzyme, optimal modification, e.g., pegylation, can be achieved without the loss of activity.

It is to be understood that other embodiments of the invention are based on the understanding that certain structural characteristics of arginine deiminase may prevent or interfere with the proper and rapid renaturation when produced via recombinant technology. In particular, these structural characteristics hinder or prevent the enzyme from assuming an active conformation during recombinant production. For purposes of the present invention, the phrase "active conformation" may be defined as a three-dimensional structure that allows for enzymatic activity by unmodified or modified arginine deiminase or chimeric arginine deiminase. The active conformation may, in particular, be necessary for catalyzing the conversion of arginine into citrulline. The phrase "structural characteristic" may be defined as any trait, quality or property of the polypeptide chain resulting from a particular amino acid or combination of amino acids. For instance, arginine deiminase may contain an amino acid that results in a bend or kink in the normal peptide chain and thus hinders the enzyme from assuming an active conformation during renaturation of the enzyme. In particular, arginine deiminase from *Mycoplasma hominis* has a proline at the 210 position that may result in a bend or kink in the peptide chain, making it more difficult to renature the enzyme during recombinant production. It is to be understood that arginine deiminase derived from other organisms may also have sites corresponding to the 210 position of arginine deiminase from *Mycoplasma hominis*.

The present invention thus again provides for certain amino acid substitutions in the polypeptide chain of wild type arginine deiminases and chimeric arginine deiminases derived therefrom. Such amino acid substitutions can eliminate the problematic structural characteristics in the peptide chain of arginine deiminase. Such amino acid substitutions provide for improved renaturation of the modified arginine deiminase. These amino acid substitutions make possible rapid renaturing of modified chimeric arginine deiminases using reduced amounts of buffer. These amino acid substitutions may also provide for increased yields of renatured modified chimeric arginine deiminase. In one embodiment of the invention, the modified chimeric arginine deiminase has an amino acid substitution at P210 or the equivalent residue. As mentioned above, arginine deiminase derived from *Mycoplasma hominis* has the amino acid proline located at the 210 position. While not limiting the present invention, it is presently believed that the presence of the amino acid proline at position 210 results in a bend or kink in the normal polypeptide chain that increases the difficulty of renaturing (i.e., refolding) arginine deiminase. Substitutions for proline at position 210 make possible the rapid renaturation of modified arginine deiminase

and chimeras derived therefrom using reduced amounts of buffer. Substitutions for proline at position 210 may also provide for increased yields of renatured modified chimeric arginine deiminase. In one embodiment, the proline at position 210 is substituted with serine. It is to be understood that in accordance with this aspect of the invention, other substitutions at position 210 may be made. Examples of other substitutions include Pro210 to Thr210, Pro210 to Arg210, Pro210 to Asn210, Pro210 to Gln210 or Pro210 to Met210. By eliminating those structural characteristics associated with the amino acid of position 210 of the wild-type arginine deiminase and chimeras derived therefrom, proper refolding of the enzyme can be achieved.

The methods of the present invention can involve either *in vitro* or *in vivo* applications. In the case of *in vitro* applications, including cell culture applications, the compounds described herein can be added to the cells in cultures and then incubated. The compounds of the present invention may also be used to facilitate the production of monoclonal and/or polyclonal antibodies, using antibody production techniques well known in the art. The monoclonal and/or polyclonal antibodies can then be used in a wide variety of diagnostic applications, as would be apparent to one skilled in the art.

The *in vivo* means of administration of the compounds of the present invention will vary depending upon the intended application. Administration of the chimeric ADI compositions described herein, in pure form or in an appropriate pharmaceutical composition, can be carried out via any of the accepted modes of administration of agents for serving similar utilities. The pharmaceutical compositions can be prepared by combining chimeric ADI, e.g., chimeric ADI-PEG, chimeric ADI-PEG 20, with an appropriate physiologically acceptable carrier, diluent or excipient, and may be formulated into preparations in solid, semi-solid, liquid or gaseous forms, such as tablets, capsules, powders, granules, ointments, solutions, suppositories, injections, inhalants, gels, microspheres, and aerosols. In addition, other pharmaceutically active ingredients (including other anti-cancer agents as described elsewhere herein) and/or suitable excipients such as salts, buffers and stabilizers may, but need not, be present within the composition. Administration may be achieved by a variety of different routes, including oral, parenteral, nasal, intravenous, intradermal, subcutaneous or topical. Modes of administration depend upon the nature of the condition to be treated or prevented. Thus, chimeric ADI-PEG, e.g., chimeric ADI-PEG 20, may be administered orally, intranasally, intraperitoneally, parenterally, intravenously, intralymphatically, intratumorally, intramuscularly, interstitially, intra-arterially, subcutaneously, intraocularly, intrasynovial, transepithelial, and transdermally. An amount that, following administration, reduces, inhibits, prevents or delays the progression and/or metastasis of a cancer is considered effective. In certain

embodiment, the chimeric ADI compositions herein increase median survival time of patients by a statistically significant amount. In one embodiment, the chimeric ADI treatments described herein increase median survival time of a patient by 4 weeks, 5 weeks, 6 weeks, 7 weeks, 8 weeks, 9 weeks, 10 weeks, 15 weeks, 20 weeks, 25 weeks, 30 weeks, 40 weeks, or longer. In certain embodiments, chimeric ADI treatments increase median survival time of a patient by 1 year, 2 years, 3 years, or longer. In one embodiment, the chimeric ADI treatments described herein increase progression-free survival by 2 weeks, 3 weeks, 4 weeks, 5 weeks, 6 weeks, 7 weeks, 8 weeks, 9 weeks, 10 weeks or longer. In certain embodiments, the chimeric ADI treatments described herein increase progression-free survival by 1 year, 2 years, 3 years, or longer.

In certain embodiments, the amount administered is sufficient to result in tumor regression, as indicated by a statistically significant decrease in the amount of viable tumor, for example, at least a 50% decrease in tumor mass, or by altered (e.g., decreased with statistical significance) scan dimensions. In certain embodiments, the amount administered is sufficient to result in stable disease. In other embodiments, the amount administered is sufficient to result in clinically relevant reduction in symptoms of a particular disease indication known to the skilled clinician.

In certain embodiments the amount administered is sufficient to inhibit NO synthesis, inhibit angiogenesis, and or is sufficient to induce apoptosis in tumor cells or any combination thereof. NO synthesis, angiogenesis and apoptosis may be measured using methods known in the art, see, e.g., *Current Protocols in Immunology* or *Current Protocols in Molecular Biology*, John Wiley & Sons, New York, N.Y.(2009 and updates thereto); Ausubel *et al.*, *Short Protocols in Molecular Biology*, 3rd ed., Wiley & Sons, 1995; and other like references. In one particular embodiment the amount administered inhibits NO synthesis and inhibits the growth of melanoma and synergizes with other chemotherapies as described herein, such as cisplatin. Accordingly, one embodiment of the present disclosure provides a method of treating melanoma by administering chimeric ADI-PEG 20 in combination with cisplatin, wherein the treatment depletes endogenous nitric oxide (NO).

The precise dosage and duration of treatment is a function of the disease being treated and may be determined empirically using known testing protocols or by testing the compositions in model systems known in the art and extrapolating therefrom. Controlled clinical trials may also be performed. Dosages may also vary with the severity of the condition to be alleviated. A pharmaceutical composition is generally formulated and administered to exert a therapeutically useful effect while minimizing undesirable side effects. The composition may be administered one time, or may be divided into a number of

smaller doses to be administered at intervals of time. For any particular subject, specific dosage regimens may be adjusted over time according to the individual need.

The chimeric ADI compositions may be administered alone or in combination with other known cancer treatments, such as radiation therapy, chemotherapy, transplantation, immunotherapy, hormone therapy, photodynamic therapy, *etc.* The compositions may also be administered in combination with antibiotics.

Typical routes of administering these and related pharmaceutical compositions thus include, without limitation, oral, topical, transdermal, inhalation, parenteral, sublingual, buccal, rectal, vaginal, and intranasal. The term parenteral as used herein includes subcutaneous injections, intravenous, intramuscular, intrasternal injection or infusion techniques. Pharmaceutical compositions according to certain embodiments of the present invention are formulated so as to allow the active ingredients contained therein to be bioavailable upon administration of the composition to a patient. Compositions that will be administered to a subject or patient may take the form of one or more dosage units, where for example, a tablet may be a single dosage unit, and a container of a herein described chimeric ADI composition in aerosol form may hold a plurality of dosage units. Actual methods of preparing such dosage forms are known, or will be apparent, to those skilled in this art; for example, see *Remington: The Science and Practice of Pharmacy*, 20th Edition (Philadelphia College of Pharmacy and Science, 2000). The composition to be administered will, in any event, contain a therapeutically effective amount of a chimeric ADI-PEG of the present disclosure, such as chimeric ADI-PEG 20, for treatment of a disease or condition of interest in accordance with teachings herein.

A pharmaceutical composition may be in the form of a solid or liquid. In one embodiment, the carrier(s) are particulate, so that the compositions are, for example, in tablet or powder form. The carrier(s) may be liquid, with the compositions being, for example, an oral oil, injectable liquid or an aerosol, which is useful in, for example, inhalatory administration. When intended for oral administration, the pharmaceutical composition is generally either solid or liquid form, where semi-solid, semi-liquid, suspension and gel forms are included within the forms considered herein as either solid or liquid.

As a solid composition for oral administration, the pharmaceutical composition may be formulated into a powder, granule, compressed tablet, pill, capsule, chewing gum, wafer or the like. Such a solid composition will typically contain one or more inert diluents or edible carriers. In addition, one or more of the following may be present: binders such as carboxymethylcellulose, ethyl cellulose, microcrystalline cellulose, gum tragacanth or gelatin; excipients such as starch, lactose or dextrans, disintegrating agents such as alginic acid, sodium alginate, Primogel, corn starch and the like; lubricants such as magnesium stearate

or Sterotex; glidants such as colloidal silicon dioxide; sweetening agents such as sucrose or saccharin; a flavoring agent such as peppermint, methyl salicylate or orange flavoring; and a coloring agent. When the pharmaceutical composition is in the form of a capsule, for example, a gelatin capsule, it may contain, in addition to materials of the above type, a liquid carrier such as polyethylene glycol or oil.

The pharmaceutical composition may be in the form of a liquid, for example, an elixir, syrup, solution, emulsion or suspension. The liquid may be for oral administration or for delivery by injection, as two examples. When intended for oral administration, preferred composition contain, in addition to the present compounds, one or more of a sweetening agent, preservatives, dye/colorant and flavor enhancer. In a composition intended to be administered by injection, one or more of a surfactant, preservative, wetting agent, dispersing agent, suspending agent, buffer, stabilizer and isotonic agent may be included.

The liquid pharmaceutical compositions, whether they be solutions, suspensions or other like form, may include one or more of the following adjuvants: sterile diluents such as water for injection, saline solution, in certain embodiments, physiological saline, Ringer's solution, isotonic sodium chloride, fixed oils such as synthetic mono or diglycerides which may serve as the solvent or suspending medium, polyethylene glycols, glycerin, propylene glycol or other solvents; antibacterial agents such as benzyl alcohol or methyl paraben; antioxidants such as ascorbic acid or sodium bisulfite; chelating agents such as ethylenediaminetetraacetic acid; buffers such as acetates, citrates or phosphates and agents for the adjustment of tonicity such as sodium chloride or dextrose. The parenteral preparation can be enclosed in ampoules, disposable syringes or multiple dose vials made of glass or plastic. Physiological saline is a preferred adjuvant. An injectable pharmaceutical composition is preferably sterile.

A liquid pharmaceutical composition intended for either parenteral or oral administration should contain an amount of chimeric ADI as herein disclosed, such as chimeric ADI-PEG 20, such that a suitable dosage will be obtained. Typically, this amount is at least 0.01% of chimeric ADI in the composition. When intended for oral administration, this amount may be varied to be between 0.1 and about 70% of the weight of the composition. Certain oral pharmaceutical compositions contain between about 4% and about 75% of chimeric ADI-PEG. In certain embodiments, pharmaceutical compositions and preparations according to the present invention are prepared so that a parenteral dosage unit contains between 0.01 to 10% by weight of chimeric ADI-PEG prior to dilution.

The pharmaceutical composition may be intended for topical administration, in which case the carrier may suitably comprise a solution, emulsion, ointment or gel base.

The base, for example, may comprise one or more of the following: petrolatum, lanolin, polyethylene glycols, bee wax, mineral oil, diluents such as water and alcohol, and emulsifiers and stabilizers. Thickening agents may be present in a pharmaceutical composition for topical administration. If intended for transdermal administration, the composition may include a transdermal patch or iontophoresis device. The pharmaceutical composition may be intended for rectal administration, in the form, for example, of a suppository, which will melt in the rectum and release the drug. The composition for rectal administration may contain an oleaginous base as a suitable nonirritating excipient. Such bases include, without limitation, lanolin, cocoa butter and polyethylene glycol.

The pharmaceutical composition may include various materials, which modify the physical form of a solid or liquid dosage unit. For example, the composition may include materials that form a coating shell around the active ingredients. The materials that form the coating shell are typically inert, and may be selected from, for example, sugar, shellac, and other enteric coating agents. Alternatively, the active ingredients may be encased in a gelatin capsule. The pharmaceutical composition in solid or liquid form may include an agent that binds to chimeric ADI-PEG and thereby assists in the delivery of the compound. Suitable agents that may act in this capacity include monoclonal or polyclonal antibodies, one or more proteins or a liposome. The pharmaceutical composition may consist essentially of dosage units that can be administered as an aerosol. The term aerosol is used to denote a variety of systems ranging from those of colloidal nature to systems consisting of pressurized packages. Delivery may be by a liquefied or compressed gas or by a suitable pump system that dispenses the active ingredients. Aerosols may be delivered in single phase, bi-phasic, or tri-phasic systems in order to deliver the active ingredient(s). Delivery of the aerosol includes the necessary container, activators, valves, subcontainers, and the like, which together may form a kit. One of ordinary skill in the art, without undue experimentation may determine preferred aerosols.

The pharmaceutical compositions may be prepared by methodology well known in the pharmaceutical art. For example, a pharmaceutical composition intended to be administered by injection can be prepared by combining a composition that comprises chimeric ADI-PEG as described herein and optionally, one or more of salts, buffers and/or stabilizers, with sterile, distilled water so as to form a solution. A surfactant may be added to facilitate the formation of a homogeneous solution or suspension. Surfactants are compounds that non-covalently interact with the chimeric ADI-PEG composition so as to facilitate dissolution or homogeneous suspension of the chimeric ADI-PEG in the aqueous delivery system.

The compositions may be administered in a therapeutically effective amount, which will vary depending upon a variety of factors including the activity of the specific compound (e.g., chimeric ADI-PEG) employed; the metabolic stability and length of action of the compound; the age, body weight, general health, sex, and diet of the patient; the mode and time of administration; the rate of excretion; the drug combination; the severity of the particular disorder or condition; and the subject undergoing therapy.

A therapeutically effective amount of one of the compounds of the present invention is an amount that is effective to inhibit tumor growth. Generally, treatment is initiated with small dosages which can be increased by small increments until the optimum effect under the circumstances is achieved. Generally, a therapeutic dosage of compounds of the present invention may be from about 1 to about 200 mg/kg twice a week to about once every two weeks. For example, the dosage may be about 1 mg/kg once a week as a 2 ml intravenous injection to about 20 mg/kg once every 3 days. In a further embodiment, the dose may be from about 50 IU/m² to about 8,000 IU/m², administered about once every 3 days, about once a week, about twice a week, or about once every 2 weeks. In certain embodiments, the dose may be about 50 IU/m², 60 IU/m², 70 IU/m², 80 IU/m², 90 IU/m², 100 IU/m², 110 IU/m², 120 IU/m², 130 IU/m², 140 IU/m², 150 IU/m², 160 IU/m², 170 IU/m², 180 IU/m², 190 IU/m², 200 IU/m², 210 IU/m², 220 IU/m², 230 IU/m², 240 IU/m², 250 IU/m², 260 IU/m², 270 IU/m², 280 IU/m², 290 IU/m², 300 IU/m², 310 IU/m², about 320 IU/m², about 330 IU/m², 340 IU/m², about 350 IU/m², 360 IU/m², 370 IU/m², 380 IU/m², 390 IU/m², 400 IU/m², 410 IU/m², 420 IU/m², 430 IU/m², 440 IU/m², 450 IU/m², 500 IU/m², 550 IU/m², 600 IU/m², 620 IU/m², 630 IU/m², 640 IU/m², 650 IU/m², 660 IU/m², 670 IU/m², 680 IU/m², 690 IU/m², 700 IU/m², 750 IU/m², 800 IU/m², 850 IU/m², 900 IU/m², 950 IU/m², 1,000 IU/m², 1,100 IU/m², 1,200 IU/m², 1,300 IU/m², 1,400 IU/m², 1,500 IU/m², 1,600 IU/m², 1,700 IU/m², 1,800 IU/m², 1,900 IU/m², 2,000 IU/m², 2,100 IU/m², 2,200 IU/m², 2,300 IU/m², 2,400 IU/m², 2,500 IU/m², 2,600 IU/m², 2,700 IU/m², 2,800 IU/m², 2,900 IU/m², 3,000 IU/m², 3,100 IU/m², 3,200 IU/m², 3,300 IU/m², 3,400 IU/m², 3,500 IU/m², 3,600 IU/m², 3,700 IU/m², 3,800 IU/m², 3,900 IU/m², 4,000 IU/m², 4,100 IU/m², 4,200 IU/m², 4,300 IU/m², 4,400 IU/m², 4,500 IU/m², 4,600 IU/m², 4,700 IU/m², 4,800 IU/m², 4,900 IU/m², 5,000 IU/m², 5,100 IU/m², 5,200 IU/m², 5,300 IU/m², 5,400 IU/m², 5,500 IU/m², 5,600 IU/m², 5,700 IU/m², 5,800 IU/m², 5,900 IU/m², 6,000 IU/m², 6,100 IU/m², 6,200 IU/m², 6,300 IU/m², 6,400 IU/m², 6,500 IU/m², 6,600 IU/m², 6,700 IU/m², 6,800 IU/m², 6,900 IU/m², 7,000 IU/m², 7,100 IU/m², 7,200 IU/m², 7,300 IU/m², 7,400 IU/m², 7,500 IU/m², 7,600 IU/m², 7,700 IU/m², 7,800 IU/m², 7,900 IU/m², or about 8,000 IU/m² administered about once every 3 days, about once a week, about twice a week, or about once every 2 weeks. In some embodiments, the dose may be about 1 mg/m², 2 mg/m², 3 mg/m², 4 mg/m², 5 mg/m², 6 mg/m², 7 mg/m², 8 mg/m², 9 mg/m², 10 mg/m², 15

mg/m², 20 mg/m², 25 mg/m², 30 mg/m², 35 mg/m², 40 mg/m², 45 mg/m², 50 mg/m², 55 mg/m², 60 mg/m², 65 mg/m², 70 mg/m², 75 mg/m², or about 80 mg/m² administered about once every 3 days, about once a week, about twice a week, or about once every 2 weeks. In certain embodiments, the dose may be modified as desired by the skilled clinician. In

5 some embodiments,

The optimum dosage with chimeric ADI-SS-PEG5,000 may be about twice a week, while the optimum dosage with chimeric ADI-SS-PEG20,000 may be from about once a week to about once every two weeks. In certain embodiments, the optimum dosage with chimeric ADI-SS-PEG20,000 may be about twice a week.

10 Chimeric ADI-PEG may be mixed with a phosphate buffered saline solution, or any other appropriate solution known to those skilled in the art, prior to injection. In one embodiment, a liquid composition comprising chimeric ADI-PEG comprises about 10 to about 12 mg of chimeric ADI, about 20 to about 40 mg of polyethylene glycol, 1.27 mg +5% monobasic sodium phosphate, USP; about 3 mg +5% dibasic sodium phosphate, USP; 7.6
15 mg +5% sodium chloride, USP; at a pH of about 6.6 to about 7; in an appropriate amount of water for injection (e.g., about 1 ml or about 2 ml). In one embodiment, a liquid composition comprising a chimeric ADI-PEG comprises histidine – HCl, and in certain embodiments, the composition buffer is from about 0.0035M Histidine-HCl to about 0.35M Histidine-HCl. In one particular embodiment, the composition is formulated in a buffer comprising 0.035 M
20 Histidine-HCl at pH 6.8 with 0.13 M sodium chloride. In another embodiment, the composition is formulated in a buffer comprising 0.02M sodium phosphate buffer at pH 6.8 with 0.13 M sodium chloride.

In one embodiment, a composition comprising chimeric ADI or chimeric ADI-PEG has a pH of about 5 to about 9, about 6 to about 8, or about 6.5 to about 7.5. In some
25 embodiments, the composition comprising chimeric ADI has a pH of about 6.8 ± 1.0.

In one embodiment, free PEG in a composition comprising chimeric ADI-PEG is between 1-10%, and in a further embodiment, is less than 7%, less than 6%, less than 5%, less than 4%, less than 3%, less than 2% or less than 1% of the total PEG. In certain
30 embodiments, the unmodified chimeric ADI in a composition comprising chimeric ADI-PEG is less than about 1%, 0.9%, 0.8%, 0.7%, 0.6%, 0.5%, 0.4%, 0.3%, 0.2% or less than 0.1%. Generally, compositions comprising chimeric ADI-PEG have total impurities less than or equal to about 4%, 3%, 2%, 1.5%, 1% or 0.5%. In one embodiment, the endotoxin limit meets the requirements stated in USP, i.e., ≤ 50 EU/mL.

In one embodiment, the free sulfhydryl in a composition comprising chimeric
35 ADI or chimeric ADI-PEG is greater than about 90%. In some embodiments, the free sulfhydryl in a composition comprising chimeric ADI or chimeric ADI-PEG is about 91%,

about 92%, about 93%, about 94% or about 95%, about 96% about 97%, about 98% about 99% or more.

In one embodiment, the chimeric ADI or chimeric ADI-PEG in a composition has a K_m of from about 0.5 μM to about 15 μM , and in a further embodiment, is from about 1 μM to about 12 μM , about 1 μM to about 10 μM , about 1.5 μM to about 9 μM , about 1.5 μM to about 8 μM or about 1.5 μM to about 7 μM . In certain embodiments, the chimeric ADI or chimeric ADI-PEG in a composition has a K_m of about 1.5 μM to about 6.5 μM . In some embodiments, the chimeric ADI or chimeric ADI-PEG in a composition has a K_m of about 1.5 μM , about 2 μM , about 2.5 μM , about 3 μM , about 3.5 μM , about 4 μM , about 4.5 μM , about 5 μM , about 5.5 μM , about 6 μM , about 6.5 μM , or about 7 μM . In one embodiment, the chimeric ADI or chimeric ADI-PEG in a composition has a reduced K_m compared to a wild-type ADI or wild-type ADI-PEG in the composition.

In one embodiment, the chimeric ADI or chimeric ADI-PEG in a composition has a K_{cat} of from about 0.5 sec^{-1} to about 15 sec^{-1} , and in a further embodiment, is from about 1 sec^{-1} to about 12 sec^{-1} , about 1 sec^{-1} to about 10 sec^{-1} , about 1.5 sec^{-1} to about 9 sec^{-1} , about 2 sec^{-1} to about 8 sec^{-1} or about 2.5 sec^{-1} to about 7 sec^{-1} . In certain embodiments, the chimeric ADI or chimeric ADI-PEG in a composition has a K_{cat} of about 2.5 sec^{-1} to about 7.5 sec^{-1} . In some embodiments, the chimeric ADI or chimeric ADI-PEG in a composition has a K_{cat} of about 2.5 sec^{-1} , about 3 sec^{-1} , about 3.5 sec^{-1} , about 4 sec^{-1} , about 4.5 sec^{-1} , about 5 sec^{-1} , about 5.5 sec^{-1} , about 6 sec^{-1} , about 6.5 sec^{-1} , about 7 sec^{-1} , about 7.5 sec^{-1} or about 8 sec^{-1} . In one embodiment, the chimeric ADI or chimeric ADI-PEG in a composition has a higher K_{cat} than a wild-type ADI or wild-type ADI-PEG in the composition.

In one embodiment, the chimeric ADI or chimeric ADI-PEG in a composition has a conductivity (also referred to in the art as specific conductance) of about 5 mS/cm to about 20 mS/cm , and in further embodiments, from about 5 mS/cm to about 15 mS/cm , about 7 mS/cm to about 15 mS/cm , about 9 mS/cm to about 15 mS/cm or about 10 mS/cm to about 15 mS/cm . In some embodiments, the chimeric ADI or chimeric ADI-PEG in a composition has a conductivity of about 9 mS/cm , about 10 mS/cm , about 11 mS/cm , about 12 mS/cm or about 13 mS/cm , about 14 mS/cm or about 15 mS/cm . In certain embodiments, the chimeric ADI or chimeric ADI-PEG in a composition has a conductivity of about 13 $\text{mS/cm} \pm 1.0 \text{ mS/cm}$.

In one embodiment, the chimeric ADI or chimeric ADI-PEG in a composition has an osmolality of about 50 mOsm/kg to about 500 mOsm/kg , about 100 mOsm/kg to about 400 mOsm/kg , about 150 mOsm/kg to about 350 mOsm/kg , about 200 mOsm/kg to about 350 mOsm/kg or about 250 mOsm/kg to about 350 mOsm/kg . In certain

embodiments, the chimeric ADI or chimeric ADI-PEG in a composition has an osmolality of about 300 ± 30 mOsm/kg.

In one embodiment, the protein concentration is about 11.0 ± 1.0 mg/mL. In certain embodiments, the protein concentration is between about 8 and about 15 mg/mL. In another embodiment, the protein concentration is about 8, 9, 10, 10.5, 11, 11.5, 12, 12.5, 13, 13.5, 14, or 15 mg/mL.

In one embodiment, the specific enzyme activity is between 5.0 and 150 IU/mg, where 1 IU is defined as the amount of enzyme that converts one μ mol of arginine into one μ mol of citrulline and 1 μ mol of ammonia in one minute at 37° C and the activity is 100 ± 20 IU/mg. In another embodiment, the specific enzyme activity is about 5.5, 6, 6.5, 7, 7.5, 8, 8.5, 9.0, 9.5, 10, 10.5, 11, 11.5, 12, 12.5, 13, 13.5, 14, 14.5, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100, 105, 110, 115, 120, 125, 130, 135, 140, 145, or about 150 ± 2.0 IU/mg. In one particular embodiment, the specific enzyme activity is 100 ± 10.0 IU/mg.

Compositions comprising chimeric ADI-PEG of the present disclosure may also be administered simultaneously with, prior to, or after administration of one or more other therapeutic agents. Such combination therapy may include administration of a single pharmaceutical dosage formulation which contains a compound of the invention and one or more additional active agents, as well as administration of compositions comprising chimeric ADI-PEG (e.g., chimeric ADI-PEG 20) of the invention and each active agent in its own separate pharmaceutical dosage formulation. For example, chimeric ADI-PEG as described herein and the other active agent can be administered to the patient together in a single oral dosage composition such as a tablet or capsule, or each agent administered in separate oral dosage formulations. Similarly, chimeric ADI-PEG as described herein and the other active agent can be administered to the patient together in a single parenteral dosage composition such as in a saline solution or other physiologically acceptable solution, or each agent administered in separate parenteral dosage formulations. Where separate dosage formulations are used, the compositions comprising chimeric ADI-PEG and one or more additional active agents can be administered at essentially the same time, *i.e.*, concurrently, or at separately staggered times, *i.e.*, sequentially and in any order; combination therapy is understood to include all these regimens.

Thus, in certain embodiments, also contemplated is the administration of the chimeric ADI compositions of this disclosure in combination with one or more other therapeutic agents. Such therapeutic agents may be accepted in the art as a standard treatment for a particular disease state as described herein, such as a particular cancer or GVHD. Exemplary therapeutic agents contemplated include cytokines, growth factors,

steroids, NSAIDs, DMARDs, anti-inflammatories, chemotherapeutics, radiotherapeutics, autophagy modulators, or other active and ancillary agents.

In certain embodiments, the chimeric ADI compositions disclosed herein may be administered in conjunction with any number of chemotherapeutic agents. Examples of chemotherapeutic agents include alkylating agents such as thiotepa and cyclophosphamide (CYTOXANTM); 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 trimethylolomelamine; 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, authramycin, azaserine, bleomycins, cactinomycin, calicheamicin, 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-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, 5-FU; androgens such as calusterone, dromostanolone propionate, epitioestanol, mepitioestane, testosterone; anti-adrenals such as aminoglutethimide, mitotane, trilostane; folic acid replenisher such as frolinic acid; aceglatone; aldophosphamide glycoside; aminolevulinic acid; amsacrine; bestrabucil; bisantrene; edatraxate; defofamine; demecolcine; diaziquone; elformithine; elliptinium acetate; etoglucid; gallium nitrate; hydroxyurea; lentinan; lonidamine; mitoguazone; mitoxantrone; mopidamol; nitracrine; pentostatin; phenamet; pirarubicin; podophyllinic acid; 2-ethylhydrazide; procarbazine; PSK.RTM.; razoxane; sizofiran; spirogermanium; tenuazonic acid; triaziquone; 2, 2',2"-trichlorotriethylamine; urethan; vindesine; dacarbazine; mannomustine; mitobronitol; mitolactol; pipobroman; gacytosine; arabinoside ("Ara-C"); cyclophosphamide; thiotepa; taxoids, e.g. paclitaxel (TAXOL®, Bristol-Myers Squibb Oncology, Princeton, N.J.) and docetaxel (TAXOTERE®, Rhne-Poulenc Rorer, Antony, France); chlorambucil; gemcitabine; 6-thioguanine; mercaptopurine; methotrexate; platinum analogs such as cisplatin and carboplatin; vinblastine; platinum;

etoposide (VP-16); ifosfamide; mitomycin C; mitoxantrone; vincristine; vinorelbine; navelbine; novantrone; teniposide; daunomycin; aminopterin; xeloda; ibandronate; CPT-11; topoisomerase inhibitor RFS 2000; difluoromethylomithine (DMFO); retinoic acid derivatives such as Targretin™ (bexarotene), Panretin™ (alitretinoin) ; ONTAK™ (denileukin diftitox) ;
5 esperamicins; capecitabine; and pharmaceutically acceptable salts, acids or derivatives of any of the above. Also included in this definition 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 anti-androgens such as flutamide,
10 nilutamide, bicalutamide, leuprolide, and goserelin. Further chemotherapeutic agents include sorafenib and other protein kinase inhibitors such as afatinib, axitinib, bevacizumab, cetuximab, crizotinib, dasatinib, erlotinib, fostamatinib, gefitinib, imatinib, lapatinib, lenvatinib, mubritinib, nilotinib, panitumumab, pazopanib, pegaptanib, ranibizumab, ruxolitinib, trastuzumab, vandetanib, vemurafenib, and sunitinib; sirolimus (rapamycin), everolimus and
15 other mTOR inhibitors. Pharmaceutically acceptable salts, acids or derivatives of any of the above are also contemplated for use herein.

In certain embodiments, the chimeric ADI compositions disclosed herein may be administered in conjunction with any number of autophagy inhibitors. In some preferred
embodiments, the autophagy inhibitor is selected from the group consisting of: chloroquine,
20 3-methyladenine, hydroxychloroquine (Plaquenil.TM.), bafilomycin A1, 5-amino-4-imidazole carboxamide riboside (AICAR), okadaic acid, autophagy-suppressive algal toxins which inhibit protein phosphatases of type 2A or type 1, analogues of cAMP, and drugs which elevate cAMP levels, adenosine, N6-mercaptopurine riboside, wortmannin, and vinblastine. In addition, antisense or siRNA that modulates expression of proteins essential for
25 autophagy, such as for example ATG5, may also be used.

In one embodiment, the combination of chimeric ADI-PEG with one or more therapeutic agents acts additively or synergistically. In this regard, synergizing agents are described herein, which include a therapeutic agent (e.g., chemotherapeutic agent, autophagy inhibitor, mTOR inhibitor, or any other therapeutic agent used for the treatment of
30 cancer, GVHD, or inflammatory bowel disease as described herein) that is capable of acting synergistically with chimeric ADI-PEG as provided herein, where such synergy manifests as a detectable effect that is greater (i.e., in a statistically significant manner relative to an appropriate control condition) in magnitude than the effect that can be detected when the chemotherapeutic agent is present but the ADI-PEG composition is absent, and/or when the
35 ADI-PEG is present but the chemotherapeutic agent is absent. Methods for measuring synergy are known in the art (see e.g., Cancer Res January 15, 2010 70; 440).

The compositions comprising chimeric ADI, and optionally other therapeutic agents, as described herein may be used in therapeutic methods for treating of cancer and methods for preventing metastasis of a cancer. Thus, the present invention provides for methods for treating, ameliorating the symptoms of, or inhibiting the progression of or prevention of a variety of different cancers. In another embodiment, the present disclosure provides methods for treating, ameliorating the symptoms of, or inhibiting the progression of GVHD. In particular the present disclosure provides methods for treating, ameliorating the symptoms of, or inhibiting the progression of a cancer or GVHD in a patient comprising administering to the patient a therapeutically effective amount of chimeric ADI composition as described herein, thereby treating, ameliorating the symptoms of, or inhibiting the progression of the cancer or GVHD. Thus, the chimeric ADI compositions described herein may be administered to an individual afflicted with inflammatory bowel disease (e.g., Crohn's disease; ulcerative colitis), GVHD or a cancer, including, but not limited to leukemia (e.g. acute myeloid leukemia and relapsed acute myeloid leukemia), melanoma, sarcomas (including, but not limited to, metastatic sarcomas, uterine leiomyosarcoma), pancreatic cancer, prostate cancer (such as, but not limited to, hormone refractory prostate cancer), mesothelioma, lymphatic leukemia, chronic myelogenous leukemia, lymphoma, small cell lung cancer, breast cancer, ovarian cancer, colorectal cancer, gastric cancer (including, but not limited to, gastric adenocarcinoma), glioma, glioblastoma multi-form, retinoblastoma, neuroblastoma, non-small cell lung cancer (NSCLC), kidney cancer (including but not limited to renal cell carcinoma), bladder cancer, uterine cancer, esophageal cancer, brain cancer, head and neck cancers (including, but not limited to, squamous cell carcinoma of the head and neck; cancer of the tongue), cervical cancer, testicular cancer, gallbladder, cholangiocarcinoma, and stomach cancer.

In one embodiment, the present disclosure provides a method of treating, ameliorating the symptoms of, or inhibiting the progression of myeloid leukemia, such as, but not limited to, acute myeloid leukemia (AML), by administering a therapeutically effective amount of a chimeric ADI-PEG 20. In certain embodiments, the myeloid leukemia, such as AML, is deficient in ASS, ASL, or both. In a further embodiment, the present disclosure provides a method of treating AML comprising administering chimeric ADI-PEG 20 about once every 3 days, about once a week, about twice a week, or about once every 2 weeks. In certain embodiments, the dose of chimeric ADI-PEG 20 administered for the treatment of AML is between about 50 IU/m² and about 8,000 IU/m², and in other embodiments is about 50 IU/m², about 100 IU/m², 150 IU/m², 200 IU/m², 250 IU/m², 300 IU/m², 350 IU/m², 400 IU/m², 450 IU/m², 500 IU/m², 550 IU/m², 600 IU/m², 650 IU/m², 700 IU/m², 750 IU/m², 800 IU/m², about 900 IU/m², about 1,000 IU/m², 1,500 IU/m² about 2,000 IU/m², about 2,500

IU/m², about 3,000 IU/m², 3,500 IU/m², 4,000 IU/m², 4,500 IU/m², 5,000 IU/m², 5,500 IU/m², 6,000 IU/m², 6,500 IU/m², 7,000 IU/m², 7,500 IU/m², or about 8,000 IU/m². In particular embodiments, the dose of chimeric ADI-PEG 20 administered for the treatment of AML is between about 1 mg/m² and about 80 mg/m² and in other embodiments is about 1 mg/m², 2 mg/m², 3 mg/m², 4 mg/m², 5 mg/m², 6 mg/m², 7 mg/m², 8 mg/m², 9 mg/m², 10 mg/m², 15 mg/m², 20 mg/m², 25 mg/m², 30 mg/m², 35 mg/m², 40 mg/m², 45 mg/m², 50 mg/m², 55 mg/m², 60 mg/m², 65 mg/m², 70 mg/m², 75 mg/m², or about 80 mg/m². In certain embodiments, the present disclosure provides a method of treating AML, wherein the dose of chimeric ADI is doubled and may be increased to 640 IU/m² per week or more. In one particular embodiment the chimeric ADI for the treatment of AML is modified with 3.5-6.5, or in one embodiment, 4.5 – 5.5 PEG molecules per chimeric ADI. In another embodiment, the present disclosure provides a method of treating AML by administering a composition comprising chimeric ADI-PEG 20 wherein the composition comprises a chimeric ADI modified with 5±1.5 PEG molecules, and in one embodiment, 5±1.5 straight chain PEG molecules, and, in certain embodiments, the composition comprises less than about 0.5% native chimeric ADI (*i.e.*, unmodified with PEG) and/or less than about 5% free PEG. In a further embodiment, the composition comprises a histidine – HCL buffer.

In one embodiment, the present disclosure provides a method of treating, ameliorating the symptoms of, or inhibiting the progression of sarcomas, including but not limited to metastatic sarcomas, by administering a therapeutically effective amount of a chimeric ADI-PEG 20. In certain embodiments, the sarcoma is deficient in ASS, ASL, or both. In a further embodiment, the present disclosure provides a method of treating a sarcoma comprising administering chimeric ADI-PEG 20 about once every 3 days, about once a week, about twice a week, or about once every 2 weeks. In certain embodiments, the dose of chimeric ADI-PEG 20 administered for the treatment of sarcomas is between about 50 IU/m² and about 8,000 IU/m², and in other embodiments is about 50 IU/m², about 100 IU/m², 150 IU/m², 200 IU/m², 250 IU/m², 300 IU/m², 350 IU/m², 400 IU/m², 450 IU/m², 500 IU/m², 550 IU/m², 600 IU/m², 650 IU/m², 700 IU/m², 750 IU/m², 800 IU/m², about 900 IU/m², about 1,000 IU/m², 1,500 IU/m² about 2,000 IU/m², about 2,500 IU/m², about 3,000 IU/m², 3,500 IU/m², 4,000 IU/m², 4,500 IU/m², 5,000 IU/m², 5,500 IU/m², 6,000 IU/m², 6,500 IU/m², 7,000 IU/m², 7,500 IU/m², or about 8,000 IU/m². In particular embodiments, the dose of chimeric ADI-PEG 20 administered for the treatment of sarcomas is between about 1 mg/m² and about 80 mg/m² and in other embodiments is about 1 mg/m², 2 mg/m², 3 mg/m², 4 mg/m², 5 mg/m², 6 mg/m², 7 mg/m², 8 mg/m², 9 mg/m², 10 mg/m², 15 mg/m², 20 mg/m², 25 mg/m², 30 mg/m², 35 mg/m², 40 mg/m², 45 mg/m², 50 mg/m², 55 mg/m², 60 mg/m², 65 mg/m², 70 mg/m², 75 mg/m², or about 80 mg/m². In certain embodiments, the

present disclosure provides a method of treating sarcoma, wherein the dose of chimeric ADI is doubled and may be increased to 640 IU/m² per week or more. In one particular embodiment the chimeric ADI for the treatment of AML is modified with 3.5-6.5, or in one embodiment, 4.5 – 5.5 PEG molecules per chimeric ADI. In another embodiment, the present disclosure provides a method of treating a sarcoma, including a metastatic sarcoma, by administering a composition comprising chimeric ADI-PEG 20 wherein the composition comprises an chimeric ADI modified with 5±1.5 PEG molecules, and in one embodiment, 5±1.5 straight chain PEG molecules, and, in certain embodiments, the composition comprises less than about 0.5% native chimeric ADI (i.e., unmodified with PEG) and/or less than about 5% free PEG. In a further embodiment, the composition comprises a histidine – HCL buffer.

In one embodiment, the present disclosure provides a method of treating, ameliorating the symptoms of, or inhibiting the progression of pancreatic cancer by administering a therapeutically effective amount of chimeric ADI-PEG 20, optionally in combination with an autophagy inhibitor, such as but not limited to chloroquine, 3-methyladenine, hydroxychloroquine, bafilomycin A1, 5-amino-4-imidazole carboxamide riboside (AICAR), okadaic acid, N6-mercaptopurine riboside, wortmannin, and vinblastine. In certain embodiments, the pancreatic cancer is deficient in ASS, ASL, or both. In a further embodiment, the present disclosure provides a method of treating pancreatic cancer comprising administering ADI-PEG 20 about once every 3 days, about once a week, about twice a week, or about once every 2 weeks; optionally in combination with a therapeutically effective amount of an autophagy inhibitor, such as chloroquine. In this regard, a therapeutically effective dose of chloroquine may be an initial dose of about 600 mg base followed by an additional 300 mg base and a single dose of 300 mg base on each of two consecutive days. This represents a total dose of 2.5 g chloroquine phosphate or 1.5 g base in three days. In further embodiments, the dose may be about 300 mg base. The dose of chloroquine, or other autophagy inhibitor, may be modified as needed by a skilled clinician using dosages known in the art. As would be understood by the skilled person, the autophagy inhibitor may be administered before, at the same time as or after a composition comprising ADI-PEG 20. In certain embodiments, the dose of ADI-PEG 20 administered for the treatment of pancreatic cancer is between about 50 IU/m² and about 8,000 IU/m², and in other embodiments is about 50 IU/m², about 100 IU/m², 150 IU/m², 200 IU/m², 250 IU/m², 300 IU/m², 350 IU/m², 400 IU/m², 450 IU/m², 500 IU/m², 550 IU/m², 600 IU/m², 650 IU/m², 700 IU/m², 750 IU/m², 800 IU/m², about 900 IU/m², about 1,000 IU/m², 1,500 IU/m² about 2,000 IU/m², about 2,500 IU/m², about 3,000 IU/m², 3,500 IU/m², 4,000 IU/m², 4,500 IU/m², 5,000 IU/m², 5,500 IU/m², 6,000 IU/m², 6,500 IU/m², 7,000 IU/m², 7,500 IU/m², or about

8,000 IU/m². In particular embodiments, the dose of ADI-PEG 20 administered for the treatment of pancreatic cancer is between about 1 mg/m² and about 80 mg/m² and in other embodiments is about 1 mg/m², 2 mg/m², 3 mg/m², 4 mg/m², 5 mg/m², 6 mg/m², 7 mg/m², 8 mg/m², 9 mg/m², 10 mg/m², 15 mg/m², 20 mg/m², 25 mg/m², 30 mg/m², 35 mg/m², 40 mg/m², 45 mg/m², 50 mg/m², 55 mg/m², 60 mg/m², 65 mg/m², 70 mg/m², 75 mg/m², or about 80 mg/m². In certain embodiments, the present disclosure provides a method of treating pancreatic cancer, wherein the dose of chimeric ADI is doubled and may be increased to 640 IU/m² per week or more. In one particular embodiment the chimeric ADI for the treatment of pancreatic cancer is modified with 3.5-6.5, or in one embodiment, 4.5 – 5.5 PEG molecules per chimeric ADI. In another embodiment, the present disclosure provides a method of treating pancreatic cancer by administering a composition comprising chimeric ADI-PEG 20, optionally in combination with chloroquine, or other appropriate autophagy inhibitor, wherein the composition comprises a chimeric ADI modified with 5±1.5 PEG molecules, and in one embodiment, 5±1.5 straight chain PEG molecules, and, in certain embodiments, the composition comprises less than about 0.5% native chimeric ADI (*i.e.*, not modified with PEG) and/or less than about 5% free PEG. In a further embodiment, the composition comprises a histidine – HCL buffer.

In one embodiment, the present disclosure provides a method of treating, ameliorating the symptoms of, or inhibiting the progression of small cell lung cancer by administering a therapeutically effective amount of ADI-PEG 20, optionally in combination with an autophagy inhibitor. In certain embodiments, the small cell lung cancer is deficient in ASS, ASL, or both. In a further embodiment, the present disclosure provides a method of treating small cell lung cancer comprising administering chimeric ADI-PEG 20 about once every 3 days, about once a week, about twice a week, or about once every 2 weeks; optionally in combination with a therapeutically effective amount of an autophagy inhibitor, such as chloroquine. In this regard, a therapeutically effective dose of chloroquine may be an initial dose of about 600 mg base followed by an additional 300 mg base and a single dose of 300 mg base on each of two consecutive days. This represents a total dose of 2.5 g chloroquine phosphate or 1.5 g base in three days. In further embodiments, the dose may be about 300 mg base. The dose of chloroquine may be modified as needed by a skilled clinician using dosages known in the art. As would be understood by the skilled person, the autophagy inhibitor may be administered before, at the same time as or after a composition comprising chimeric ADI-PEG 20. In certain embodiments, the dose of chimeric ADI-PEG 20 administered for the treatment of small cell lung cancer is between about 50 IU/m² and about 8,000 IU/m², and in other embodiments is about 50 IU/m², about 100 IU/m², 150 IU/m², 200 IU/m², 250 IU/m², 300 IU/m², 350 IU/m², 400 IU/m², 450 IU/m², 500 IU/m², 550

IU/m², 600 IU/m², 650 IU/m², 700 IU/m², 750 IU/m², 800 IU/m², about 900 IU/m², about 1,000 IU/m², 1,500 IU/m² about 2,000 IU/m², about 2,500 IU/m², about 3,000 IU/m², 3,500 IU/m², 4,000 IU/m², 4,500 IU/m², 5,000 IU/m², 5,500 IU/m², 6,000 IU/m², 6,500 IU/m², 7,000 IU/m², 7,500 IU/m², or about 8,000 IU/m². In particular embodiments, the dose of chimeric ADI-

5 PEG 20 administered for the treatment of small cell lung cancer is between about 1 mg/m² and about 80 mg/m² and in other embodiments is about 1 mg/m² and about 80 mg/m² and in other embodiments is about 1 mg/m², 2 mg/m², 3 mg/m², 4 mg/m², 5 mg/m², 6 mg/m², 7 mg/m², 8 mg/m², 9 mg/m², 10 mg/m², 15 mg/m², 20 mg/m², 25 mg/m², 30 mg/m², 35 mg/m², 40 mg/m², 45 mg/m², 50 mg/m², 55 mg/m², 60 mg/m², 65 mg/m², 70 mg/m², 75 mg/m², or
10 about 80 mg/m². In certain embodiments, the present disclosure provides a method of treating small cell lung cancer, wherein the dose of chimeric ADI is doubled and may be increased to 640 IU/m² per week or more. In one particular embodiment the chimeric ADI for the treatment of small cell lung cancer is modified with 3.5-6.5, or in one embodiment, 4.5 – 5.5 PEG molecules per chimeric ADI. In another embodiment, the present disclosure
15 provides a method of treating small cell lung cancer by administering a composition comprising chimeric ADI – PEG 20 optionally in combination with chloroquine, wherein the composition comprises an chimeric ADI modified with 5±1.5 PEG molecules, and in one embodiment, 5±1.5 straight chain PEG molecules, and, in certain embodiments, the composition comprises less than about 0.5% native chimeric ADI (*i.e.*, not modified with
20 PEG) and/or less than about 5% free PEG. In a further embodiment, the composition comprises a histidine – HCL buffer.

In one embodiment, the present disclosure provides a method of treating, ameliorating the symptoms of, or inhibiting the progression of sarcomas (including but not limited to, metastatic sarcomas) by administering a therapeutically effective amount of
25 chimeric ADI-PEG 20, optionally in combination with an autophagy inhibitor. In certain embodiments, the sarcoma is deficient in ASS, ASL, or both. In a further embodiment, the present disclosure provides a method of treating sarcoma comprising administering chimeric ADI-PEG 20 about once every 3 days, about once a week, about twice a week, or about once every 2 weeks; optionally in combination with a therapeutically effective amount of an
30 autophagy inhibitor, such as chloroquine. In this regard, a therapeutically effective dose of chloroquine may be an initial dose of about 600 mg base followed by an additional 300 mg base and a single dose of 300 mg base on each of two consecutive days. This represents a total dose of 2.5 g chloroquine phosphate or 1.5 g base in three days. In further
35 embodiments, the dose may be about 300 mg base. The dose of chloroquine may be modified as needed by a skilled clinician using dosages known in the art. As would be understood by the skilled person, the autophagy inhibitor may be administered before, at the

same time as or after a composition comprising ADI-PEG 20. In certain embodiments, the dose of ADI-PEG 20 administered for the treatment of sarcoma is between about 50 IU/m² and about 8,000 IU/m², and in other embodiments is about 50 IU/m², about 100 IU/m², 150 IU/m², 200 IU/m², 250 IU/m², 300 IU/m², 350 IU/m², 400 IU/m², 450 IU/m², 500 IU/m², 550 IU/m², 600 IU/m², 650 IU/m², 700 IU/m², 750 IU/m², 800 IU/m², about 900 IU/m², about 1,000 IU/m², 1,500 IU/m², about 2,000 IU/m², about 2,500 IU/m², about 3,000 IU/m², 3,500 IU/m², 4,000 IU/m², 4,500 IU/m², 5,000 IU/m², 5,500 IU/m², 6,000 IU/m², 6,500 IU/m², 7,000 IU/m², 7,500 IU/m², or about 8,000 IU/m². In certain embodiments, the dose of ADI-PEG 20 administered for the treatment of sarcoma is between about 1 mg/m² and about 80 mg/m² and in other embodiments is about 1 mg/m², 2 mg/m², 3 mg/m², 4 mg/m², 5 mg/m², 6 mg/m², 7 mg/m², 8 mg/m², 9 mg/m², 10 mg/m², 15 mg/m², 20 mg/m², 25 mg/m², 30 mg/m², 35 mg/m², 40 mg/m², 45 mg/m², 50 mg/m², 55 mg/m², 60 mg/m², 65 mg/m², 70 mg/m², 75 mg/m², or about 80 mg/m². In certain embodiments, the present disclosure provides a method of treating sarcoma, wherein the dose of chimeric ADI is doubled and may be increased to 640 IU/m² per week or more. In one particular embodiment the chimeric ADI for the treatment of sarcoma is modified with 3.5-6.5, or in one embodiment, 4.5 – 5.5 PEG molecules per chimeric ADI. In another embodiment, the present disclosure provides a method of treating sarcoma by administering a composition comprising chimeric ADI-PEG 20, optionally in combination with chloroquine, wherein the composition comprises a chimeric ADI modified with 5±1.5 PEG molecules, and in one embodiment, 5±1.5 straight chain PEG molecules, and, in certain embodiments, the composition comprises less than about 0.5% native chimeric ADI (*i.e.*, not modified with PEG) and/or less than about 5% free PEG. In a further embodiment, the composition comprises a histidine – HCL buffer.

In one embodiment, the present disclosure provides a method of treating, ameliorating the symptoms of, or inhibiting the progression of melanoma by administering a therapeutically effective amount of chimeric ADI-PEG 20, optionally in combination with docetaxel. In certain embodiments, the melanoma is deficient in ASS, ASL, or both. In a further embodiment, the present disclosure provides a method of treating melanoma comprising administering chimeric ADI-PEG 20 about once every 3 days, about once a week, about twice a week, or about once every 2 weeks; optionally in combination with a therapeutically effective amount of docetaxel. In this regard, a therapeutically effective dose of docetaxel may comprise 75mg/m² or 100 mg/m² administered intravenously over between 30 minutes and 1 hour about every 3 weeks. As would be understood by the skilled clinician, the dose of docetaxel may be modified depending on disease indication and/or prior treatments, and docetaxel may be administered before, at the same time as or after a composition comprising chimeric ADI-PEG 20. In certain embodiments, the dose of chimeric

ADI-PEG 20 administered for the treatment of melanoma is between about 50 IU/m² and about 8,000 IU/m², and in other embodiments is about 50 IU/m², about 100 IU/m², 150 IU/m², 200 IU/m², 250 IU/m², 300 IU/m², 350 IU/m², 400 IU/m², 450 IU/m², 500 IU/m², 550 IU/m², 600 IU/m², 650 IU/m², 700 IU/m², 750 IU/m², 800 IU/m², about 900 IU/m², about 1,000 IU/m², 1,500 IU/m² about 2,000 IU/m², about 2,500 IU/m², about 3,000 IU/m², 3,500 IU/m², 4,000 IU/m², 4,500 IU/m², 5,000 IU/m², 5,500 IU/m², 6,000 IU/m², 6,500 IU/m², 7,000 IU/m², 7,500 IU/m², or about 8,000 IU/m². the dose of chimeric ADI-PEG 20 administered for the treatment of melanoma is between about 1 mg/m² and about 80 mg/m² and in other embodiments is about 1 mg/m², 2 mg/m², 3 mg/m², 4 mg/m², 5 mg/m², 6 mg/m², 7 mg/m², 8 mg/m², 9 mg/m², 10 mg/m², 15 mg/m², 20 mg/m², 25 mg/m², 30 mg/m², 35 mg/m², 40 mg/m², 45 mg/m², 50 mg/m², 55 mg/m², 60 mg/m², 65 mg/m², 70 mg/m², 75 mg/m², or about 80 mg/m². In certain embodiments, the present disclosure provides a method of treating melanoma, wherein the dose of chimeric ADI is doubled and may be increased to 640 IU/m² per week or more. In one particular embodiment the chimeric ADI for the treatment of melanoma is modified with 3.5-6.5, or in one embodiment, 4.5 – 5.5, PEG molecules per chimeric ADI. In another embodiment, the present disclosure provides a method of treating melanoma by a composition comprising chimeric ADI-PEG 20, optionally in combination with docetaxel, wherein the composition comprises an chimeric ADI modified with 5±1.5 PEG molecules, and in one embodiment, 5±1.5 straight chain PEG molecules, and, in certain embodiments, the composition comprises less than about 0.5% native chimeric ADI (*i.e.*, not modified with PEG) and/or less than about 5% free PEG. In a further embodiment, the composition comprises a histidine – HCL buffer.

In one embodiment, the present disclosure provides a method of treating, ameliorating the symptoms of, or inhibiting the progression of melanoma by administering a therapeutically effective amount of chimeric ADI-PEG 20, optionally in combination with cisplatin. In certain embodiments, the melanoma is deficient in ASS, ASL, or both. In a further embodiment, the present disclosure provides a method of treating melanoma comprising administering chimeric ADI-PEG 20 about once every 3 days, about once a week, about twice a week, or about once every 2 weeks; optionally in combination with a therapeutically effective amount of cisplatin. In this regard, a therapeutically effective dose of cisplatin may comprise administration either once per cycle (every 3-4 weeks) at 50-100 mg/m², or daily for 5 days for a total of 100 mg/m² per cycle. As would be understood by the skilled clinician, the dose of cisplatin may be modified depending on disease indication, individual patient, and/or prior treatments, and cisplatin may be administered before, at the same time as or after a composition comprising chimeric ADI-PEG 20. In certain embodiments, the dose of chimeric ADI-PEG 20 administered for the treatment of melanoma

is between about 50 IU/m² and about 8,000 IU/m², and in other embodiments is about 50 IU/m², about 100 IU/m², 150 IU/m², 200 IU/m², 250 IU/m², 300 IU/m², 350 IU/m², 400 IU/m², 450 IU/m², 500 IU/m², 550 IU/m², 600 IU/m², 650 IU/m², 700 IU/m², 750 IU/m², 800 IU/m², about 900 IU/m², about 1,000 IU/m², 1,500 IU/m² about 2,000 IU/m², about 2,500 IU/m², about 3,000 IU/m², 3,500 IU/m², 4,000 IU/m², 4,500 IU/m², 5,000 IU/m², 5,500 IU/m², 6,000 IU/m², 6,500 IU/m², 7,000 IU/m², 7,500 IU/m², or about 8,000 IU/m². In certain embodiments, the dose of chimeric ADI-PEG 20 administered for the treatment of melanoma is between about 1 mg/m² and about 80 mg/m² and in other embodiments is about 1 mg/m², 2 mg/m², 3 mg/m², 4 mg/m², 5 mg/m², 6 mg/m², 7 mg/m², 8 mg/m², 9 mg/m², 10 mg/m², 15 mg/m², 20 mg/m², 25 mg/m², 30 mg/m², 35 mg/m², 40 mg/m², 45 mg/m², 50 mg/m², 55 mg/m², 60 mg/m², 65 mg/m², 70 mg/m², 75 mg/m², or about 80 mg/m². In certain embodiments, the present disclosure provides a method of treating melanoma, wherein the dose of chimeric ADI is doubled and may be increased to 640 IU/m² per week or more. In one particular embodiment the chimeric ADI for the treatment of melanoma is modified with 3.5-6.5, or in one embodiment, 4.5 – 5.5, PEG molecules per chimeric ADI. In another embodiment, the present disclosure provides a method of treating melanoma by administering a composition comprising chimeric ADI-PEG 20, optionally in combination with cisplatin, wherein the composition comprises a chimeric ADI modified with 5±1.5 PEG molecules, and in one embodiment, 5±1.5 straight chain PEG molecules, and, in certain embodiments, the composition comprises less than about 0.5% native chimeric ADI (*i.e.*, not modified with PEG) and/or less than about 5% free PEG. In a further embodiment, the composition comprises a histidine – HCL buffer.

In one embodiment, the present disclosure provides a method of treating, ameliorating the symptoms of, or inhibiting the progression of renal cell carcinoma by administering a therapeutically effective amount of chimeric ADI-PEG 20, optionally in combination with an mTOR inhibitor, such as but not limited to rapamycin, temsirolimus, everolimus, and ridaforolimus. In certain embodiments, the renal cell carcinoma is deficient in ASS, ASL, or both. In a further embodiment, the present disclosure provides a method of treating renal cell carcinoma comprising administering chimeric ADI-PEG 20 about once every 3 days, about once a week, about twice a week, or about once every 2 weeks; optionally in combination with a therapeutically effective amount of an mTOR inhibitor, such as rapamycin. The dose of rapamycin, or other mTOR inhibitor, may be determined as needed by a skilled clinician using dosages known in the art. As would be understood by the skilled person, the mTOR inhibitor may be administered before, at the same time as or after a composition comprising chimeric ADI-PEG 20. In certain embodiments, the dose of chimeric ADI-PEG 20 administered for the treatment of renal cell carcinoma is between

about 50 IU/m² and about 8,000 IU/m², and in other embodiments is about 50 IU/m², about 100 IU/m², 150 IU/m², 200 IU/m², 250 IU/m², 300 IU/m², 350 IU/m², 400 IU/m², 450 IU/m², 500 IU/m², 550 IU/m², 600 IU/m², 650 IU/m², 700 IU/m², 750 IU/m², 800 IU/m², about 900 IU/m², about 1,000 IU/m², 1,500 IU/m² about 2,000 IU/m², about 2,500 IU/m², about 3,000 IU/m², 3,500 IU/m², 4,000 IU/m², 4,500 IU/m², 5,000 IU/m², 5,500 IU/m², 6,000 IU/m², 6,500 IU/m², 7,000 IU/m², 7,500 IU/m², or about 8,000 IU/m². In certain embodiments, the dose of chimeric ADI-PEG 20 administered for the treatment of melanoma is between about 1 mg/m², 2 mg/m², 3 mg/m², 4 mg/m², 5 mg/m², 6 mg/m², 7 mg/m², 8 mg/m², 9 mg/m², 10 mg/m², 15 mg/m², 20 mg/m², 25 mg/m², 30 mg/m², 35 mg/m², 40 mg/m², 45 mg/m², 50 mg/m², 55 mg/m², 60 mg/m², 65 mg/m², 70 mg/m², 75 mg/m², or about 80 mg/m². In certain embodiments, the present disclosure provides a method of treating renal cell carcinoma, wherein the dose of chimeric ADI is doubled and may be increased to 640 IU/m² per week or more. In one particular embodiment the chimeric ADI for the treatment of renal cell carcinoma is modified with 3.5-6.5, or in one embodiment, 4.5 – 5.5 PEG molecules per chimeric ADI. In another embodiment, the present disclosure provides a method of treating renal cell carcinoma by administering a composition comprising chimeric ADI-PEG 20, optionally in combination with rapamycin, or other appropriate mTOR inhibitor, wherein the composition comprises a chimeric ADI modified with 5±1.5 PEG molecules, and in one embodiment, 5±1.5 straight chain PEG molecules, and, in certain embodiments, the composition comprises less than about 0.5% native chimeric ADI (*i.e.*, not modified with PEG) and/or less than about 5% free PEG. In a further embodiment, the composition comprises a histidine – HCL buffer.

The present disclosure also provides methods of treating, ameliorating the symptoms of, or inhibiting the progression of an inflammatory disorder in a patient comprising administering to the patient a composition comprising chimeric ADI (e.g., chimeric ADI-PEG, in particular chimeric ADI-PEG 20), as described herein, alone or in combination with one or more other therapeutic agents. In one embodiment, the present disclosure also provides methods of treating, ameliorating the symptoms of, or inhibiting the progression of an inflammatory bowel disease in a patient comprising administering to the patient a composition comprising chimeric ADI (e.g., chimeric ADI-PEG, in particular chimeric ADI-PEG 20), as described herein, alone or in combination with one or more other therapeutic agents. In this regard, the present disclosure provides methods of treating, ameliorating the symptoms of, or inhibiting the progression of Crohn's disease or ulcerative colitis in a patient comprising administering to the patient a composition comprising chimeric ADI (e.g., chimeric ADI-PEG, in particular chimeric ADI-PEG 20), as described herein, alone or in combination with one or more other therapeutic agents.

In another embodiment, the present disclosure provides a method of treating, ameliorating the symptoms of, or inhibiting the progression of a cancer in a patient comprising administering to the patient a composition comprising chimeric ADI, and optionally one or more other therapeutic agents, as described herein, wherein the cancer is deficient in ASS, ASL, or both. In this regard, ASS or ASL deficiency may be a reduction in expression as measured by mRNA expression or protein expression, or may be a reduction in protein activity, and generally comprises a statistically significant reduction in expression or activity as determined by the skilled person. Reduced ASS or ASL expression or activity may be a reduction in expression or activity of about 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45%, 50%, 55%, 60%, 65%, 70%, or more, as compared to expression or activity in an appropriate control sample known to be cancer free. In certain embodiments, ASS or ASL expression or activity is reduced by at least twofold as compared to expression or activity in a non-cancer control sample.

In certain embodiments, the reduced expression or activity of ASS or ASL results from methylation of the ASS or ASL promoter. In another embodiment the reduction in expression or activity of ASS or ASL results from a DNA mutation (e.g., one or more point mutations, small deletions, insertions, and the like) or a chromosomal abnormality resulting in deletion of the gene. In one embodiment, the cancer is ASS or ASL negative, meaning no expression or activity is observed.

Reduction in ASS or ASL expression or activity may be measured using any methods known in the art, such as but not limited to, quantitative PCR, immunohistochemistry, enzyme activity assays (e.g., assay to measure conversion of citrulline into argininosuccinate or conversion of argininosuccinate into arginine and fumarate), and the like.

Thus, the present invention provides methods for treating, ameliorating the symptoms of, or inhibiting the progression of a cancer in a patient comprising administering to the patient a composition comprising chimeric ADI as described herein, wherein the cancer exhibits reduced expression or activity of ASS or ASL, or both, wherein the cancer includes, but is not limited to leukemia (e.g. acute myeloid leukemia and relapsed acute myeloid leukemia), melanoma, sarcomas (including, but not limited to, metastatic sarcomas, uterine leiomyosarcoma), pancreatic cancer, prostate cancer (such as, but not limited to, hormone refractory prostate cancer), mesothelioma, lymphatic leukemia, chronic myelogenous leukemia, lymphoma, small cell lung cancer, breast cancer, ovarian cancer, colorectal cancer, gastric cancer (including, but not limited to, gastric adenocarcinoma), glioma, glioblastoma multi-form, retinoblastoma, neuroblastoma, non-small cell lung cancer (NSCLC), kidney cancer (including but not limited to renal cell carcinoma), bladder cancer,

uterine cancer, esophageal cancer, brain cancer, head and neck cancers (including, but not limited to, squamous cell carcinoma of the head and neck; cancer of the tongue), cervical cancer, testicular cancer, gallbladder, cholangiocarcinoma, and stomach cancer.

Various studies in the literature have shown that ASS is deficient in the

5 following tumors:

Table 1: ASS-Deficient Tumors	
Tumor Type	ASS Deficiency (%)
Prostate	88/88 (100%)
Renal	98/98 (100%) 41/45 (91%) 31/31 (100%)
Lymphoma	511/532 (96%)
Sarcoma	619/701 (88%)
Pancreatic	41/47 (87%)
Acute Myelogenous Leukemia	46/53 (87%)
Small Cell Lung	7/16 (44%)
HCC	33/44 (75%) 20/20 (100%)
Melanoma	119/119 (100%) 24/29 (83%) 17/27 (63%) 20/20 (100%)
Bladder	31/48 (65%) 133/242 (55%)
Mesothelioma	52/82 (63%)
Gastric	68/121 (56%)
Breast	46/111 (41%)
Non-Small Cell Lung	28/90 (31%)
Glioblastoma	39/55 (71%)
Colorectal	31 (3%)
Ovarian	23/54 (43%) at diagnosis 25/34 (74%) at relapse

Accordingly, treatment of these ASS-deficient cancers is specifically contemplated herein, with chimeric ADI-PEG alone or in combination with other treatments.

10 The present invention further provides methods for treating, ameliorating the symptoms of, or inhibiting the progression of cancer in a patient comprising administering to the patient a composition comprising chimeric ADI as described herein (e.g., chimeric ADI-PEG and in particular chimeric ADI-PEG 20), in combination with an autophagy inhibitor. In one embodiment, the present invention provides methods for treating cancer in a patient
15 comprising administering to the patient a therapeutically effective amount of a composition comprising chimeric ADI as described herein in combination with autophagy inhibitor wherein the cancer is pancreatic cancer or small cell lung cancer.

In certain embodiments, the present invention provides methods of treatment where administration of the compositions comprising chimeric ADI described herein depletes arginine in the plasma for at least one month, 2 months, 3 months, 4 months, 5 months, 6 months or longer.

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EXAMPLES

EXAMPLE 1

CHIMERIC ADI ENZYMES ARE ACTIVE AND LESS CROSS-REACTIVE WITH PATIENT ANTI-ADI-PEG
20 ANTIBODIES

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This Example describes the generation of artificially engineered chimeric ADI enzymes composed of (1) protein with arginine deiminase enzymatic activity, (2) reduced cross reactivity with anti-ADI-PEG 20 antibodies, (3) reduced number of lysine residues, and/or (4) PEG conjugation with chemically stable linkers.

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ADI Preparation. Recombinant chimeric ADI enzymes were cloned, expressed, and purified for testing according to standard protocols, as described, for example, in Gallego et al., PLOS One, 7(10):e47886, 2012; Monstadt and Holldorf, Biochem. J. 273:739-745, 1990; Joo Noh et al., Molecules and Cells. 13:137-143, 2002; and Sugimura et al., Infection and Immunity. 58:2510-2515, 1990. See Table A1 for the amino acid sequences of the chimeric ADI enzymes.

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Human Anti-ADI-PEG20 Antibody Purification. Anti-ADI-PEG20 antibody was purified from plasma samples of patients who had received ADI-PEG20 during a clinical study. A total of 60 ml of plasma was pooled from 8 different patients that had reached high titer (titer ≥ 4) against ADI-PEG20 as determined by an ELISA assay. A two-step purification was used, a Protein "A" chromatography (GE Healthcare) followed by an ADI affinity chromatography. ~20 mg of purified antibody was obtained and stored at -80°C in aliquots until needed.

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ADI Enzyme Assays. Arginine deiminase (ADI) catalyzes the conversion of L-arginine to L-citrulline and ammonia. The amount of L-citrulline can be detected by a colorimetric endpoint assay (see, for example, Knipp and Vasak, Analytical Biochem. 286:257-264, 2000) and compared to a standard curve of known amounts of L-citrulline in order to calculate the specific activity of ADI expressed as IU/mg of protein. One IU of enzyme activity is defined as the amount of enzyme that produces 1 μ mol of citrulline per minute at the pH and temperature being tested. Standard assay conditions were performed at 37°C in Physiological HEPES Buffer (PHB) 50 mM HEPES, 160 mM NaCl pH 7.4 (Lang

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and Zander, Clin Chem Lab Med. 37:563-571, 1999) plus 0.1% BSA. All samples and standards were run in duplicate or triplicate where conditions permitted.

K_m and K_{cat} values were determined by using a variation of the activity assay described above. As with the activity assay, all reactions were run at 37°C in PHB plus 0.1% BSA. Enzyme concentration, reaction time, and substrate concentration range were adjusted for each of the ADI or ADIr constructs to account for their differences in activity. In general, 2 nM enzyme, 5 minute reaction time, and a 0 – 160 μM arginine was used as starting conditions. When optimizing the conditions, particular attention was paid towards the amount of substrate consumed as a percentage of total substrate added to the reaction. The lower limit of detection is 1 μM of citrulline with the lower limit of quantitation being 2 μM. A citrulline standard curve was run on every plate and used to quantify the citrulline produced by the enzymatic reaction.

Calculations. The citrulline concentration (μM) produced in each reaction well was calculated and averaged using the citrulline standard curve. The velocity of each reaction was then calculated in μM/min/50 nM ADI. Specific activity (IU/mg or μmoles product/min/mg ADI) was calculated by multiplying this value by the "IU" factor (IU factor was calculated from the molecular weight of the ADI and the reaction volume).

Arginine deiminase enzymatic activity. The results of the ADI enzyme assays are shown in Table E1.

Table E1. Chimeric ADI Enzymes.				
Name	SEQ ID NO:	Catalytic Domain	α-Helical Domain	Specific Activity
<i>M. hominis</i>	1	<i>M. hominis</i>	<i>M. hominis</i>	+++
DS1	4	<i>M. arginini</i> (1-74, 153-410)	<i>M. arthritidis</i> (75-152)	+++
DS2	5	<i>M. arginini</i> (1-74, 153-410)	<i>M. hominis</i> (75-151)	+++
DS3	6	<i>M. arthritidis</i> (1-74, 153-410)	<i>M. arginini</i> (75-152)	+++
DS4	7	<i>M. arthritidis</i> (1-74, 153-410)	<i>M. hominis</i> (75-151)	+++
C2DS1	22	<i>M. arginini</i> (1-74, 153-410)	<i>M. alligatoris</i> (71-148)	+
C2DS3	23	<i>M. arginini</i> (1-74, 153-410)	<i>M. arthritidis</i> (75-152)	+++
C2DS4	24	<i>M. arginini</i> (1-74, 153-410)	<i>M. columbinum</i> (68-147)	+++
C2DS5	25	<i>M. arginini</i> (1-74, 153-410)	<i>M. gateae</i> (75-152)	+++
C2DS6	26	<i>M. arginini</i> (1-74, 153-410)	<i>M. phocicerebrale</i> (75-152)	+++
C2DS7	27	<i>M. arginini</i> (1-74, 153-410)	<i>M. phocidae</i> (75-152)	+++
C4DS1	28	<i>M. columbinum</i> (1-67, 148-401)	<i>M. alligatoris</i> (71-148)	n.d.
C4DS2	29	<i>M. columbinum</i> (1-67, 148-401)	<i>M. arginini</i> (75-152)	n.d.

Table E1. Chimeric ADI Enzymes.				
Name	SEQ ID NO:	Catalytic Domain	α -Helical Domain	Specific Activity
C4DS3	30	<i>M. columbinum</i> (1-67, 148-401)	<i>M. arthritidis</i> (75-152)	+++
C4DS5	31	<i>M. columbinum</i> (1-67, 148-401)	<i>M. gateae</i> (75-152)	+++
C4DS6	32	<i>M. columbinum</i> (1-67, 148-401)	<i>M. phocicerebrale</i> (75-152)	++
C4DS7	33	<i>M. columbinum</i> (1-67, 148-401)	<i>M. phocidae</i> (75-152)	n.d.
C4DS8	34	<i>M. columbinum</i> (1-67, 148-401)	<i>M. gallinarum</i> (68-147)	++++
C4DS9	35	<i>M. columbinum</i> (1-67, 148-401)	<i>M. iners</i> (68-147)	+++++
C5DS1	36	<i>M. gateae</i> (1-74, 153-410)	<i>M. alligatoris</i> (71-148)	+++
C5DS2	37	<i>M. gateae</i> (1-74, 153-410)	<i>M. arginini</i> (75-152)	++++
C5DS3	38	<i>M. gateae</i> (1-74, 153-410)	<i>M. arthritidis</i> (75-152)	+++
C5DS4	39	<i>M. gateae</i> (1-74, 153-410)	<i>M. columbinum</i> (68-147)	+++
C5DS6	40	<i>M. gateae</i> (1-74, 153-410)	<i>M. phocicerebrale</i> (75-152)	+++
C5DS7	41	<i>M. gateae</i> (1-74, 153-410)	<i>M. phocidae</i> (75-152)	+++
C6DS1	42	<i>M. phocicerebrale</i> (1-74, 153-410)	<i>M. alligatoris</i> (71-148)	n.d.
C6DS2	43	<i>M. phocicerebrale</i> (1-74, 153-410)	<i>M. arginini</i> (75-152)	++++
C6DS3	44	<i>M. phocicerebrale</i> (1-74, 153-410)	<i>M. arthritidis</i> (75-152)	+
C6DS4	45	<i>M. phocicerebrale</i> (1-74, 153-410)	<i>M. columbinum</i> (68-147)	n.d.
C6DS5	46	<i>M. phocicerebrale</i> (1-74, 153-410)	<i>M. gateae</i> (75-152)	+++
C6DS7	47	<i>M. phocicerebrale</i> (1-74, 153-410)	<i>M. phocidae</i> (75-152)	+++
C7DS1	48	<i>M. phocidae</i> (1-74, 153-410)	<i>M. alligatoris</i> (71-148)	n.d.
C7DS2	49	<i>M. phocidae</i> (1-74, 153-410)	<i>M. arginini</i> (75-152)	++++
C7DS3	50	<i>M. phocidae</i> (1-74, 153-410)	<i>M. arthritidis</i> (75-152)	+++
C7DS4	51	<i>M. phocidae</i> (1-74, 153-410)	<i>M. columbinum</i> (68-147)	+++
C7DS5	52	<i>M. phocidae</i> (1-74, 153-410)	<i>M. gateae</i> (75-152)	+++
C7DS6	53	<i>M. phocidae</i> (1-74, 153-410)	<i>M. phocicerebrale</i> (75-152)	++++
C8DS3	54	<i>M. gallinarum</i> (1-67, 148-401)	<i>M. arthritidis</i> (75-152)	n.d.
C8DS4	55	<i>M. gallinarum</i> (1-67, 148-401)	<i>M. columbinum</i> (68-147)	+++++
C8DS9	56	<i>M. gallinarum</i> (1-67, 148-401)	<i>M. iners</i> (68-147)	+++++

Table E1. Chimeric ADI Enzymes.				
Name	SEQ ID NO:	Catalytic Domain	α -Helical Domain	Specific Activity
C9DS3	57	<i>M. iners</i> (1-67, 148-401)	<i>M. arthritis</i> (75-152)	n.d.
C9DS4	58	<i>M. iners</i> (1-67, 148-401)	<i>M. columbinum</i> (68-147)	+++++
C9DS8	59	<i>M. iners</i> (1-67, 148-401)	<i>M. gallinarum</i> (68-147)	++++
Chimeric molecules were engineered from <i>M. arginini</i> (SEQ ID NO:2), <i>M. arthritis</i> (SEQ ID NO:3), and <i>M. hominis</i> (Phoenix sequence set forth in SEQ ID NO:14, with modifications). The parenthetical numbers specify the amino acid residues from the natural enzymes, used to form the domains. A C-terminal tryptophan was added to the published <i>M. arthritis</i> sequence and mutation C251S was made for <i>M. arginini</i> and <i>M. arthritis</i> . The ADI specific activity (IU/mg) of these non-pegylated enzymes is shown relative to ADI-PEG 20 (+++).				

The results in Table E1 show that the engineered chimeric ADI enzymes described herein have efficient catalytic activity. The catalytic parameters K_m and k_{cat} for these enzymes is sufficient to remove arginine and maintain low arginine concentrations in the blood. These parameters are preferably less than 20 μM and greater than 1 sec^{-1} , respectively. The pH optimum is around 7.4 so as to maintain efficient catalytic activity in blood. The enzyme stability, as well as that of the covalently linked PEG, is such that it should be maintained during long-term storage and patient treatment at 37°C.

Reduced cross reactivity with anti-ADI-PEG 20 antibodies. ADI is composed of two domains, a catalytic domain and an α -helical domain. The present invention is directed in part to engineered, artificial, chimeric, recombinant enzymes with ADI activity. Each is composed of two domains, where each domain is selected from a number of possible species. Domain boundaries are determined by examination of ADI X-ray crystal structures from *M. hominis* and *M. arginini*, and extending this to other *Mycoplasma* ADI enzymes by homology.

The use of domains from different species of ADI enzymes can maintain the catalytic activity while changing a number of surface residues. Some of these surface residues form epitopes for anti-ADI-PEG 20 antibodies developed during a patient's treatment with ADI-PEG 20. Their replacement can reduce the antigenicity with respect to anti-ADI-PEG 20 antibodies, therefore reducing anti-ADI-PEG 20 antibody neutralization and clearance of the modified drug. This is shown in Table E2, where two preparations of anti-ADI-PEG 20 antibodies showed less binding to the DS1, DS2, DS3, and DS4 antigens, compared to *M. hominis* ADI. This can be attributed to residue changes on the surface of these antigens that alter the epitopes and disrupt antibody-antigen binding interactions.

Table E2. Reduction of Anti-ADI-PEG 20 Antibody Binding to ADI Antigens Compared to ADI-PEG 20					
Antibody	Antigens				
	Conc	DS1	DS2	DS3	DS4
	µg/mL	1µg/mL	1µg/mL	1µg/mL	1µg/mL
Human anti-ADI-PEG 20 IgG (titer 3)	10.0	Yes	No	Yes	No
Human anti-ADI-PEG 20 IgG (titer 3)	25.0	Yes	No	Yes	No
Human anti-ADI-PEG 20 IgG (titer 3)	50.0	Yes	Yes	Yes	Yes
Human anti-ADI-PEG 20 IgG (titer 4)	0.5	Yes	No	Yes	No
Human anti-ADI-PEG 20 IgG (titer 4)	1.0	Yes	No	Yes	No
Human anti-ADI-PEG 20 IgG (titer 4)	5.0	Yes	Yes	Yes	Yes

Surface Lysine Residue Content Reduction. The *M. arginini* (catalytic domain) - *M. arthritidis* (α -helical domain) chimeras were further modified by replacing surface lysine residues with amino acid residues other than lysine and monitoring ADI activity. Four mutants were made (Table E3) and their ADI activity was determined.

Table E3. ADI Lysine Replacement Mutants for DS1 (<i>M. arginini</i> (catalytic): <i>M. arthritidis</i> (α -helical))																							
Lysine residues				5	5	6	8	9	9	9	1	1	1	1	1	2	2	2	3	3	3	4	
		7	9	6	9	6	8	1	3	6	5	6	7	1	8	9	4	9	5	6	0	6	
DS1		K	K	K	K	K	K	K	K	K	K	K	K	K	K	K	K	K	K	K	K	K	
DS1-1		H	K	K	K	K	R	K	K	K	K	K	R	K	K	R	K	K	K	K	T	K	
DS1-2		H	N	K	Q	K	R	K	K	K	R	N	R	K	I	R	K	K	K	K	T	K	
DS1-3		H	N	K	Q	R	R	Q	N	K	R	N	R	G	I	R	K	R	K	K	T	K	
DS1-4		H	N	T	Q	R	R	Q	N	L	R	N	R	G	I	R	R	R	R	R	T	R	
DS1 Lysine replacement mutants, made in groups of 5 or 6.																							

DS1 Lysine replacement mutants, made in groups of 5 or 6.

Table E4 shows ADI activity of the DS1 (*M. arginini* - *M. arthritidis*) enzyme and 4 lysine replacement mutants. Lysine reduction was undertaken to reduce the number of potential pegylation sites.

Table E4. ADI Enzyme Activity		
ADI Enzyme Yield and Activity		
Enzyme	Number of Lys Residues	ADI Specific Activity
DS1	29	+++
DS1-1	24	+++
DS1-2	19	+++
DS1-3	14	+++
DS1-4	8	+++

With around 30 potential pegylation sites, the PEG occupancy is generally small at each site. Reducing the number of potential pegylation sites will result in higher

PEG occupancies and more complete shielding at each remaining site. This is expected to increase proteolytic protection and reduce immune cross reactivity to affinity matured anti-ADI-PEG 20 antibodies from previous treatments. It will also produce a more uniform drug.

5 In summary, the present Examples describes engineered ADI enzymes with excellent ADI activity, with anti-ADI-PEG 20 antibody epitopes removed to reduce antibody neutralization and clearance, and with protection from proteolysis and renal clearance by pegylation.

10 The various embodiments described above can be combined to provide further embodiments. All of the U.S. patents, U.S. patent application publications, U.S. patent application, foreign patents, foreign patent application and non-patent publications referred to in this specification and/or listed in the Application Data Sheet are incorporated herein by reference, in their entirety. Aspects of the embodiments can be modified, if
15 necessary to employ concepts of the various patents, application and publications to provide yet further embodiments.

20 These and other changes can be made to the embodiments in light of the above-detailed description. In general, in the following claims, the terms used should not be construed to limit the claims to the specific embodiments disclosed in the specification and the claims, but should be construed to include all possible embodiments along with the full scope of equivalents to which such claims are entitled. Accordingly, the claims are not limited by the disclosure.

CLAIMS

1. A recombinant chimeric arginine deiminase (ADI) comprising a catalytic domain of an ADI protein derived from a first microorganism and an α -helical domain of an ADI protein derived from a second microorganism which differs from the first microorganism, wherein the first microorganism is selected from the group consisting of *Mycoplasma gallinarum*, *Mycoplasma iners*, and *Mycoplasma columbinum* and wherein the second microorganism is selected from the group consisting of *Mycoplasma gallinarum*, *Mycoplasma iners*, and *Mycoplasma columbinum*.
2. The recombinant chimeric ADI of claim 1, wherein:
the first microorganism is *M. gallinarum* and the second microorganism is *M. columbinum*;
the first microorganism is *M. gallinarum* and the second microorganism is *M. iners*;
the first microorganism is *M. columbinum* and the second microorganism is *M. iners*;
the first microorganism is *M. columbinum* and the second microorganism is *M. gallinarum*;
the first microorganism is *M. iners* and the second microorganism is *M. columbinum*; or
the first microorganism is *M. iners* and the second microorganism is *M. gallinarum*.
3. The recombinant chimeric ADI of claim 1, wherein the recombinant chimeric ADI comprises the amino acid sequence set forth in any one of SEQ ID NOs: 55, 56, 35, 58, 34 or 59 or a variant having at least 90% identity to any one of SEQ ID NOs: 55, 56, 35, 58, 34 or 59.
4. The recombinant chimeric ADI of any one of claims 1-3, wherein the recombinant chimeric ADI has been modified to remove at least one pegylation site.
5. The recombinant chimeric ADI of any one of claims 1-3, wherein at least one lysine residue has been modified by an amino acid substitution, or wherein at least 5 lysine residues have been modified by an amino acid substitution, or wherein at least 10 lysine residues have been modified by an amino acid substitution, or wherein at least 15 lysine residues have been modified by an amino acid substitution, or wherein at least 20 lysine residues have been modified by an amino acid substitution.

6. The recombinant chimeric ADI of any one of claims 1-5, wherein the recombinant chimeric ADI is covalently bonded via a biocompatible linker to polyethylene glycol.
7. The recombinant chimeric ADI of claim 6, wherein the arginine deiminase is covalently bonded to more than one polyethylene glycol molecule.
8. The recombinant chimeric ADI of claim 6, wherein the arginine deiminase is covalently bonded to about 1 to about 10 polyethylene glycol molecules.
9. The recombinant chimeric ADI of claim 6, wherein the arginine deiminase is covalently bonded to 5 ± 3 PEG molecules.
10. The recombinant chimeric ADI of claim 6, wherein the PEG molecules are straight chain or branch chain PEG molecules.
11. The recombinant chimeric ADI of claim 6, wherein the polyethylene glycol has a total weight average molecular weight of from about 1,000 to about 40,000.
12. The recombinant chimeric ADI of claim 6, wherein the polyethylene glycol has a total weight average molecular weight of from about 10,000 to about 30,000.
13. The recombinant chimeric ADI of claim 6, wherein the biocompatible linker comprises a succinyl group, an amide group, an imide group, a carbamate group, an ester group, an epoxy group, a carboxyl group, a hydroxyl group, a carbohydrate, a tyrosine group, a cysteine group, a histidine group, a methylene group, or a combination thereof.
14. The recombinant chimeric ADI of claim 13, wherein the source of the succinyl group is succinimidyl succinate.
15. A polynucleotide encoding the recombinant chimeric of claim 1, or a vector comprising the polynucleotide, or an isolated host cell comprising the vector.

16. A composition comprising the recombinant chimeric ADI of any one of claims 1-14 and a physiologically acceptable carrier.

17. Use of a composition according to claim 16 in the manufacture of a medicament for the treatment of cancer or ameliorating the symptoms of, or inhibiting the progression of cancer.

18. The use according to claim 17, wherein the cancer is selected from the group consisting of melanoma, pancreatic cancer, prostate cancer, small cell lung cancer, mesothelioma, lymphocytic leukemia, chronic myelogenous leukemia, lymphoma, hepatoma, sarcoma, leukemia, acute myeloid leukemia, relapsed acute myeloid leukemia, breast cancer, ovarian cancer, colorectal cancer, gastric cancer, glioma, glioblastoma multiforme, non-small cell lung cancer (NSCLC), kidney cancer, bladder cancer, uterine cancer, esophageal cancer, brain cancer, head and neck cancers, cervical cancer, testicular cancer, and stomach cancer.