GLYCINAMIDE DERIVATIVE FOR INHIBITING HIV REPLICATION

FIELD OF THE INVENTION

A new class of drugs that inhibit the replication of human immunodeficiency virus (HIV) has been discovered. Several methods to identify metabolites of glycinamide that inhibit the replication of HIV are described. Embodiments include methods to identify and synthesize modified glycinamide compounds and compositions comprising modified glycinamide compounds.

BACKGROUND OF THE INVENTION

Human immunodeficiency virus (HIV) is the name given to a lentivirus that infects humans and that causes acquired immuno-deficiency syndrome (AIDS). HIV is a complex retrovirus containing at least nine genes. The viral structural genes, designated *gag*, *pol*, and *env*, respectively code for *inter alia* the viral core proteins, reverse transcriptase, and the viral glycoproteins of the viral envelope. The remaining HIV genes are accessory genes involved in viral replication. The *gag* and *env* genes encode polyproteins, *i.e.*, the proteins synthesized from each of these genes are post-translationally cleaved into several smaller proteins.

Although the overall shape of HIV is spherical, the nucleocapsid is asymmetrical having a long dimension of about 100nm, a wide free end about 40-60nm, and a narrow end about 20nm in width. The nucleocapsid within each mature virion is composed of two molecules of the viral single-stranded RNA genome encapsulated by proteins proteolytically processed from the Gag precursor polypeptide. Cleavage of the *gag* gene polyprotein $Pr55^{gag}$ by a viral coded protease (PR) produces mature capsid proteins.

Since the discovery of HIV-1 as the etiologic agent of AIDS, significant progress has been made in understanding the mechanisms by which the virus causes disease. While many diagnostic tests have been developed, progress in HIV vaccine therapy has been slow largely due to the heterogeneous nature of the virus and the lack of suitable animal models. (*See e.g.*, Martin, *Nature*, 345:572-573 (1990)).

A variety of pharmaceutical agents have been used in attempts to treat AIDS. HIV reverse transcriptase (RT) is one drug target because of its crucial role in viral replication, however, many, if not all, of the drugs that inhibit the enzyme are limited in their usefulness as therapeutic agents. These are nucleoside/nucleotide analogue RT inhibitors (NRTI:s) that will induce chain termination and agents that directly inhibit the enzyme, referred to as non-nucleoside analogue RT inhibitors (NNRTI:s). Nucleoside derivatives, such as azidothymidine (AZT, zidovudine®) and the other RT inhibitors cause serious side effects such that many patients cannot tolerate administration.

Another drug target is the HIV protease (PR) crucial to virus maturation. PR is an aspartic acid protease and can be inhibited by synthetic compounds. (*See e.g.*, Richards, *FEBS Lett.*, 253:214-216 (1989)). Protease inhibitors strongly inhibit the replication of HIV but prolonged

therapy has been associated with metabolic diseases such as lipodystrophy, hyperlipidemia, and insulin resistance.

Additionally, HIV quickly develops resistance to NRTI:s, NNRT:s and protease inhibitors. Resistant virus can also spread between patients. Studies have shown, for example, that in the US one tenth to one fifth of the individuals recently infected by HIV already have virus that has developed resistance to one or more antiviral drug, probably because they were infected by a person that at the time of transmission carried a virus that had developed resistance.

Over the last decade it has been discovered that several peptide amides inhibit the replication of HIV. (*See, e.g.*, U.S. Patent Nos. 5,627,035; 6,258,932; 6,455,670; and U.S. Patent Application Nos. 09/827,822; 09/938,806; 10/072,783; 10/217,933; and 10/235,158). These peptides amides appear to inhibit HIV replication in a manner that is different than reverse transcriptase inhibitors and protease inhibitors and have few, if any, side-effects. Despite these efforts, the need for more selective therapeutic agents that inhibit HIV replication is manifest.

BRIEF SUMMARY OF THE INVENTION

It has been discovered that enzymatically prepared and synthetically prepared α-hydroxyglycinamide inhibit the replication of HIV in human serum. Accordingly, aspects of the invention include therapeutic compositions that consist, consist essentially of, or comprise modified glycinamide compounds. Modified glycinamide compounds (*e.g.*, Metabolite X, alpha hydroxyglycinamide, or AlphaHGA) in either enantiomer (L or D) or both or either isomer (R or S) or both are provided as active ingredients of pharmaceuticals and medicaments that inhibit the replication and/or propagation of HIV. Modified glycinamide compounds, such as α-hydroxyglycinamide (alpha-hydroxy-gly-NH_2), α-peroxyglycinamide dimer (NH_2-gly-O-O-gly-NH_2), diglycinamide ether (NH_2-gly-O-gly-NH_2) and alpha-methoxyglycinamide (alpha-MeO-gly-NH_2), or pharmaceutically acceptable salts thereof are the preferred active ingredients for incorporation into a pharmaceutically acceptable formulation that can be used to inhibit the replication of HIV.

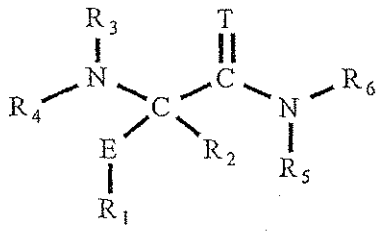
Accordingly, antiretroviral pharmaceuticals and medicaments can be prepared by providing a modified glycinamide compound (*e.g.*, a compound provided by formulas A, B, C, D, E, F, G, H, or I) or a pharmaceutically acceptable salt thereof in either enantiomer (L or D) or both or either isomer (R or S) or both. Preferred compounds for formulation into an antiretroviral pharmaceutical or medicament include, for example, α-hydroxyglycinamide (formula C), α-peroxyglycinamide dimer (formula E), diglycinamide ether (formula F), and alpha-methoxyglycinamide, or pharmaceutically acceptable salts thereof in either enantiomer (L or D) or both or either isomer (R or S) or both. The antiretroviral pharmaceuticals and medicaments describe herein can be provided in unit dosage form (*e.g.*, tablets, capsules, gelcaps, liquid doses, injectable doses, transdermal or intranasal doses) and can contain, in addition to the modified glycinamide compound, a

pharmaceutically acceptable carrier or exipient. Containers comprising said pharmaceuticals and medicaments (*e.g.*, sterile vials, septum sealed vials, bottles, jars, syringes, atomizers, swabs) whether in bulk or in individual doses are also embodiments and, preferably, said formulations are prepared according to certified good manufacturing processes (GMP) (*e.g.*, suitable for or accepted by a governmental regulatory body, such as the Federal Drug Administration (FDA)) and said containers comprise a label or other indicia that reflects approval of said formulation from said governmental regulatory body. Nutriceuticals containing said compounds with or without structure-function indicia are also embodiments, however.

Some embodiments also include a precursor or prodrug for one or more of said antiretroviral compounds (*e.g.*, Metabolite X, α-hydroxyglycinamide (formula C), α-peroxyglycinamide dimer (formula E), diglycinamide ether (formula F), and alpha-methoxyglycinamide, in either enantiomer (L or D) or both or either isomer (R or S) or both). Such precursors or prodrugs include, for example, a glycinamide containing peptide or glycinamide itself (*e.g.*, GPG-NH_2 or ALGPG-NH_2). These precursors or prodrugs are provided in conjunction with (*e.g.*, coadministration in a mixture or before or after delivery of the prodrug) with a material (*e.g.*, a cofactor(s) containing material such as fetal calf serum, bovine serum, plasma, or milk, horse serum, plasma, or milk, cat or dog serum in isolated, enriched, or raw form) capable of converting the precursor or prodrug into a modified glycinamide compound (*e.g.*, a compound provided by formulas A, B, C, D, E, F, G, H, or I) in either enantiomer (L or D) or both or either isomer (R or S) or both, such as Metabolite X). As above, said prodrug/cofactor formulations can be prepared according to certified good manufacturing processes (GMP) (*e.g.*, suitable for or accepted by a governmental regulatory body, such as the Federal Drug Administration (FDA)) and said containers comprise a label or other indicia that reflects approval of said formulation from said governmental regulatory body. Nutriceuticals containing said formulationss with or without structure-function indicia are also embodiments.

Alpha-hydroxyglycinamide (α-hydroxyglycinamide) or a pharmaceutically acceptable salt thereof (also referred to collectively as "alphaHGA") is a preferred active ingredient for incorporation into pharmaceuticals and/or medicaments that can be used to inhibit the replication of HIV. Pharmaceuticals and medicaments that consist of, consist essentially of, or comprise L -alphaHGA (*in* R or S *isomer*) or D -*alpha HGA* (*in* R or S *isomer*) or both (with either R or S or both isomers) are embodiments. These compositions (*e.g.*, ampules, capsules, pills, tablets, intravenous solutions, transdermal, intranasal solutions, and other pharmaceutically acceptable formulations) preferably contain, provide, or deliver an amount of enzymatically prepared (Metabolite X) or synthetically prepared (alphaHGA) alpha hydroxyglycinamide that inhibits the replication and/or propagation of HIV.

Embodiments include, for example, pharmaceuticals and medicaments consisting, consisting essentially of, or comprising a modified glycinamide compound of formula (A):

(A) 

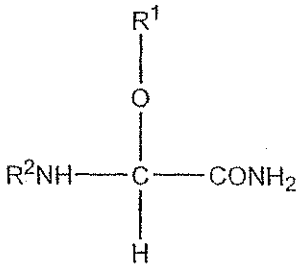
or a pharmaceutically acceptable salt, amide, ester, or prodrug thereof; wherein:

a) E is selected from the group consisting of oxygen, sulfur, and NR_7;

b) T is selected from the group consisting of oxygen, sulfur, and NR_8; and

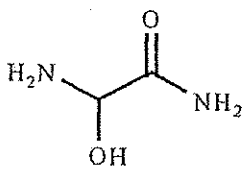
c) R_1-R_8 are each independently selected from the group consisting of hydrogen; optionally substituted alkyl; optionally substituted alkenyl; optionally substituted alkynyl; optionally substituted cycloalkyl; optionally substituted heterocyclyl; optionally substituted cycloalkylalkyl; optionally substituted heterocyclylalkyl; optionally substituted aryl; optionally substituted heteroaryl; optionally substituted alkylcarbonyl; optionally substituted alkoxyalkyl; and optionally substituted perhaloalkyl.

Desirable compositions include pharmaceuticals and medicaments that consist of, consist essentially of, or comprise a modified glycinamide compound of formula (B):

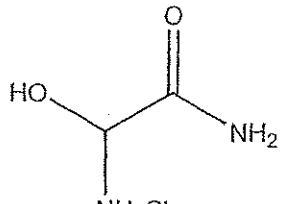
(B) 

wherein, R^1 is a hydrogen atom, a lower alkyl group, a lower alkenyl group, a lower alkynyl group, a benzyl group, or a silyl group substituted with an alkyl group or an alkyl group and an aromatic group and R^2 is a hydrogen atom or an amino protecting group, or a salt thereof.

Preferred compositions include pharmaceuticals and medicaments that consist of, consist essentially of, or comprise a modified glycinamide compound of formula (C):

(C) 

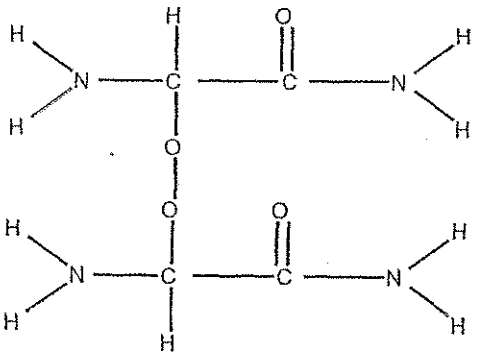
or a pharmaceutically acceptable salt, amide, ester, or prodrug thereof. Particularly preferred compositions include pharmaceuticals and medicaments that consist of, consist essentially of, or comprise a modified glycinamide salt of formula (D):



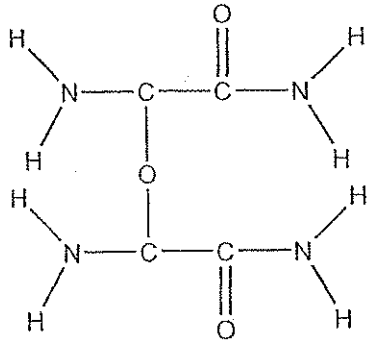
(D)

The compound of formula (C), α-hydroxyglycinamide, also referred to as Metabolite X or alphaHGA, has been produced by an enzymatic process and isolated using cation exchange HPLC and the compound of formula (D) has been made synthetically. In some contexts, both the compounds of formula (C) and (D) in either enantiomer (L or D) or both or either isomer (R or S) or both are referred to as "Metabolite X," "alphaHGA," or "modified glycinamide," interchangeably.

Preferred compositions also include pharmaceuticals and medicaments that consist of, consist essentially of, or comprise a modified glycinamide compound of formula (E) or formula (F) or a pharmaceutically acceptable salt thereof:

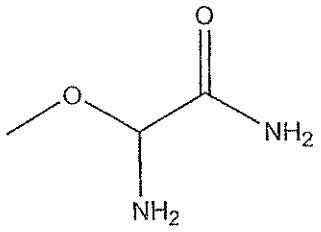


(E)



(F)

Preferred compositions also include pharmaceuticals and medicaments that consist of, consist essentially of, or comprise a modified glycinamide compound of formula (G) or a pharmaceutically acceptable salt thereof:



(G)

Alpha-methoxyglycinamide has also been prepared synthetically and this compound has been found to be more stable than alpha-hydroxyglycinamide.

Embodiments also include several methods to identify and isolate modified glycinamide compounds that inhibit the replication of HIV and methods to synthesize these compounds. Some embodiments concern methods to inhibit the replication and/or propagation of HIV, wherein a subject in need of an agent that inhibits the replication of HIV is provided an amount of enzymatically prepared (Metabolite X) or synthetically prepared alpha hydroxyglycinamide (alphaHGA) sufficient to inhibit the propagation or replication of the virus. In some of these methods, the affect on HIV replication is measured (*e.g.*, by observing or monitoring a reduction in viral lode or a marker thereof). Additional embodiments include approaches to treat and/or prevent HIV infection, wherein an afflicted patient or a person at risk for contracting HIV is provided an amount of modified glycinamide (*e.g.*, alpha-hydroxyglycinamide, α-peroxyglycinamide dimer, diglycinamide ether or alpha-methoxyglycinamide) sufficient to inhibit the replication of HIV. As above, in some embodiments, the compound or a pharmaceutical containing the compound is provided to a subject in need of an agent that inhibits HIV replication and, in other embodiments, the affect on HIV replication is measured (*e.g.*, by measuring a reduction in the viral lode or marker thereof, such as p24 accumulation or reverse transcriptase activity).

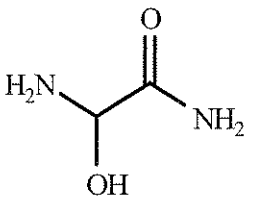
In one embodiment, there is provided the use of a composition comprising α-hydroxyglycinamide (formula C) or a pharmaceutical salt thereof, in the manufacture of a medicament used to treat or prevent HIV infection. In one embodiment, there is provided the use of the present invention, wherein said composition comprises the α-hydroxyglycinamide salt of formula D. In another embodiment, there is provided the use of the present invention, wherein said α-hydroxyglycinamide (formula C) is a L-α-hydroxyglycinamide. In another embodiment, there is provided the use of the present invention, wherein said α-hydroxyglycinamide (formula C) is a D-α-hydroxyglycinamide. In another embodiment, there is provided the use of the present invention, wherein said α-hydroxyglycinamide (formula C) is a S-α-hydroxyglycinamide. In another embodiment, there is provided the use of the present invention, wherein said α-hydroxyglycinamide (formula C) is a R-α-hydroxyglycinamide. In another embodiment, there is provided the use of the present invention, wherein said composition is an oral formulation. In another embodiment, there is provided the use of the present invention, wherein said composition is an intravenous formulation. In another embodiment, there is provided the use of the present invention, wherein said composition is an oral formulation. In another embodiment, there is provided the use of the present invention, wherein said composition is an intranasal formulation.

In another embodiment, there is provided the use of α-hydroxyglycinamide (formula C) or a salt of α-hydroxyglycinamide (formula D) to prepare a medicament to treat or prevent HIV infection. In another embodiment, there is provided the use of the present invention, wherein the salt of α-hydroxyglycinamide (formula D) is used. In another embodiment, there is provided the use of the present invention, wherein an L-α-hydroxyglycinamide is used. In another embodiment, there is provided the use of the present invention, wherein an D-α-hydroxyglycinamide is used. In another embodiment, there is provided the use of the present invention, wherein an S-α-hydroxyglycinamide is used.

In another embodiment, there is provided the use of the present invention, wherein an R-α-hydroxyglycinamide is used. In another embodiment, there is provided the use of the present invention, wherein said medicament is an oral formulation. In another embodiment, there is provided the use of the present invention, wherein said medicament is an intravenous formulation. In another embodiment, there is provided the use of the present invention, wherein said medicament is an oral formulation. In another

embodiment, there is provided the use of the present invention, wherein said medicament is an intranasal formulation.

In one aspect, there is provided the use of a composition comprising α hydroxyglycinamide (formula C) or a pharmaceutical salt thereof, in the manufacture of a medicament used to treat or prevent HIV infection.

(C) 

In a another aspect, there is provided the use of α-hydroxyglycinamide (formula C) or a salt of α-hydroxyglycinamide (formula D) to prepare a medicament to treat or prevent HIV infection.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 shows the structures of glycylprolylglycinamide (GPG-NH_2), sarcosylpyrolylglycinamide (SAR-PG-NH_2), cyclic pyrroglutaminylprolylglycinamide (PyrQPG-NH_2), glutaminylprolylglycinamide (QPG-NH_2), and glycinamide (G-NH_2).

FIGURE 2 shows the CD26 activity in human T-lymphocytes (CEM, C8166, Molt4/C8, MT-4) and PBMC suspensions (**panel A**) or in several different serum (human (HS), murine (MS), bovine (BS) (**panel B**)) as a function of time. The substrate was glycylprolyl-p-nitroanilide (GP-pNA). Enzyme activity was measured by absorption at 400nm.

FIGURE 3 shows the purified CD26-mediated conversion of unlabeled GPG-NH_2 to GP-OH and G-NH_2. The detection was performed by mass spectrometry.

FIGURE 4 shows the conversion of radiolabeled [^{14}C]GPG-NH_2 to [^{14}C]G-NH_2 by bovine serum (BS) at 5% in phosphate buffered saline (PBS), Human serum (HS) at 5% in PBS, and CEM cell suspensions (10^6 cells).

FIGURE 5 shows the inhibitory affect of the CD26-specific inhibitor IlePyr on the dipeptidylpeptidase activity of CD26 in 5% bovine serum (BS) in PBS and 10^6 CEM cell suspensions in PBS using GP-pNA as the substrate.

FIGURE 6 shows the effect of the CD26 inhibitor IlePyr on the anti-HIV-1 activity of GPG-NH2 and G-NH2 in CEM cell cultures.

FIGURE 7 shows the results of an analysis of several lots of human sera and fetal bovine sera for their ability to convert G-NH_2 to modified G-NH_2 (Metabolite X).

FIGURE 8 shows the results of an analysis of different animal sera for their ability to convert G-NH_2 to modified G-NH_2 (Metabolite X).

FIGURE 9 shows the results of a competition assay, wherein the ability of different concentrations of glycine, L-serine-NH_2, L-alanine-NH_2, or GPG-NH_2 to inhibit the conversion of G-NH_2 to modified G-NH_2 (Metabolite X) were evaluated.

FIGURE 10 shows the results of an analysis of different fractions of fetal bovine serum, obtained by size exclusion chromatography, to convert G-NH_2 to modified G-NH_2 (Metabolite X).

FIGURE 11 illustrates the results of a reverse transcriptase (RT) activity assay, wherein enzymatically prepared alpha-hydroxyglycinamide (Metabolite X or Met-X) inhibited the replication of HIV in cultures containing boiled fetal calf serum but G-NH_2 did not.

FIGURE 12 shows the results of a reverse transcriptase (RT) assay, wherein enzymatically prepared alpha-hydroxyglycinamide (Metabolite X or Met-X) that had been dialysed five times inhibited the replication of HIV in cultures containing boiled fetal calf serum.

FIGURE 13 shows the results of a reverse transcriptase (RT) assay, wherein the antiretroviral activity (IC_{50}) of various concentrations of enzymatically prepared alpha-hydroxyglycinamide (Metabolite X or Met-X) were analysed.

FIGURE 14 shows the results of an HIV infectivity assay (in fetal calf serum) that monitored the accumulation of p24, wherein enzymatically prepared alpha-hydroxyglycinamide (Metabolite X or Met-X) inhibited HIV as effectively as GPG-NH_2.

FIGURE 15 shows the results of an HIV infectivity assay (in fetal calf serum) that monitored the accumulation of p24, wherein synthetically prepared alpha-hydroxyglycinamide (AlphaHGA) was observed to inhibit HIV as effectively as GPG-NH_2.

FIGURE 16 shows the results of an HIV infectivity assay (in fetal calf serum **(panel A)** and human serum **(panel B)**) that monitored the accumulation of p24, wherein enzymatically prepared alpha-hydroxyglycinamide (Metabolite X or Met-X) and synthetically prepared alpha-hydroxyglycinamide (AlphaHGA) inhibited HIV as effectively as G-NH_2 in fetal calf serum **(panel A)** but only enzymatically prepared alpha-hydroxyglycinamide (Metabolite X or Met-X) and synthetically prepared alpha-hydroxyglycinamide (AlphaHGA) were able to inhibit HIV replication in human serum **(panel B)**.

FIGURE 17 shows the results of a reverse transcriptase (RT) assay (in fetal calf serum), wherein the antiretroviral activity of G-NH_2, freshly diluted synthetically prepared alpha-hydroxyglycinamide (AlphaHGA), and synthetically prepared alpha-hydroxyglycinamide , which had been incubated at 37°C for three days(AlphaHGA 37), was compared.

DETAILED DESCRIPTION OF THE INVENTION

It has been discovered that some tripeptide amides and glycinamide are prodrugs that are metabolized into compounds that inhibit the replication of HIV. These antiviral agents are highly selective inhibitors in cell culture (*e.g.*, GPG-NH_2 and glycinamide or "G-NH_2" inhibit HIV replication in CEM cell cultures to an equal extent (50% effective concentration: ~ 30 μM)). The focus of research in this area has been on the conversion of tripeptide amides to glycinamide (G-NH_2) since G-NH_2 also inhibits the replication of HIV. (*See* U.S. Patent Application No. 10/235,158). It is now known that the lymphocyte surface glycoprotein marker CD26 efficiently converts GPG-NH_2 to G-NH_2 releasing the dipeptide GP-OH and that this cleavage is required for GPG-NH_2 to exert its antiretroviral activity.

It has also been discovered that G-NH_2 is itself a prodrug that is metabolized to one or more compounds (*e.g.*, cyclic, charged, or uncharged forms of glycinamide) that inhibit the replication of HIV. These metabolites that are derived from G-NH2 are referred to as "modified glycinamide," "glycinamide derivatives," or "Metabolite X." Mass spectrometry and nuclear magnetic resonance (NMR) spectrometry analysis of the modified glycinamide peak fraction isolated after chromatographic separation revealed that it contained α-hydroxyglycinamide ("AlphaHGA" or ($C_2H_6N_2O_2$) or ($C_2H_7ClN_2O_2$)). Both α-hydroxyglycinamide and α-methoxyglycinamide were prepared by organic synthesis. It was found that enzymatically prepared alpha-hydroxyglycinamide (Metabolite X) and synthetically prepared alpha-hydroxyglycinamide (AlphaHGA) effectively

inhibit HIV in human serum. The formulation of pharmaceuticals and medicaments containing these modified glycinamides is straightforward and the use of these compounds to inhibit replication of HIV in subjects in need thereof is provided herein. The section below describes the discovery that CD26 converts GPG-NH2 to G-NH2 in greater detail.

CD26 mediates the conversion of GPG-NH2 to G-NH2

The lymphocyte surface glycoprotein CD26 has been originally described as a T-cell activation/differentiation marker. (*See* Fox *et al.*, *J. Immunol.*, 132:1250-1256 (1984)). CD26 is abundantly expressed on the target cells of HIV (*i.e.*, lymphocytic CEM, Molt, C8166 and MT-4, and peripheral blood mononuclear cells) and is also present in serum from bovine, murine and human origin. It is a membrane-associated peptidase identical to dipeptidyl-peptidase IV (DPP IV, EC3.4.14.5) and has a high (but not exclusive) selectivity for peptides that contain a proline or alanine as the penultimate amino acid at the N-terminus. (*See* Yaron and Naider, *Biochem. Mol. Biol.*, 28:31-81 (1993); De Meester *et al.*, *Immunol. Today*, 20:367-375 (1999) and Mentlein, *Regul. Pept.*, 85:9-24 (1999)). It is not only expressed on a variety of leukocyte cell subsets, but also on several types of epithelial, endothelial and fibroblast cells. (*Id.*). A soluble form of CD26 also exists. It lacks the transmembrane regions and intracellular tail and is detected in plasma and cerebrospinal fluids at low amounts. (*See* Yaron and Naider, *Biochem. Mol. Biol.*, 28:31-81 (1993); De Meester *et al.*, *Immunol. Today*, 20:367-375 (1999)).

Several cytokines, hematopoietic growth factors, hormones and neuropeptides contain a X-Pro or X-Ala motif at their N-terminus. (*See* De Meester *et al.*, *Immunol. Today*, 20:367-375 (1999)). The presence of a proline near the N-terminus serves as a structural protection against non-specific proteolytic degradation. (*See* Vanhoof *et al.*, *FASEB J.*, 9:736-744 (1995)). In particular, relatively small peptides may serve as natural substrates (*e.g.*, the chemokines RANTES (68 amino acids) and SDF-1α (68 amino acids), and the glucagon/VIP (Vasoactive Intestinal Protein) family peptides such as GIP (42 amino acids) and GLP-2 (33 amino acids)). (*See* De Meester *et al.*, *Immunol. Today*, 20:367-375 (1999)). In some cases, the peptides are very short (*e.g.*, the neuropeptides endomorphin 2 (4 amino acids) and substrate P (11 amino acids)). Enterostatin, consisting of only 5 amino acids is also found to be a substrate for CD26.

Interestingly, in certain cases, CD26 was shown to alter the biological functions of natural peptides after it cleaved off a dipeptide part from the N-terminal part of the molecule. (Oravecz *et al.*, *J. Exp. Med.*, 186:1865-1872 (1997); Proost *et al.*, *J. Biol. Chem.*, 273:7222-7227 (1998)). Indeed, truncated RANTES (3-68) was found to have a markedly increased anti-HIV-1 activity compared with intact RANTES (*see* Schols *et al.*, *Antiviral Res.*, 39:175-187 (1998)); whereas N-terminal processing SDF-1α by CD26 significantly diminished its anti-HIV-1 potency. (*See* Ohtsuki *et al.*, *FEBS Lett.*, 431:236-240 (1998); Proost *et al.*, *FEBS Lett.*, 432:73-76 (1998)). Also,

it was recently shown that CD26 regulates SDF-1α-mediated chemotaxis of human cord blood $CD34^+$ progenitor cells. (*See* Christopherson *et al.*, *J. Immunol.*, 169:7000-7008 (2002)).

The tripeptide glycylprolylglycinamide (GPG-NH_2) has been found to inhibit HIV replication at non-toxic concentrations. (*See e.g.*, U.S. Pat. No. 5,627,035) but its association with CD26 has not been made until this disclosure. Glycylprolylglycinamide blocks a wide variety of HIV-1 laboratory strains and clinical isolates within a range of 2-40 μM. Since there exist two GPG motifs in HIV p24 and one GPG motif in the V3 loop of the viral envelope protein gp120 initial research had been focussed on these viral proteins as potential targets for this novel tripeptide derivative. (*See* Su, Ph.D. thesis at the Karolinska Institute (ISBN 91-628-4326-5), Stockholm, Sweden (2000) and Su et al., *AIDS Res. Human Retrovir.*, 16:37-48 (2000)).

Although an increased SDS-PAGE mobility of gp160/120 was observed at high concentrations of GPG-NH_2, it was found that GPG-NH_2 did not affect an early event in the infection cycle of HIV. (*See* Su et al., *J. Hum. Virol.*, 4:8-15 (2001)). In addition, binding of GPG-NH_2 with the p24 protein has been demonstrated and an increased number of misassembled core structures of virus particles was observed in GPG-NH_2-treated HIV-1-infected cells. (*See* Hoglund et al., *Antimicrob. Agents Chemother.*, 46:3597-3605 (2002)). Also, viral capsid (p24) formation was found to be disturbed in the presence of the drug. (*See* Hoglund et al., *Antimicrob. Agents Chemother.*, 46:3597-3605 (2002)). It became clear that GPG-NH_2 inhibited replication of HIV by a novel mechanism.

Given the presence of a proline residue in the middle (equivalent to the penultimate amino acid at the amino terminus) of the GPG-NH_2 peptide molecule, it was thought that GPG-NH_2 can be a substrate for CD26/dipeptidylpeptidase IV and that CD26 enzymatic activity can modulate the antiretroviral activity of the compound. Accordingly experiments were conducted to determine whether CD26/dipeptidylpeptidase IV could convert GPG-NH_2 to G-NH_2 and, indeed, it was discovered that CD26 selectively and efficiently cleaved GPG-NH_2 after the proline residue to release the dipeptide GP-OH and G-NH_2. Moreover, it was also demonstrated that this cleavage was required for GPG-NH_2 to exert its antiretroviral activity. The example below describes these findings in greater detail.

EXAMPLE 1

In initial experiments, several HIV-1 and HIV-2 strains were evaluated for their sensitivity to the inhibitory activity of GPG-NH_2, G-NH_2 and related compounds. (*See* **TABLE 1** and **FIGURE 1**). Glycylprolylglycinamide (GPG-NH_2), glutaminylprolylglycinamide (Q-PG-NH_2), sarcosinylprolylglycinamide (Sar-PG-NH_2) and glycinamide (G-NH_{-2}) were provided by TRIPEP AB (Huddinge, Sweden); whereas, Pyrroglutaminylprolylglycinamine (PyrQ-PG-NH_2) was synthesized at the Rega Institute. Human T-lymphocytic CEM cells were obtained from the American Type culture Collection (Rockville, MD) and cultured in RPMI-1640 medium (Gibco,

Paisley, Scotland supplemented with 10% fetal bovine serum (FBS) (BioWittaker Europe, Verviers, Belgium), 2mM L-glutamine (Gibco) and 0.075 M $NaHCO_3$ (Gibco). HIV-1(III_B) was obtained from Dr. R.C. Gallo and Dr. M. Popovic (at that time at the National Cancer Institute, NIH, Bethesda, MD). HIV-1(NL4.3) was from the National Institute of Allergy and Infectious Disease AIDS Reagent Program (Bethesda, MD). The HIV-2 isolates ROD and EHO were provided by Dr. L. Montagnier (Pasteur Institute, Paris, France).

Human T-lymphocytic CEM cells (4.5×10^5 cells per ml) were suspended in fresh cell culture medium and infected with HIV-1 (III_B and NL4.3) or HIV-2 (ROD or EHO) at 100 $CCID_{50}$ (1 $CCID_{50}$ being the virus dose infective for 50% of the cell cultures) per ml of cell suspension. Then, 100µl of the infected cell suspension were transferred to microplate wells, mixed with 100µl of appropriate (freshly prepared) dilutions of the test compounds (*i.e.*, at final concentrations of 2000, 400, 80, 16, 3.2 and 0.62µM), and were further incubated at 37°C. After 4 to 5 days, giant cell formation was recorded microscopically in the CEM cell cultures. The 50% effective concentration (EC_{50}) corresponded to the compound concentrations required to prevent syncytium formation in the virus-infected CEM cell cultures by 50%.

TABLE 1

Inhibitory activity of tripeptide derivatives against several virus strains in CEM cell cultures

Compound	EC_{50}[a] (µM)				
	HIV-1		HIV-2		CEM
	III_B	NL3.4	ROD	EHO	
GPG-NH_2	35 ± 8.7	50 ± 0.0	30 ± 10	42 ± 14	>2000
G-NH_2	32 ± 7.6	45 ± 7.1	35 ± 8.7	37 ± 5.8	>2000
PyrQ-PG-NH_2	>2000	>2000	>2000	>2000	>2000
SAR-PG-NH_2	31 ± 4.9	49	35 ± 9.8	56	>1500
Q-PG-NH_2	86	265	89	82	>1500

[a] 50% Effective concentration, or compound concentration required to inhibit HIV-reduced syncytia formation in T-lymphocytic CEM cell cultures

Interestingly, both GPG-NH_2 and G-NH_2 were equally effective in suppressing virus replication on a molar basis, regardless the nature of the virus used in the antiviral assays. Their EC_{50} (50% effective concentration) ranked between 30 and 50µM in CEM cell cultures. Both compounds did not show cytotoxicity at concentrations as high as 1500 to 2000µM. Sar-PG-NH_2 and Q-PG-NH_2 were also inhibitory to HIV replication, although to a lower extent as GPG-NH_2. A novel tripeptide (PyrQ-PG-NH_2) derivative was synthesized containing G-NH_2 at its carboxy terminal end but a cyclic pyrroglutamine at its amino terminal end. In contrast with GPG-NH_2 and

the other tripeptide amide derivatives, PyrQ-PG-NH_2 was found to be ineffective at inhibiting HIV replication in cell culture

Next, it was confirmed that CD26 dipeptidylpeptidase activity could be detected in purified CD26 and bovine, murine and human serum and with human lymphocytic or peripheral blood mononuclear cell suspensions. CD26 enzyme activity was recorded by conversion of the synthetic substrate glycylprolyl p-nitroanilide (GP-pNA) to glycylproline (GP-OH) and p-nitroaniline (pNA), a yellow dye, whose formation could be monitored by an increase of the absorption at 400nm. Approximately, two hundred microliters of purified CD26 (1 milliUnit/ml) in phosphate buffered saline (PBS), or human, murine or bovine serum (5% in PBS) or 10^6 human lymphocytic CEM, C8166, Molt4/C8, MT-4 or peripheral blood mononuclear cell suspensions in PBS were added to 200µl-microtiter plate wells after which the substrate for measuring the CD26 enzymatic activity (glycylprolyl-para-nitroanilide) (GP-pNA) at 3 mM final concentration was added. Glycylprolyl-p-nitroanilide (GP-pNA) and glycylphenylalaninyl-p-nitroanilide (GF-pNA) were obtained from Sigma Chemicals (St. Louis, MO). The release of p-nitro-aniline (pNA) was monitored at 37°C in function of time by measuring the amount of (yellow-colored) para-nitroaniline (pNA) released from GlyPro-pNA. The pNA release was recorded by the increase of absorption [optical density (OD) at 400 nm] in a Spectramax microplate spectrometer (Molecular Devices, Sunnyvale, CA). Under the experimental conditions, the reaction proceeded linearly for at least 60 min. The OD_{400} values of blank reaction mixtures (lacking the CD26 enzyme, serum or cells) were subtracted from the obtained OD_{400} values to represent the real increase of OD_{400} value as a measurement of the enzyme activity.

It was found that GP-pNA was only converted by CD26 and not by the action of other dipeptidyl/peptidases since the addition of a specific inhibitor of CD26 to the cell suspensions virtually completely blocked the release of p-nitroaniline from the synthetic substrate GP-pNA (*infra*). All lymphocytic cell suspensions (CEM, C8166, MT-4, Molt4/C8) and also PBMC at which GP-pNA had been administered efficiently converted GP-pNA to p-nitroaniline in a time-dependent fashion. (*See* **FIGURE 2A**). The CD26 activity was highest in CEM cell suspensions and lowest in the MT-4 cell suspensions. Also, fetal bovine and murine serum and in particular human serum efficiently released p-nitroaniline from GP-pNA (*See* **FIGURE 2B**). Thus, both human T-lymphocytic cell suspensions and serum display a prominent CD26/dipeptidylpeptidase enzyme activity. Once it was determined that CD26 activity could be efficiently monitored, experiments were conducted to determine if CD26 could convert GPG-NH_2 to G-NH_2.

In a sample, approximately, 100µM GPG-NH_2 was exposed to 25 units/l of purified CD26 and the mixture was incubated for up to 400 minutes at room temperature. The lymphocyte surface glycoprotein CD26/dipeptidylpeptidase IV was purified as described before. (*See* De Meester, *J. Immunol. Methods*, 189:99-105 (1996)). At different time points, an aliquot of the reaction mixture was withdrawn and analyzed on an electrospray ion trap mass spectrometer (Esquire, Bruker,

Bremen, Germany). The appearance of the dipeptide GP-OH upon release from the amino terminal end of the GPG-NH_2 molecule, as well as, the disappearance of intact GPG-NH_2 from the reaction mixture was determined and monitored by electrospray ion trap mass spectometric analysis at different time points. (*See* **FIGURE 3**). Under these experimental conditions, CD26 released GP-OH in a time-dependent manner from GPG-NH_2, and virtually completely converted GPG-NH_2 to GP-OH and G-NH_2 within 4 to 6 hrs of the reaction. In contrast, CD26 was unable to release G-NH_2 from PyrroQ-PG-NH_2.

Next, the conversion of radiolabeled [^{14}C]GPG-NH_2 to [^{14}C]G-NH_2 by purified CD26, fetal bovine serum (FBS), human serum (HS) and CEM cell suspensions was analyzed. Radiolabeled [^{14}C]GPG-NH_2 (radiospecificity: 58 mCi/mmol), in which the radiolabeled carbon is located in the main chain carbon of the glycine at the carboxylic acid end of the tripeptide, and [^{14}C]G-NH_2 (radiospecificity: 56 mCi/mmol) in which carbon-2 was radiolabeled were synthesized by Amersham Pharmacia Biotech (Buckinghamshire, England). A variety of these [^{14}C]GPG-NH_2 concentrations were exposed to purified CD26, FBS, HS and CEM cell suspensions and the conversion to G-NH_2 was analyzed.

In one set of experiments, for example, five-ml CEM cell cultures (5 x 10^5 cells/ml) were exposed to 20 μM [^{14}C]GPG-NH_2 for 24 hrs. Then, the cells were centrifuged for 10 min at 1,200 rpm, washed, and the cell pellet was treated with 60% ice-cold methanol for 10 min. The methanol cell extract was centrifuged for 10 min at 15,000 rpm, after which the supernatant was injected on a cation exchange Partisphere-SCX column (Whattman) to separate GPG-NH_2 from G-NH_2. The following gradient was used: 0-15 min: isocratic buffer A (7 mM sodium phosphate, pH 3.5); 15-40 min linear gradient from buffer A to buffer B (250 mM sodium phosphate, pH 3.5); 40-45 min linear gradient from buffer B to buffer A; 45-55 min: isocratic buffer A. The retention time of [^{14}C]GPG-NH_2 and [^{14}C]G-NH_2 under these elution conditions were 26-28 min and 14-16 min, respectively.

In another set of experiments, after one hour of exposure, disappearance of intact [^{14}C]GPG-NH_2 was determined by HPLC analysis, as described above, using a cation-exchange Partisphere SCX column and a sodium phosphate buffer gradient at pH 3.5. GPG-NH_2 was well-separated from G-NH_2 (retention times: 25-27 min and 15-17 min, respectively). The K_m value of CD26-catalyzed conversion of GPG-NH_2 to G-NH_2 was calculated to be 0.183 mM. The estimated K_m values of GPG-NH_2 for dipeptidylpeptidase activity associated with HS and FBS were 0.45 and 1.4 mM, respectively, as derived from the GPG-NH_2 disappearance curves depicted in **FIGURE 4**. The GPG-NH_2 conversion by the CEM cell suspensions proceeded linearly up to 1.5 mM. Only at higher GPG-NH_2 concentrations (*e.g.*, 3 and 5.4mM), did the conversion curve for the CEM cell suspensions start to level-off slightly.

Next, the inhibitory effect of L-isoleucinepyrrolidine (IlePyr) on CD26 was analyzed. Isoleucinepyrrolidine (IlePyr) has recently been reported to be a relatively potent and selective

inhibitor of purified CD26-associated dipeptidylpeptidase activity. (*See* De Meester, *J. Immunol. Methods*, 189:99-105 (1996)). All enzyme activity assays were performed in 96-well microtiter plates (Falcon, Becton Dickinson, Franklin Lakes, NJ). To each well were added 5µl purified CD26 in PBS (final concentration of 0.2 milliUnits/200µl-well), 10µl fetal bovine serum (BS) (final concentration: 5% in PBS; preheated at 56°C for 30 min), or one million CEM cells in PBS, 5µl of an appropriate concentration of the IlePyr inhibitor solution in PBS (500 and 200µM) and PBS to reach a total volume of 150µl. The reaction was started by the addition of 50µl substrate GP-pNA at 4 mg/ml (final concentration in the 200 µl reaction mixture: 1 mg/ml or 3 mM) and carried out at 37°C. The 50% inhibitory concentration of IlePyr against dipeptidylpeptidase activity associated with CD26, BS and CEM cell suspensions was defined as the compound concentration required to inhibit the enzyme-catalyzed hydrolysis of GP-pNA to pNA and GP-OH by 50%.

In initial experiments, CD26 inhibition in CEM cell suspensions (in fetal bovine serum) subjected to IlePyr using GP-pNA as the substrate was analyzed. Purified CD26 was included as a positive control. (*See* **FIGURE 5**). The inhibitor IlePyr dose-dependently prevented release of p-nitroaniline from GP-NA exposed to CEM cell suspensions as well as to fetal bovine serum at a 50% inhibitory concentration (IC_{50}) of 110 and 99µM, respectively. Purified CD26 was inhibited at an IC_{50} value of 22µM. Thus, the 50% inhibitory concentration (IC_{50}) value of the inhibitor IlePyr exposed to serum and CEM cell suspensions was ~ 5-fold higher than the inhibitor concentrations required to inhibit purified CD26 by 50%.

Then, experiments were conducted to determine if the antiretroviral activity observed with GPG-NH_2 was associated with the CD26-catalyzed release of G-NH_2 from the tripeptide derivative. HIV-1-infected CEM cell cultures were exposed to different concentrations of GPG-NH_2 in the presence of non-toxic concentrations of IlePyr (500µM and 200µM). Similar combinations of G-NH_2 with IlePyr were included in this study. In these experiments, the CD26-specific inhibitor L-isoleucinepyrrolidine (IlePyr), was added to each cell culture microplate prior to the addition of the test compounds and the virus-infected cells.

In contrast with G-NH_2, which fully preserved its anti-HIV activity in CEM cell cultures in the presence of 200 and 500µM of IlePyr (EC_{50}. 35-43µM), GPG-NH_2 markedly lost its inhibitory activity against virus-induced cytopathicity in the presence of the specific CD26 inhibitor. (*See* **FIGURE 6**). The highest inhibitor concentration (500µM) was slightly more efficient in reversing the anti-HIV-1 activity of the tripeptide GPG-NH_2 than the lower (200µM) inhibitor concentration. A similar result was observed for Sar-GP-NH_2, another tripeptide amide derivative that is also endowed with antiretroviral activity in cell culture.

The results presented this example, demonstrate that GPG-NH_2 requires hydrolysis to release glycinamide before it is able to exert its anti-HIV activity in cell culture. The data also provide evidence that the release of G-NH_2 from GPG-NH_2 is induced by the enzymatic activity of

the lymphocyte surface glycoprotein activation/differentiation marker CD26. The formation of G-NH_2 from GPG-NH_2 was conducted with purified CD26, human T-lymphocyte cell suspensions and human and bovine serum. Moreover, the pronounced antiviral activity of Q-PG-NH_2, the complete lack of antiviral activity of PyrQ-PG-NH_2 (that is resistant to enzymatic attack by CD26) and the loss of antiviral efficacy of GPG-NH_2 and Sar-GP-NH_2 in the presence of a specific inhibitor of CD26 provide strong evidence that GPG-NH_2 acts as an efficient prodrug of G-NH_2 and that CD26-catalyzes the conversion of GPG-NH_2 to G-NH_2.

Accordingly, it was discovered that the lymphocyte surface glycoprotein CD26, which is a membrane associated dipeptidyl peptidase, is the enzyme responsible for metabolizing GPG-NH_2, QPG-NH_2, and sarcosylprolylglycinamide (SAR-PG-NH_2) to G-NH_2, for example. More evidence that CD26 was responsible for metabolizing peptide amides into a form that inhibits the replication of HIV was obtained from experiments that employed the selective CD26 inhibitor L-isoleucinepyrrolidine (IlePyr), wherein a significant reduction in the anti-HIV activity of GPG-NH_2 and SAR-PG-NH_2 was observed. The IlePyr inhibitor had no affect on the ability of G-NH_2 to inhibit replication of HIV, however. Thus, X-Pro-glycinamide-containing peptide amides are antiretroviral prodrugs or precursors that are metabolized by the lymphocyte surface glycoprotein CD26 to G-NH_2. The next section describes the discovery that glycinamide inhibits replication of HIV in greater detail.

Glycinamide inhibits the replication of HIV

Initially, it was determined that G-NH_2 efficiently inhibits the replication of HIV but compounds that are similar in structure do not. HIV-1 (III_B)-infected CEM cell cultures were incubated with various concentrations of G-NH_2 or various concentrations of a compound that has a structure similar to G-NH_2 and the inhibition of HIV replication was evaluated using standard procedures. These experiments are described in the next example.

EXAMPLE 2

Human T-lymphocytic CEM cells (approx. 4.5 X 10^5 cells/ml) were suspended in fresh medium and were infected with HIV-1 (III_B) at approx. 100$CCID_{50}$ per ml of cell suspension (1$CCID_{50}$ being the virus dose infective for 50% of the cell cultures). Then, 100µl of the infected cell suspension was transferred to individual wells of a microtiter plate (100µl/well) and was mixed with 100µl of freshly diluted test compound (2000, 400, 80, 16, 3.2, or 0.62µM). Subsequently, the mixtures were incubated at 37°C. After 4 to 5 days of incubation, giant cell formation was recorded microscopically in the CEM cultures. The 50% effective concentration (EC_{50}) corresponded to the concentrations of the compounds required to prevent syncytium formation in the virus-infected CEM cell cultures by 50%.

The results of these experiments are shown in **TABLE 2**. Glycinamide was found to be the only compound that appreciably inhibited HIV replication in the cell culture. The EC_{50} for G-NH_2 was approximately 21.3μM, whereas the other compounds tested showed no inhibition of HIV. These results confirmed that G-NH_2 has a particular structure that inhibits HIV replication.

TABLE 2

Inhibitory activity of compounds against HIV-1(III_B) in CEM cell cultures

	$EC_{50}(\mu M)^a$
Glycinamide	21.3 ± 16.3
Glycin-thioamide	> 500
Cyclic glycin-thioamide	> 500
L-Alaninamide	> 500
L-Leucinamide	> 500
L-Isoleucinamide	> 500
L-Valinamide	> 500
L-Lysinamide	> 500
L-Asparaginamide	> 500
L-Val β-naphthylamide	> 100
Ala-Pro-Gly-Trp-amide	> 500
DL-Leucinamide	> 500
DL-Tryptophanamide	> 500
L-Tyrosinamide	> 500
D-Asparagine	> 500
L-Phenylalaninamide	> 500
L-Methioninamide	> 500
L-Threoninamide	> 500
L-Argininamide	> 500
L-Tryptophanamide	> 200
L-Prolinamide	> 1000
L-Asparaginamide	> 1000
DL-Phenylalaninamide	> 1000
D-Leucine	> 1000
Sarcosinamide	> 1000
L-Serinamide	> 1000
L-Alanine	> 500
L-Leucine	> 500
L-Proline	> 500
Glycine	> 500
1,3-diaminoaceton	> 1000
Ethylene diamine	> 1000
1,4-diamino-2-butanone	-
1,3-diamino-2-hydroxypropane	> 1000
DL-2,3-diaminopropionic acid	> 1000
Glycine methylamide	> 500

[a]50% effective concentration

Subsequent analysis revealed that G-NH_2 was a specific inhibitor of HIV. The cytotoxicity and antiviral activity of various concentrations of G-NH_2 and GPG-NH_2 were evaluated in cell cultures that were infected with various types of viruses. Conventional host cell culture, viral infection, and infectivity analysis for each different type of cell and virus were followed. Compounds that were known to inhibit replication of the particular types of viruses analyzed were used as controls.

TABLES 3-5 show the results of these experiments. The data show that G-NH_2 and GPG-NH_2 were ineffective at inhibiting the replication of Herpes simplex virus-1 (KOS), Herpes simplex virus-2 (G), Herpes simplex virus-1 TK^- KOS ACV^r, Vaccinia virus, Vesicular stomatis virus, Coxsackie virus B4, Respiratory syncytial virus, Parainfluenza-3 virus, Reovirus-1, Sindbis virus, and Punta Toro virus. These results confirmed that G-NH_2 and GPG-NH_2 are selective inhibitors of HIV.

TABLE 3

Cytotoxicity and antiviral activity of compounds in HEL cell cultures

Compound	Minimum Cytotoxic Concentration[a] (μg/ml)	Minimum inhibitory concentration[b]				
		Herpes simplex virus-1 (KOS)	Herpes simplex virus-2 (G)	Vaccinia virus	Vesicular stomatitis virus	Herpes simplex virus-1 TK^- KOS ACV^r
G-NH_2 (μM)	>2000	>2000	>2000	>2000	>2000	>2000
GPG-NH_2 (μM)	>400	>400	>400	>400	>400	>400
BVDU (μg/ml)	>400	0.0256	>400	0.64	400	400
Ribavirin (μg/ml)	>400	48	>400	240	>400	80
ACG (μg/ml)	>400	0.0768	0.0768	>400	>400	9.6
DHPG (μg/ml)	>100	0.0038	0.0192	60	>400	0.48

[a]Required to cause a microscopically detectable alteration of normal cell morphology.
[b]Required to reduce virus-induced cytopathogenicity by 50%.

TABLE 4

Cytotoxicity and antiviral activity of compounds in HeLa cell cultures

Compound	Minimum cytotoxic concentration[a] (μg/ml)	Minimum inhibitory concentration[b]		
		Vesicular stomatitis virus	Coxsackie virus B4	Respiratory syncytial virus
G-NH_2 (μM)	>2000	>2000	>2000	>2000
GPG-NH_2 (μM)	>400	>400	>400	>400
Brivudin (μg/ml)	≥400	>400	>400	>400
(S)-DHPA (μg/ml)	>400	240	>400	>400
Ribavirin (μg/ml)	>400	9.6	48	16

[a]Required to cause a microscopically detectable alteration of normal cell morphology.
[b]Required to reduce virus-induced cytopathogenicity by 50%.

TABLE 5

Cytotoxicity and antiviral activity of compounds in Vero cell cultures

Compound	Minimum cytotoxic concentration[a] (μg/ml)	Minimum inhibitory concentration[b]				
		Parainfluenza-3 virus	Reovirus-1	Sindbis virus	Coxsackie virus B4	Punta Toro virus
G-NH_2 (μM)	>2000	>2000	>2000	>2000	>2000	>2000
GPG-NH_2 (μM)	>400	>400	>400	>400	>400	>400
BVDU (μg/ml)	>400	>400	>400	>400	>400	>400
(S)-DHPA (μg/ml)	>400	240	80	>400	>400	>400
Ribavirin (μg/ml)	>400	48	16	>400	>400	48

[a]Required to cause a microscopically detectable alteration of normal cell morphology.
[b]Required to reduce a virus-induced cytopathogenicity by 50%.

It has also been discovered that G-NH_2 is itself a prodrug or precursor that is metabolized by an enzyme or cofactor(s) present in the plasma and sera of some animals to one or more compounds (*e.g.*, cyclic, charged, or uncharged forms of glycinamide) that inhibit the replication of HIV. The section below describes this discovery in greater detail.

Cofactor(s) present in the plasma and sera of some animals converts G-NH_2 to a metabolite that inhibits HIV

Evidence is provided herein that at least one cofactor present in the serum and plasma of some animals metabolizes G-NH_2 to an active form ("modified glycinamide" or Metabolite X), which is transported into cells and inhibits the replication of HIV. Accordingly, G-NH_2 is a precursor or prodrug for an antiretroviral compound and G-NH_2 can be formulated for administration with said cofactor or a material containing said cofactor. Chromatographic methods were used to isolate this cofactor. This cofactor can be purified, cloned, and sequenced using the approaches described herein and conventional techniques in molecular biology. Accordingly, some embodiments include a pharmaceutical or nutriceutical preparation containing G-NH_2 or a compound that metabolizes to G-NH_2 (*e.g.*, GPG-NH_2) formulated in a mixture or administered in conjunction (before or after administration of G-NH_2) with a material that converts G-NH_2 to Metabolite X (*e.g.*, pig serum, plasma, or milk, horse serum, plasma, or milk, bovine serum, plasma, or milk in purified, enriched, or isolated form).

The active form of G-NH_2 (modified glycinamide or Metabolite X) is readily produced by incubation of G-NH_2 in certain serums or plasma and the modified glycinamide is easily isolated by the chromatographic methods described *infra*. Throughout this disclosure, glycinamide metabolites (the antiretrovirally active forms of glycinamide) are collectively referred to as "modified glycinamide," "modified G-NH_2," or "fast peak glycinamide." Examples of modified G-NH_2 include, but are not limited to α-hydroxyglycinamide, α-peroxyglycinamide dimer (NH_2-gly-O-O-gly-NH_2), diglycinamide ether (NH_2-gly-O-gly-NH_2), α-methoxyglycinamide, α-ethoxyglycinamide, and salts and/or derivatives of these compounds. Mass spectrometry and nuclear magnetic resonance (NMR) spectrometry analysis of the modified glycinamide peak fraction isolated after chromatographic separation revealed that it contained α-hydroxyglycinamide. The compound α-peroxyglycinamide dimer (NH_2-gly-O-O-gly-NH_2) may be more stable than α-hydroxyglycinamide and both α-hydroxyglycinamide and α-methoxyglycinamide have been prepared by organic synthesis. Those of skill in the art can readily prepare other modified glycinamide compounds using the procedures described herein and other available synthetic approaches. (*See e.g.*, JP 5097789A2 to Hayakawa *et al.*, entitled "Alpha-hydroxyglycinamide Derivative and its Preparation," filed October 3, 1991). HIV infectivity studies conducted in the

presence of synthetically or enzymatiucally produced AlphaHGA (α-hydroxyglycinamide) revealed that the compound effectively inhibited HIV replication in human serum.

Formulation of the modified G-NH_2 into pharmaceuticals and medicaments, whether the modified G-NH_2 is synthetically produced or produced enzymatically by incubation of G-NH_2 in serum, is straightforward. Accordingly, antiretroviral pharmaceuticals and medicaments can be prepared by providing a modified glycinamide compound (*e.g.*, a compound provided by formulas A, B, C, D, E, F, G, H, or I) or a pharmaceutically acceptable salt thereof in either enantiomer (L or D) or both or either isomer (R or S) or both. Preferred compounds for formulation into an antiretroviral pharmaceutical or medicament include, for example, α-hydroxyglycinamide (formula C), α-peroxyglycinamide dimer (formula E), diglycinamide ether (formula F), and alpha-methoxyglycinamide, or pharmaceutically acceptable salts thereof in either enantiomer (L or D) or both or either isomer (R or S) or both. The antiretroviral pharmaceuticals and medicaments describe herein can be provided in unit dosage form (*e.g.*, tablets, capsules, gelcaps, liquid doses, injectable doses, transdermal or intranasal doses) and can contain, in addition to the modified glycinamide compound, a pharmaceutically acceptable carrier or exipient. Containers comprising said pharmaceuticals and medicaments (*e.g.*, sterile vials, septum sealed vials, bottles, jars, syringes, atomizers, swabs) whether in bulk or in individual doses are also embodiments and, preferably, said formulations are prepared according to certified good manufacturing processes (GMP) (*e.g.*, suitable for or accepted by a governmental regulatory body, such as the Federal Drug Administration (FDA)) and said containers comprise a label or other indicia that reflects approval of said formulation from said governmental regulatory body. Nutriceuticals containing said compounds with or without structure-function indicia are also embodiments, however.

Some embodiments are a preparation for the inhibition of HIV that consists of or is enriched with a modified glycinamide compound (*e.g.*, pharmaceuticals and medicaments for the inhibition of HIV, which consist of, consist essentially of, or comprise, a modified glycinamide compound in an isolated, purified, or synthetic form in an amount that inhibits replication of the virus.) Preferred embodiments include a pharmaceutical or medicament that consists of, consists essentially of, or comprises α-hydroxyglycinamide, α-peroxyglycinamide dimer (NH_2-gly-O-O-gly-NH_2), diglycinamide ether (NH_2-gly-O-gly-NH_2), α-methoxyglycinamide, α-ethoxyglycinamide, or derivatives of these compounds.

As used herein, "enriched" means that the concentration of the material is up to 1000 times its natural concentration (for example), advantageously 0.01%, by weight, preferably at least about 0.1% by weight. Enriched preparations from about 0.5%, 1%, 5%, 10%, and 20% by weight are also contemplated. The term "isolated" requires that the material be removed from its original environment (*e.g.*, the natural environment if it is naturally occurring). The term "purified" does not require absolute purity; rather, it is intended as a relative definition. Isolated proteins can be

conventionally purified by chromatography and/or gel electrophoresis. Purification of starting material or natural material to at least one order of magnitude, preferably two or three orders, and more preferably four or five orders of magnitude is expressly contemplated.

The following example describes an approach that was used to purify commercially obtained glycinamide. Aspects of this approach were used to purify metabolites of glycinamide produced after incubation in various animal serum, as described *infra*.

EXAMPLE 3

It was observed that when unpurified preparations of [^{14}C]G-NH_2 were separated by cation exchange high performance liquid chromatography (HPLC) two populations of G-NH_2 were resolved. (*See* **TABLE 6**). Crude preparations of radiolabeled G-NH_2 and radiolabeled GPG-NH_2 were separated by HPLC using a cation exchange column (*e.g.*, Partisphere SCX-Whattman). The following gradient was used: 0-15 minutes (isocratic Buffer A composed of 5mM ammonium phosphate, pH 3.5); 15-40 minutes linear gradient from Buffer A to Buffer B (composed of 250mM ammonium phosphate, pH 3.5); 40-45 minutes Buffer B; 45-55 minutes linear gradient to Buffer A; and 55-60 minutes isocratic Buffer A to equilibrate the column for the next run.

By this separation approach, the majority of crude [^{14}C]GPG-NH_2 typically eluted in 26-28 minutes (fractions 26-28), however, trace amounts of radiolabeled compounds eluted in 20-22 minutes (fractions 20-22), 15-17 minutes (fractions 15-17), and 2-3 minutes (fractions 2-3). Approximately 89% of the crude [^{14}C]G-NH_2 typically eluted in 15-17 minutes (fractions 15-17) but approximately 11% of the crude [^{14}C]G-NH_2 eluted in 2-3 minutes (fractions 2-3). Trace amounts of crude [^{14}C]G-NH_2 were also detected in fractions 20-22 and fractions 5-6.

Slight alterations in the buffers and the gradient led to slight shifts in the time of elution of the compounds but, in all preparations, two main populations of glycinamide were detected, a first population that quickly eluted from the column (referred to as the fast peak, fraction 2-3 or fraction 3-4, or impurity in radiolabeled G-NH_2, or modified G-NH_2) and a second population that strongly bound to the column (referred to as the slow peak, fraction 13-14 or fraction 15-17 or G-NH_2). For example, another protocol to isolate modified G-NH_2 used also Buffer A (5mM ammoniumphosphate pH 3.5) and Buffer B (250mM ammoniumphosphate pH 3.5). The gradient used with these buffers was as follows: 10 minutes Buffer A; linear gradient to Buffer B for 6 minutes; 2 minutes at Buffer B; then linear gradient to Buffer A for 6 minutes; and equilibration in Buffer A for 6 minutes. By this approach, as well, the G-NH_2, and impurity in radiolabeled G-NH_2 eluted at 10-11 minutes and 2-3 minutes, respectively.

TABLE 6

Purity of [^{14}C]radiolabeled stock of GPG-NH_2 and G-NH_2

Drug	Fraction Number on HPLC (cation exchange)					Total
	2-3	5-6	15-17	20-22	26-28	
G-NH_2	53,000 (11%)	1,700 (<0.5%)	435,000 (89%)	1,300 (<0.5%)	-	490,000 (100%)
GPG-NH_2	5,100 (1.5%)	-	700 (<0.5%)	10,600 (3%)	339,000 (95%)	355,400 (100%)

In this example, an approach to purify commercially obtained G-NH_2 is provided. A modification of this approach has been used to purify modified glycinamide, as described *infra*. It should be understood that many different cation exchange columns are available for these procedures and many different buffers and gradients can be used. Given the disclosure herein, one of skill in the art can rapidly adapt a particular type of cation exchange column, FPLC or HPLC, buffer, or gradient to isolate modified G-NH_2 (Metabolite X). That is, modifications of the procedures described above are within the skill in the art and are equivalent to the methods described herein.

As discussed in the sections that follow, it was discovered that modified G-NH_2 (fractions 2-3) can be made from unmodified G-NH_2 (fractions 15-17) by incubating unmodified G-NH_2 in various serums or plasma. Modified G-NH_2 that is made in this manner (enzymatically prepared) can then be isolated using one of the approaches above. Using conventional techniques in structure analysis, it was determined that the modified G-NH_2 isolated by the chromatographic procedure above comprised α-hydroxyglycinamide.

Initially, it was observed that if cell culture medium containing fetal bovine serum was heated for 30 minutes at 95°C, the ability of G-NH_2 to inhibit the replication of HIV was lost. In some experiments, human T-lymphocytic CEM cells (approx. 4.5 X 10^5 cells/ml) were suspended in fresh medium and were infected with HIV-1 (III_B) at approx. 100$CCID_{50}$ per ml of cell suspension. Subsequently, the infected cells were provided various concentrations of G-NH_2 that had been dissolved in serum (10% fetal bovine serum in PBS) containing RPMI-1640 medium or G-NH_2 that had been dissolved in heat inactivated serum (10% fetal bovine serum in PBS that had been heated to 95°C for 30 minutes) containing RPMI-1640 medium. The cell resuspensions were then incubated at 37°C and, after 4 to 5 days, HIV replication was evaluated. It was discovered that the G-NH_2 that had been incubated in heat inactivated serum containing medium had lost its ability to inhibit the replication of HIV. These results provided strong evidence that a heat labile protein present in serum metabolized G-NH_2 to a modified G-NH_2 form that inhibited replication of HIV.

Following the discovery that a heat labile cofactor(s), present in fetal calf serum, could convert G-NH_2 to a antiretrovirally-active form of glycinamide, experiments were conducted to determine if this cofactor(s) was present in human serum and sera from other animals. The following example describes these experiments in greater detail.

EXAMPLE 4

Several lots of human sera and fetal bovine sera were analyzed for their ability to convert G-NH_2 to modified G-NH_2. Radiolabeled cation exchange HPLC purified G-NH_2 (*see* **EXAMPLE 3**) was incubated with the various sera at a 10% final concentration in PBS at 37°C for 15 minutes and 1, 6, 24, or 72 hours. Subsequently, the amount of radiolabeled modified G-NH_2 was evaluated using the cation exchange HPLC approach described above. The results are shown in **FIGURE 7**. Each of the 10 different human serum samples showed less than 10% conversion of G-NH_2 to modified G-NH_2 after 24 hours of incubation. All of the fetal bovine sera tested showed significant conversion of G-NH_2 to modified G-NH_2 after 6 hours (6-10%) and 24 hours (18-32%) of incubation. The results confirmed that fetal bovine sera contained the cofactor(s) that significantly metabolizes G-NH_2 to modified G-NH_2 but human serum does not.

Next, an evaluation of sera obtained from other animals was analyzed for their ability to convert G-NH_2 to modified G-NH_2. Serum obtained from pigs (PS), mice (MS), dogs (CS), cats (FS), horse (ES), and monkey (SS) was incubated with HPLC purified G-NH_2 and at 15 minutes, 1 hour, 6 hours, and/or 24 hours an aliquot of the mixture was removed and analyzed by cation exchange HPLC, as described above. Approximately a 10% dilution of serum in PBS was used. As shown in **FIGURE 8**, the sera obtained from pigs, dogs, cats, horse, and monkeys rapidly converted G-NH_2 to modified G-NH_2, whereas, the mice serum poorly metabolized G-NH_2. The data showed that although several animals were able to metabolize G-NH_2 to modified G-NH_2, the ability of the cofactor(s) to metabolize G-NH_2 was not evolutionarily conserved in humans and mice.

Several experiments were also performed to better characterize the cofactor(s) found in pig plasma. In one set of experiments, pig plasma was dialyzed (MW cut off 10,000) and the dialysate was evaluated for the ability to convert G-NH_2 to modified G-NH_2. Various concentrations of G-NH_2 were mixed with either 90% pig plasma or 90% dialyzed pig plasma and were incubated for 24 hours at 37°C. Subsequently, aliquots of the mixtures were separated by cation exchange HPLC, as described previously, and the conversion of G-NH_2 to modified G-NH_2 was evaluated. **TABLE 7** shows the results of these experiments. The data show that the conversion of G-NH_2 to modified G-NH_2 was almost identical in both the pig plasma and dialyzed pig plasma samples. Saturation of the enzyme activity of cofactor(s) in pig plasma (90% in PBS) occurred between 1,000μM and 10,000μM G-NH_2. These results provided more evidence that the cofactor(s) that metabolizes G-NH_2 to modified G-NH_2 is a protein found in plasma or serum.

TABLE 7

Conversion of G-NH_2 to modified G-NH_2 by dialyzed pig plasma (24 hr)

Concentration G-NH_2 (μM)	conversion to modified G-NH_2 (24 hr) (percent conversion)	
	Pig plasma[a]	Dialysed Pig plasma
18	99.7	99.8
100	99.7	99.8
1,000	98.7	99.8
10,000	~24.5	24.7

[a]Plasma: 90% in PBS.

In another set of experiments, the saturation point of the cofactor(s) found in dialyzed pig plasma was more closely scrutinized. Dialyzed pig plasma (90% in PBS) was mixed with concentrations of G-NH_2 between 2,000μM and 10,000μM. Subsequently, the mixtures were incubated at 37°C for 6 hours and aliquots were separated by cation exchange HPLC, as before. The results shown in **TABLE 8** confirmed that the saturation point of the cofactor(s) in pig plasma was near 2,000μM G-NH_2.

TABLE 8

Conversion of G-NH_2 to modified G-NH_2 by dialyzed pig plasma[a] (6 hr)

Concentration G-NH_2 (μM)	Percent conversion	μM formation
2,000	82.6	1,652
4,000	42.1	1,684
6,000	24.9	1,494
8,000	21.0	1,680
10,000	17.0	1,700

[a]Plasma: 90% in PBS.

Amino acid competition studies were also employed to determine if the cofactor(s) present in pig serum was specific for G-NH_2. In these experiments, approximately 10% pig serum in PBS was incubated for 6 hours at 37°C in the presence of 18μM G-NH_2 and a competitor (10μM, 40μM, 100μM, 400μM, 1000μM, 4,000μM, or 10,000 μM glycine, 10,000μM L-serine-NH_2, 10,000μM L-alanine-NH_2, 1000μM, 4,000μM, or 10,000μM GPG-NH_2). A control without competitor was also evaluated. Subsequently, the conversion of G-NH_2 to modified G-NH_2 was analyzed by cation exchange HPLC, as before. The results shown in **FIGURE 9** provided evidence that the cofactor(s) present in pig serum was specific for G-NH_2 although GPG-NH_2 seemed also to have an inhibitory effect on the G-NH_2 conversion.

Once it had been confirmed that certain sera contained the cofactor(s) that could convert G-NH_2 to modified G-NH_2, experiments were conducted to isolate the cofactor(s). The example below describes these experiments in greater detail.

EXAMPLE 5

In a first set of experiments designed to isolate the cofactor(s) that converts G-NH_2 to modified G-NH_2, size exclusion chromatography (Superdex 200) was employed to separate the components present in fetal bovine serum. The separation was for 60 minutes in milli Q water and 30 fractions (0.5ml/min) were collected. The presence of cofactor(s) in the various fractions was ascertained by incubating an aliquot of the isolated fraction with HPLC purified G-NH_2 followed by an analysis of the presence or absence of modified G-NH_2, as determined by cation exchange HPLC. As shown in **FIGURE 10**, the majority of the cofactor eluted from the size exclusion column in fractions 10-12. Fractions 10-12 were found to efficiently convert G-NH_2 to modified G-NH_2, as determined by monitoring the accumulation of modified G-NH_2 by HPLC cation exchange chromatography, as described previously. Fractions 10-12 were also found to restore the anti-HIV activity of G-NH_2 in heated serum. The activity detected in later fractions may be a result of partially degraded co-factor or cofactor that non-specifically interacted with the resin employed. This data confirmed that the cofactor that converts G-NH_2 to modified G-NH_2 had been isolated. The cofactor can now be purified, sequenced, and cloned using conventional techniques in protein purification and molecular biology.

After incubating the G-NH_2 with serum, the modified G-NH_2 can be isolated from G-NH_2 using cation exchange HPLC, by chromatography (*e.g., see* **EXAMPLE 3**), and the anti-HIV activity of purified, modified G-NH_2 (fractions 2-3) and purified G-NH_2 (fractions 15-17) can be compared in a conventional HIV infectivity assay. The effects of modified glycinamide compounds (*e.g.*, α-hydroxyglycinamide, α-peroxyglycinamide dimer (NH_2-gly-O-O-gly-NH_2), diglycinamide ether (NH_2-gly-O-gly-NH_2), α-methoxyglycinamide, α-ethoxyglycinamide, and/or derivatives thereof), on HIV replication can also be analysed in this manner.

For example, the EC_{50} for the purified, modified G-NH_2 (fractions 2-3), purified G-NH_2 (fractions 15-17), α-hydroxyglycinamide, α-peroxyglycinamide dimer (NH_2-gly-O-O-gly-NH_2), diglycinamide ether (NH_2-gly-O-gly-NH_2), α-methoxyglycinamide, and α-ethoxyglycinamide or a derivative thereof is determined using the HIV infectivity assay described previously. Briefly, human T-lymphocytic CEM cells (approx. 4.5 X 10^5 cells/ml) are suspended in fresh medium and are infected with HIV-1 (III_B) at approx. 100$CCID_{50}$ per ml of cell suspension. Then, 100µl of the infected cell suspension is transferred to individual wells of a microtiter plate (100µl/well) and is mixed with 100µl of freshly diluted modified G-NH_2 (fraction 2-3), G-NH_2 (fraction 15-17), α-hydroxyglycinamide, α-peroxyglycinamide dimer (NH_2-gly-O-O-gly-NH_2), diglycinamide ether (NH_2-gly-O-gly-NH_2), α-methoxyglycinamide, α-ethoxyglycinamide, or a derivative thereof (*e.g.*, 2000, 400, 80, 16, 3.2, and 0.62 µM). Subsequently, the mixtures are incubated at 37°C. After 4 to

5 days, giant cell formation is recorded microscopically in the CEM cultures. The 50% effective concentration (EC_{50}) is then determined.

The results from this set of experiments will show that modified G-NH_2 (fraction 2-3), α-hydroxyglycinamide, α-peroxyglycinamide dimer (NH_2-gly-O-O-gly-NH_2), diglycinamide ether (NH_2-gly-O-gly-NH_2), α-methoxyglycinamide, α-ethoxyglycinamide, or the derivative thereof has a comparable or lower EC_{50} than G-NH_2 (fraction 15-17). For example, modified G-NH_2, α-hydroxyglycinamide, α-peroxyglycinamide dimer (NH_2-gly-O-O-gly-NH_2), diglycinamide ether (NH_2-gly-O-gly-NH_2), α-methoxyglycinamide, α-ethoxyglycinamide, and the derivative will have an EC_{50} of approximately 25μM or less, whereas, G-NH_2 will have an EC_{50} of approximately 30μM. These experiments will provide more evidence that G-NH_2 is metabolized to modified G-NH_2, which is the active form of the anti-viral agent.

As another example, the ability of modified G-NH_2 to inhibit the replication of HIV in heat inactivated serum (30 minutes at 95°C) or human serum-containing medium is compared. Human T-lymphocytes (*e.g.*, approx. 4.5 X 10^5 cells/ml of CEM cells) are suspended in fresh medium containing fetal bovine serum and are infected with HIV-1 (III_B) at approx. 100$CCID_{50}$ per ml of cell suspension. Then, the infected cells are washed in PBS and resuspended in medium containing 10% fetal bovine serum that was heated for 30 minutes at 95°C or human serum. Next, 100μl of the infected cell suspension is transferred to individual wells of a microtiter plate (100μl/well) and is mixed with 100μl of freshly diluted purified, modified G-NH_2 (fraction 2-3), α-hydroxyglycinamide, α-peroxyglycinamide dimer (NH_2-gly-O-O-gly-NH_2), diglycinamide ether (NH_2-gly-O-gly-NH_2), α-methoxyglycinamide, α-ethoxyglycinamide, or a derivative thereof, or purified G-NH_2 (fraction 15-17) (*e.g.*, 2000, 400, 80, 16, 3.2, and 0.62 μM). Subsequently, the mixtures are incubated at 37°C. After 4 to 5 days of incubation, giant cell formation is recorded microscopically in the cultures. The 50% effective concentration (EC_{50}) is then determined. The results from this set of experiments will show that the purified, modified G-NH_2 (fraction 2-3), α-hydroxyglycinamide, α-peroxyglycinamide dimer (NH_2-gly-O-O-gly-NH_2), diglycinamide ether (NH_2-gly-O-gly-NH_2), α-methoxyglycinamide, α-ethoxyglycinamide, or a derivative thereof efficiently inhibits replication of HIV in the boiled fetal bovine serum or human serum samples, whereas purified G-NH_2 (fraction 15-17) does not. The following example describes experiments that demonstrated that enzymatically prepared α-hydroxyglycinamide (Metabolite X) effectively inhibits the replication of HIV.

EXAMPLE 6

Modified glycinamide was enzymatically produced, isolated, and analysed for its ability to inhibit the replication of HIV. Dialysis tubing (3500kD molecular weight cut-off) was shaken in distilled water with PEST buffer (RPMI with streptomycin and penicillin) for 30min at room

temperature followed by shaking in 2% sodium bicarbonate and 1mM EDTA for 30min at 60°C. The tubing was rinsed two times in distilled water with PEST. After that, the tubing was boiled in distilled water with PEST for 5min. After boiling, the tubing was transferred to a beaker filled with PBS + PEST, and stored at +4°C until used.

The tubing was used 20 days after boiling. On a sterile bench, the dialysis tubing was washed with sterile and deionised water. Approximately, 10ml of porcine serum (Promeda corp.) was added to the tubing. The tubing was put in a glass beaker filled with 200ml PBS-A/PEST (1ml PEST+1L PBS-A). The beaker was taken out of the sterile bench and placed on an orbital shaker. After 1h, the PBS-A/PEST was replaced with 200ml fresh PBS-A= "pre-wash". The tubing was pre-washed five times with five portions of PBS-A for 1h as described above. After the pre-wash, the dialysis tubing containing serum, was transferred to a sterile glass bottle filled with 100ml of sterile filtrated 1mM glycinamide (Bachem) and a magnetic stirring bar. The bottle containing the glycinamide and serum was incubated on a magnetic stirring plate at 37°C. After approximately 48h, the dialysis was stopped, the dialysis solution was divided into three portions (10ml+38ml+50ml) and was transferred to labelled glass bottles, which were sealed and frozen at –85°C. A portion of the frozen dialysis solution was then freeze dried.

The freeze-drying system (Vacuum oil (Heto 88900100), Milli-Q water, water purification equipment, Freeze-dryer, and -85°C freezer) were prepared. Frozen dialysis solution (the 38ml portion from 1-1) was transferred from the –85°C freezer to the freeze-drying chamber. The lid was placed over the chamber and the vacuum was turned on. The freeze-drying process was stopped after approximately 72h. The vacuum was turned off and the glass bottle was removed from the freeze-drying chamber.

Next, freeze-dried product was purified by HPLC. Approximately, 2L of 0.1M KH_2PO_4 (Merck no. 14873-250/Lot: A397373251) was prepared by weighing 27.22g KH_2PO_4 and dissolving it in 2L water (pH~4.06). The column (Hypersil SCX ion-exchange column 5um/250x10mm (ThermoQuest 3-34087/Batch: 5/100/5580) and HPLC-system including software D-7000 HSM) was equilibrated with mobile phase (90% 0.1M KH_2PO_4 / 10% acetonitrile (Scharlau AC0329/Batch:57048)) for 60min at 5ml/min. The UV-detector wavelength was set for 206nm. The dried dialysis "sample" was dissolved in 2ml water (19mM glycine-amide was present at the start of dialysis) and was injected and analysed (RUN-1) with a 10min isocratic run of mobile phase (see above) at 5ml/min. The injection volume for RUN 1 was approximately 100µl.

After calibration, 200µl of sample was injected nine more times (RUN-2→10) and fractions eluting at 2.5-3.1 min were collected for each run using a TIME-mode collection set for 0.1min/fraction. Between RUN-8 and 9, 1L 0.1M KH_2PO_4 was prepared by weighing 13.61g KH_2PO_4 and dissolving it in 1L water. The corresponding fractions collected in RUN-2→10, were pooled and were injected over the column (RUN-11→16). In RUN-11→16 each injection

contained approximately 100µl. The fractions were collected between 2.6-2.8min and were pooled. Approximately, 1.25mg of modified glycinamide (Metabolite X) was obtained, as determined from the amount of original glycinamide and the area of the collected peaks. The pooled 2.6-2.8min fractions in 7.5ml of mobile phase (90% 0.1M KH_2PO_4 / 10% acetonitrile) were transferred to a labelled glass bottle that was sealed and frozen at –85°C. Additionally, 7.5ml mobile phase was frozen at –85°C as a salt control. HPLC-analysis revealed that all detectable glycinamide (retention time~ 5.9min) had been converted to modified glycinamide (~2.7min). After analysis/purification, the column was washed with 40% acetonitrile / water for 31min at 5ml/min and the enzymatically prepared modified glycinamide ("Meatbolite X") was freeze-dried using the approach described above.

An HIV infectivity assay was then performed with the enzymatically prepared modified glycinamide (MetX). The lyophilised MetX (1.25mg) was dissolved in 7.5ml sterile distilled water (2.24mM MetX). Approximately, 3.7ml of 2.24mM MetX was mixed with 4.8ml each of normal and boiled RPMI++ (RPMI-medium with 10% FCS and 0.1% PEST). That is, two lots of 8.5ml of 1mM MetX were prepared. Then, approximately 3ml 1mM MetX was mixed with 3ml each of normal and boiled RPMI++ (*i.e.*, 2 x 6ml of 500uM MetX). Approximately, 1ml 500uM MetX was then mixed with 4ml each of normal and boiled RPMI++ yielding 2 x 5ml of 100uM MetX. The lyophilised salt control was dissolved and diluted exactly the same as MetX, above. A 1mM stock solution of unmodified glycinamide was also used to prepare 100µM glycinamide in normal and boiled RPMI++(controls) as described for MetX, as well.

H9 cells were counted in three A-squares of a Burke chamber (a mean of 1.2 x 10^6 cells/ml, which is 4 x 10^6 cells in 3.3ml). Approximately, 4 x 10^6 cells (3.3ml) were added to two 50ml tubes. Next, approximately 14.7ml of normal RPMI++ was added to the first tube and approximately 14.7ml boiled RPMI++ was added to the second tube (*i.e.*, 18ml H9 cells+ normal/boiled RPMI++). Then approximately 2ml of virus stock (SF2+H9, day9:22/3-02 2) was added to each 50ml tube containing the cells and medium, about 20ml/tube, and the solutions were mixed. The two virus/cell mixtures were split into two new 50ml tubes (*i.e.*, four tubes with 10ml of cell/virus (two tubes with normal RPMI++ and two with boiled RPMI++)). The cell/virus tubes were incubated at 37°C for 90min with mixing after 50min. The infection was stopped by collecting the cells (5min at 1200rpm). The cells were then resuspended and transferred to 12 10ml tubes (0.5 x 10^6 cells/tube). That is, six tubes of cells suspended in normal RPMI++ and six tubes of cells suspended in boiled RPMI++. The cells were washed with RPMI (without additives) and collected (5min at 1500rpm). The supernatants were discarded and the cells were resuspended in 4.5ml each of:

- Normal RPMI++
- Boiled RPMI++
- 100μM glycine-amide in normal RPMI++
- 100μM glycine-amide in boiled RPMI++
- 500μM MetX in normal RPMI++
- 500μM MetX in boiled RPMI++
- 100μM MetX in normal RPMI++
- 100μM MetX in boiled RPMI++
- 500μM salt in normal RPMI++
- 500μM salt in boiled RPMI++
- 100μM salt in normal RPMI++
- 100μM salt in boiled RPMI++

Approximately, 0.9ml/well of each cell suspension (four replicates of each) was added to a 48-well plate as follows:

PLATE-1:

- 4 wells with 100μM glycine-amide in normal RPMI++
- 4 wells with 100μM glycine-amide in boiled RPMI++
- 4 wells with 500μM MetX in normal RPMI++
- 4 wells with 500μM MetX in boiled RPMI++
- 4 wells with 100μM MetX in normal RPMI++
- 4 wells with 100μM MetX in boiled RPMI++

PLATE-2:

- 4 wells untreated normal RPMI++
- 4 wells untreated boiled RPMI++
- 4 wells "100μM" salt in normal RPMI++
- 4 wells "100μM" salt in boiled RPMI++
- 4 wells "500μM" salt in normal RPMI++
- 4 wells "500μM" salt in boiled RPMI++

The remaining wells were filled with sterile distilled water. The cell culture plates were incubated at 37°C and 5% CO_2. After four days the medium was changed, after eight days the medium was changed and the cells were collected. After 11 days, the infection was stopped, the cells were viewed in a 10X magnification microscope and 650μl of each cell supernatant was collected and frozen at –80°C for further analysis. After five more days, the supernatants were thawed and used in a conventional reverse transcriptase (RT) activity assay (*e.g.*, Roche

AMPLICOR MONITOR™) or a p24 quantification assay (*e.g.*, Abbott Laboratories, Chicago). (*See* U.S. Pat. No. 6,258,932 and U.S. Pat. App. No. 10/235,158). The results are shown in **FIGURE 11** and **TABLE 9**.

TABLE 9

Sample	Visible syncytia
100μM MetX in normal RPMI++	negative
100μM MetX in boiled RPMI++	negative
500μM MetX in normal RPMI++	negative
500μM MetX in boiled RPMI++	negative
100μM glycinamide in normal RPMI++ control	negative
100μM glycinamide in boiled RPMI++ control	positive
Untreated normal RPMI control	positive
Untreated boiled RPMI control	positive
100μM salt control in normal RPMI++	positive
100μM salt control in boiled RPMI++	positive
500μM salt control in normal RPMI++	negative
500μM" salt in boiled RPMI++	negative

By visual inspection, modified glycinamide (Metabolite X) effectively inhibited replication and/or propagation of HIV in the boiled fetal calf serum but glycinamide did not (**TABLE 9**). The reverse transcriptase (RT) activity data (**FIGURE 11**) confirmed that modified glycinamide (Met-X or Metabolite X) effectively inhibited replication HIV in the boiled fetal calf serum sample even though G-NH_2 was unable to inhibit replication of HIV under these conditions. That is, the antiviral activity of modified glycinamide (MetX) does not require a cofactor(s) that is present in fetal calf serum but glycinamide does. This data also indicates that the heating of the fetal calf serum denaturated the enzyme (cofactor(s)) that converts glycinamide to modified glycinamide.

In another set of related experiments, the antiretroviral activity of Metabolite X that had been dialysed five times was compared to Metabolite X prepared by the approach above. In brief, HIV infectivity assays were performed with G-NH_2 in fetal calf serum, as above, with the five-times dialysed Metabolite X and the Metabolite X prepared by the approach above. The results of these experiments are shown in **FIGURE 12**. A significant change in the activity of the five-time dialysed alpha-hydroxyglycinamide (Metabolite X), as compared to the standard preparation of the enzymatically produced alpha-hydroxyglycinamide (Metabolite X) was not observed.

The modified glycinamide obtained according to the enzymatic approach described above has been analysed by mass spectroscopy and NMR and the structure analysis revealed alpha-hydroxyglycinamide ("AlphaHGA"). Thus, the experiments in this example have shown that modified glycinamide (alpha-hydroxyglycinamide or Metabolite X) effectively inhibits the

replication of HIV in the absence of the cofactor(s) present in fetal calf serum that is required for the antiretroviral activity of G-NH_2. Alpha hydroxyglycinamide ("AlphaHGA") has also been prepared synthetically and was found to inhibit HIV replication in the absence of the cofactor(s), as described *infra*.

In more experiments, the 50% inhibitory concentration (IC_{50}) of Metabolite X was analysed in cell cultures containing fetal calf serum. The example below describes these experiments in greater detail.

EXAMPLE 7

Approximately, 0.1 x 10^6 H9 cells were infected with 50 $TCID_{50}$ HIV (SF2 virus) and the infected cells were treated with enzymatically prepared Metabolite X (*see* **EXAMPLE 6**) at various concentrations. Fetal bovine serum was included in the assay. The cells were cultured for 10 days (fresh medium was added to the cultures day 7), after which the supernatants were collected and analyzed by a conventional reverse transcriptase (RT) quantification assay. The data is shown in **FIGURE 13.** The results show that effective inhibition of HIV replication occurs at low concentrations of Metabolite X (*e.g.*, between 3.9μM – 15.6μM) and that when concentrations reach 15.6μM or higher, the inhibition of HIV replication is virtually complete.

In more experiments, enzymatically prepared modified glycinamide (Metabolite X) was incubated with HIV infected H9 cells (SF2 virus) and the morphology of the treated virus was sent to be analysed by electron microscopy. As a positive control, GPG-NH_2 was used. (*See* U.S. Pat. No. 6,258,932, for an approach to perform these type of electron microscopy experiments). The example below describes these experiments in greater detail.

EXAMPLE 8

By one approach, modified glycinamide (Metabolite X) was enzymatically prepared by the dialysis of purified G-NH_2 against pig serum (*see* **EXAMPLE 6**); the modified glycinamide was then used to treat HIV (SF2 virus) infected H9 cells, and the infected cells were sent for analysis by electron microscopy. In brief, dialysis tubing (3500 MW cut-off—Spectrum) was loaded with pig serum (Biomedia) and the pig serum was pre-dialyzed against RPMI 1640 buffer four times for one hour each to remove molecules that were less than 3500 daltons. The pre-washed serum was then dialysed against 1mM purified G-NH_2 in RPMI 1640 at 37°C for 48 hours. The dialysed buffer containing the modified G-NH_2 (Metabolite X) was then sterile filtered, aliquoted, and frozen, as described in **EXAMPLE 6.**

Next, a 100μm Metabolite X or 100μM GPG-NH_2 concentration was established in four bottles containing (each) approximately 0.5 x 10^6 H9 cells in 10 ml of RPMI (containing fetal calf serum). The cells in the samples were counted and then centrifuged. The cells were then resuspended in 10 ml of RPMI 1640 (containing fetal calf serum) and either 100μm Metabolite X or

100μM GPG-NH_2. Uninfected control and untreated control samples were also included in the experiment. The samples were then incubated overnight at 37°C at 5% CO_2.

Then, the amount of p24 in the samples was analysed using a conventional p24 detection assay (*see* U.S. Pat. No. 6,258,932). As shown in **FIGURE 14**, 100μM modified glycinamide (Metabolite X) or 100μM GPG-NH_2 effectively inhibited HIV replication in the presence of fetal calf serum; whereas, the untreated control samples showed appreciable HIV replication. These results were confirmed by a conventional reverse transcriptase (RT) activity assay, which showed appreciable amounts of reverse transcriptase activity in the untreated control samples but no reverse transcriptase activity in the samples treated with 100μM modified glycinamide or 100μM GPG-NH_2. Having verified that the samples treated with 100μM modified glycinamide or 100μM GPG-NH_2 contained virus that had been inhibited, the samples were sent to be analysed by electron microscopy.

By one approach, H9 cells that were infected by SF2 virus can be fixed in 2.5% glutaraldehyde by conventional means. The fixed cells are then postfixed in 1% OsO_4 and are dehydrated, embedded with epoxy resins, and the blocks are allowed to polymerize. Epon sections of virus infected cells are made approximately 60-80 nm thin in order to accommodate the width of the nucleocapsid. The sections are mounted to grids stained with 1.0% uranyl acetate and were analyzed in a Zeiss CEM 902 microscope at an accelerating voltage of 80 kV. The microscope is equipped with a spectrometer to improve image quality and a liquid nitrogen cooling trap iss used to reduce beam damage. The grids having sections of control GPG-NH_2 incubated cells and metabolite X incubated cells are examined in several blind studies.

The electron microscopy of untreated HIV particles will show the characteristic conical-shaped nucleocapsid and enclosed uniformly stained RNA that stretched the length of the nucleocapsid; whereas, the cells having HIV-1 particles that are treated with GPG-NH_2 or Metabolite X will show HIV-1 particles having conical-shaped capsid structures that appear to be relatively intact but the RNA was amassed in a ball-like configuration either outside the capsid or at the top (wide-end) of the capsid. Some capsids from the GPG-NH_2 or Metabolite X treated samples may be observed to have misshapen structures with little or no morphology resembling a normal nucleocapsid and the RNA may be either outside the structure or inside the structure at one end.

In still more experiments, the antiretroviral activity of G-NH_2, GPG-NH_2, enzymatically prepared modified glycinamide (Metabolite X), and synthetically prepared modified glycinamide (AlphaHGA) were compared. The example below describes these experiments in greater detail.

EXAMPLE 9

HIV infectivity assays were performed in the presence of fetal calf serum, as described in the preceding examples (*see* **EXAMPLES 6-8**), however, various concentrations of G-NH_2, GPG-NH_2, and enzymatically prepared modified glycinamide (Metabolite X), and 100μM synthetically

produced modified glycinamide (AlphaHGA) were used. (*See* **TABLE 10**). Three replicate samples ("replicates") of uninfected samples and untreated samples were also included in the experiment as controls. The inhibition of HIV replication was monitored by quantifying the levels of p24 using a conventional detection kit.

TABLE 10

Peptide	Conc.	Samples
GPG-NH_2	100μM 50μM 25μM 12.5μM 6.25μM 3.1μM 1.6μM 0.8μM	3 replicates at each concentration
G-NH_2	100μM 50μM 25μM 12.5μM 6.25μM 3.1μM 1.6μM 0.8μM	3 replicates at each concentration
Met-X (enzymatically prepared by dialysis)	100μM 50μM 25μM 12.5μM 6.25μM 3.1μM 1.6μM 0.8μM	3 replicates at each concentration
AlphaHGA (synthetically produced by Chemilia)	100μM	3 replicates

FIGURE 15 shows some of the results of these experiments. As shown, on day 11 of the experiment, the synthetically produced alpha-hydroxyglycinamide (AlphaHGA) inhibited HIV replication as effectively as GPG-NH_2 in fetal calf serum-containing media. Similar results were also observed at day 7. This data demonstrate that synthetically produced alpha-hydroxyglycinamide (AlphaHGA) effectively inhibits HIV replication.

In still more experiments, the antiretroviral activity of enzymatically prepared and synthetically prepared alpha hydroxyglycinamide, in the presence of human or fetal calf serum, were compared. The following example describes these experiments in greater detail.

EXAMPLE 10

HIV infectivity assays were performed in the presence of human serum or fetal calf serum, as described in the preceding examples (*see* **EXAMPLES 6-8**), however, various concentrations of G-NH_2, enzymatically prepared modified glycinamide (Metabolite X), and 100μM synthetically produced modified glycinamide (AlphaHGA) were used. (*See* **TABLES 11** and **12**). Three

replicates of uninfected samples and untreated samples were also included in the experiment as controls.

TABLE 11

Human serum

Peptide	Conc.	Samples
G-NH_2	100μM 50μM	3 replicates at each concentration
Met-X (enzymatically prepared by dialysis)	100μM 50μM	3 replicates at each concentration
Alpha HGA (synthetically prepared by Chemilia)	50μM	3 replicates
Uninfected control	0μM	3 replicates
Infected control	0μM	3 replicates

TABLE 12

Fetal calf serum

Peptide	Conc.	Samples
G-NH_2	100μM 50μM	3 replicates at each concentration
Met-X (enzymatically prepared by dialysis)	100μM 50μM	3 replicates at each concentration
Alpha HGA (synthetically prepared by Chemilia)	50μM	3 replicates
Uninfected control	0μM	3 replicates
Infected control	0μM	3 replicates

The results of these experiments are provided in **TABLES 13** and **14** and in **FIGURES 16A** and **16B**. The data show that on day 12, the enzymatically prepared modified glycinamide (Metabolite X), and the synthetically produced alpha-hydroxyglycinamide (AlphaHGA) inhibited HIV replication as effectively as G-NH_2 in fetal calf serum-containing media; however, only the enzymatically prepared modified glycinamide (Metabolite X), and synthetically produced alpha-hydroxyglycinamide (AlphaHGA) were able to inhibit HIV replication in human serum. That is, G-NH_2 was unable to inhibit HIV replication in human serum but both enzymatically prepared modified glycinamide (Metabolite X), and synthetically produced alpha hydroxyglycinamide (AlphaHGA) were effective inhibitors of HIV replication in human serum. Similar results were observed at day 7. This data provides strong evidence that both enzymatically prepared modified glycinamide (Metabolite X), and synthetically produced alpha hydroxyglycinamide (AlphaHGA) are potent inhibitors of HIV replication in infected humans.

TABLE 13

Fetal Calf serum

	OD1	OD2	meanOD	mean OD - blank	conc p24 (ng/ml)
100µM G-NH2 (1)	0.078	0.075	0.077	0.035	0.09
100µM G-NH2 (2)	0.071	0.069	0.070	0.028	0.08
100µM G-NH2 (3)	0.077	0.071	0.074	0.032	0.09
50µM G-NH2 (1)	0.319	0.335	0.327	0.285	0.49
50µM G-NH2 (2)	0.182	0.183	0.183	0.141	0.26
50µM G-NH2 (3)	0.105	0.103	0.104	0.062	0.14
100µM Met-X (1)	0.193	0.343	0.268	0.226	0.40
100µM Met-X (2)	0.081	0.107	0.094	0.052	0.12
100µM Met-X (3)	0.144	0.152	0.148	0.106	0.21
50µM Met-X (1)	1.105	1.089	1.097	1.055	1.71
50µM Met-X (2)	1.895	1.887	1.891	1.849	2.98
50µM Met-X (3)	2.351	2.230	2.291	2.249	3.61
50µM AlphaHGA (1)	0.183	0.185	0.184	0.142	0.26
50µM AlphaHGA (2)	0.232	0.216	0.224	0.182	0.33
50µM AlphaHGA (3)	0.147	0.139	0.143	0.101	0.20
0µM (1/500) (1)	0.691	0.717	0.704	0.662	544.90
0µM (1/500) (2)	0.673	0.637	0.655	0.613	505.98
0µM (1/500) (3)	0.544	0.568	0.556	0.514	427.33
Control (1)	0.042	0.039	0.041	-0.001	0.04
Control (2)	0.042	0.037	0.040	-0.002	0.03
Control (3)	0.046	0.045	0.046	0.004	0.04

TABLE 14

Human serum

	OD1	OD2	meanOD	mean OD - blank	conc p24 (ng/ml)
100µM G-NH2 (1/500) (1)	1.194	1.196	1.195	1.111	780.21
100µM G-NH2 (1/500) (2)	1.184	1.221	1.203	1.119	785.24
100µM G-NH2 (1/500) (3)	1.315	1.362	1.339	1.255	876.34
50µM G-NH2 (1/500) (1)	1.079	1.114	1.097	1.013	714.23
50µM G-NH2 (1/500) (2)	0.996	1.015	1.006	0.922	653.27
50µM G-NH2 (1/500) (3)	1.176	1.194	1.185	1.101	773.51
100µM Met-X (1/100) (1)	0.117	0.114	0.116	0.032	11.41
100µM Met-X (1/100) (2)	0.269	0.281	0.275	0.191	32.78
100µM Met-X (1/100) (3)	0.377	0.378	0.378	0.294	46.52
50µM Met-X (1/500) (1)	0.698	0.728	0.713	0.629	457.33
50µM Met-X (1/500) (2)	0.676	0.662	0.669	0.585	427.85
50µM Met-X (1/500) (3)	0.418	0.422	0.420	0.336	261.05
50µM AlphaHGA (1)	1.546	1.546	1.546	1.462	2.03
50µM AlphaHGA (2)	1.183	1.219	1.201	1.117	1.57
50µM AlphaHGA (3)	0.665	0.679	0.672	0.588	0.86
0µM (1/1000) (1)	0.887	0.857	0.872	0.788	1127.68
0µM (1/1000) (2)	0.827	0.791	0.809	0.725	1043.27
0µM (1/1000) (3)	0.472	0.472	0.472	0.388	591.77
Control (1)	0.095	0.089	0.092	0.008	0.08
Control (2)	0.091	0.089	0.090	0.006	0.08
Control (3)	0.081	0.089	0.085	0.001	0.07

In another series of experiments, the stability of synthetically prepared alpha-hydroxyglycinamide (AlphaHGA) to prolonged heating at 37°C was analysed. Diluted samples of synthesized AlphaHGA ($C_2H_7ClN_2O_2$), were incubated at 37°C for periods of time and then the antiretroviral activity of the incubated compound was compared to that of freshly diluted AlphaHGA. These experiments are described in greater detail in the example below.

EXAMPLE 11

HIV infectivity assays were performed in the presence of fetal calf serum, as described in the preceding examples (*see* **EXAMPLES 6-8**), however, various concentrations of G-NH_2, synthetically produced modified glycinamide (AlphaHGA), and synthetically produced modified glycinamide that had been incubated at 37°C for three days were used (AlphaHGA 37). (*See* **TABLE 15**). Three replicates of unninfected samples and untreated samples were also included in the experiment as controls.

TABLE 15

Peptide	Conc.	Samples
αHGA	32μM 16μM 8μM 4μM 2μM 1μM 0.5μM	3 replicates at each concentration
αHGA 37 (incubated at 37°C for three days)	32μM 16μM 8μM 4μM 2μM 1μM 0.5μM	3 replicates at each concentration
G-NH_2	32μM 16μM 8μM 4μM 2μM 1μM 0.5μM	3 replicates at each concentration

The results of these experiments are shown in **FIGURE 17** and **TABLE 16**. **FIGURE 17** shows a plot of the RT activity detected at day 7. Similar results were obtained when the RT activity was analysed at day 11. The data show that synthetically prepared AlphaHGA is stable to incubation at 37°C for at least three days. Very little difference in the antiretroviral activity of freshly diluted AlphaHGA and the incubated compound was observed. Further, these data show that appreciable inhibition of HIV replication occurs with synthetic AlphaHGA (whether heat-treated or not) at concentrations above 8μM, better antiretroviral activity was observed at

concentrations above 16μM, and very efficient inhibition of HIV replication was seen at concentrations above 30μM. Interestingly, the Metabolite X formed from the conversion of G-NH_2 by the fetal calf serum in the assay (*see* the data on the G-NH_2 sample) was more active than the synthetically purified AlphaHGA, which provides evidence that one enantiomer and/or isomer of AlphaHGA has more antiretroviral activity than the other.

TABLE 16

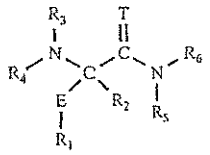
Compound	Conc. (μM)	$OD_{405-620}$	$OD_{405-620}$ - Blank	RT (pg/ml)	StAv	Conc.	mean
Control	0	0.631	0.605	6318			
	0	0.622	0.596	6221	420	0	6029
	0	0.56	0.534	5547			
G-NH2	32	*	*	*			
	32	0.155	0.129	23	2	32	21
	32	0.141	0.115	20			
	16	0.563	0.537	112			
	16	0.861	0.835	176	40	16	158
	16	0.902	0.876	185			
	8	0.274	0.248	2438			
	8	0.302	0.276	2742	315	8	2750
	8	0.332	0.306	3068			
	4	0.781	0.755	7949			
	4	0.493	0.467	4818	1682	4	6029
	4	0.539	0.513	5318			
	2	0.868	0.842	8895			
	2	0.903	0.877	9275	2252	2	7789
	2	0.528	0.502	5199			
	1	0.563	0.537	5579			
	1	0.672	0.646	6764	838	1	6514
	1	0.712	0.686	7199			
	0.5	0.871	0.845	8927			
	0.5	0.896	0.87	9199	205	0.5	9152
	0.5	0.908	0.882	9329			
αHGA	32 μM	0.269	0.243	48			
	32 μM	0.373	0.347	70	25	32	72
	32 μM	0.497	0.471	97			
	16 μM	0.189	0.163	1514			
	16 μM	0.111	0.085	666	431	16	1134
	16 μM	0.162	0.136	1221			
	8 μM	0.665	0.639	6688			
	8 μM	0.507	0.481	4971	1256	8	5300
	8 μM	0.44	0.414	4242			

	4 μM	0.541	0.515	5340			
	4 μM	0.481	0.455	4688	615	4	5315
	4 μM	0.594	0.568	5916			
	2 μM	0.786	0.76	8003			
	2 μM	0.647	0.621	6492	2397	2	5934
	2 μM	0.354	0.328	3308			
	1 μM	0.564	0.538	5590			
	1 μM	0.462	0.436	4482	945	1	4594
	1 μM	0.391	0.365	3710			
	0.5 μM	0.692	0.666	6982			
	0.5 μM	0.962	0.936	9916	2153	0.5	7539
	0.5 μM	0.576	0.55	5721			
αHGA 37	32 μM	0.198	0.172	32			
	32 μM	0.243	0.217	42	11	32	43
	32 μM	0.296	0.27	54			
	16 μM	0.171	0.145	1318			
	16 μM	0.219	0.193	1840	282	16	1641
	16 μM	0.212	0.186	1764			
	8 μM	0.549	0.523	5427			
	8 μM	0.322	0.296	2960	1654	8	3558
	8 μM	0.26	0.234	2286			
	4 μM	0.33	0.304	3047			
	4 μM	0.444	0.418	4286	909	4	4050
	4 μM	0.493	0.467	4818			
	2 μM	0.64	0.614	6416			
	2 μM	0.317	0.291	2905	1847	2	4329
	2 μM	0.387	0.361	3666			
	1 μM	0.512	0.486	5025			
	1 μM	0.473	0.447	4601	713	1	4420
	1 μM	0.384	0.358	3634			
	0.5 μM	0.891	0.865	9145			
	0.5 μM	0.496	0.47	4851	2147	0.5	6978
	0.5 μM	0.688	0.662	6938			

The section that follows describes the preparation of pharmaceuticals that contain modified glycinamide and the use of these compositions to treat, prevent, and/or inhibit replication of HIV.

Compounds that inhibit HIV

As discussed above, in addition to G-NH_2 and modified G-NH_2, certain derivatives and metabolites of G-NH_2 inhibit HIV replication and these compounds can be formulated into a medicament or pharmaceutical, which can be used to inhibit HIV replication and treat and/or prevent HIV infection. Some pharmaceuticals or medicaments consist of, consist essentially of, or comprise a compound of formula A:

(A) 

or a pharmaceutically acceptable salt, amide, ester, or prodrug thereof; wherein:

a) E is selected from the group consisting of oxygen, sulfur, and NR_7;

b) T is selected from the group consisting of oxygen, sulfur, and NR_8; and

c) R_1-R_8 are each independently selected from the group consisting of hydrogen; optionally substituted alkyl; optionally substituted alkenyl; optionally substituted alkynyl; optionally substituted cycloalkyl; optionally substituted heterocyclyl; optionally substituted cycloalkylalkyl; optionally substituted heterocyclylalkyl; optionally substituted aryl; optionally substituted heteroaryl; optionally substituted alkylcarbonyl; optionally substituted alkoxyalkyl; and optionally substituted perhaloalkyl.

Accordingly, the term "modified G-NH_2 or modified glycinamide compound" includes derivatives and metabolites of glycinamide, such as those of formula A, as described herein, whether enriched or isolated from a cell or synthetically prepared (*e.g.*, α-hydroxyglycinamide, α-peroxyglycinamide dimer (NH_2-gly-O-O-gly-NH_2), α-methoxyglycinamide, α-ethoxyglycinamide, and/or derivatives thereof).

Some of these compounds have been extracted from the HPLC column after glycinamide was incubated in serum, as described above, and identified by mass spectrometry and nuclear magnetic resonance (NMR) spectrometry. These compounds and derivatives or related compounds can be synthesized from available starting materials, as described below.

The term "pharmaceutically acceptable salt" refers to a formulation of a compound that does not cause significant irritation to an organism to which it is administered and does not abrogate the biological activity and properties of the compound. Pharmaceutical salts can be obtained by reacting a compound of the invention with inorganic acids such as hydrochloric acid, hydrobromic acid, sulfuric acid, nitric acid, phosphoric acid, methanesulfonic acid, ethanesulfonic acid, p-toluenesulfonic acid, salicylic acid and the like. Pharmaceutical salts can also be obtained by reacting a compound of the invention with a base to form a salt such as an ammonium salt, an alkali metal salt, such as a sodium or a potassium salt, an alkaline earth metal salt, such as a calcium or a magnesium salt, a salt of organic bases such as dicyclohexylamine, N-methyl-D-glucamine, tris(hydroxymethyl)methylamine, and salts with amino acids such as arginine, lysine, and the like.

The term "ester" refers to a chemical moiety with formula -$(R)_n$-COOR', where R and R' are independently selected from the group consisting of alkyl, cycloalkyl, aryl, heteroaryl (bonded through a ring carbon) and heteroalicyclic (bonded through a ring carbon), and where n is 0 or 1.

An "amide" is a chemical moiety with formula $-(R)_n-C(O)NHR'$ or $-(R)_n-NHC(O)R'$, where R and R' are independently selected from the group consisting of alkyl, cycloalkyl, aryl, heteroaryl (bonded through a ring carbon) and heteroalicyclic (bonded through a ring carbon), and where n is 0 or 1. An amide may be an amino acid or a peptide molecule attached to a molecule of the present invention, thereby forming a prodrug.

Any amine, hydroxy, or carboxyl side chain on the compounds of the present invention can be esterified or amidified. The procedures and specific groups to be used to achieve this end is known to those of skill in the art and can readily be found in reference sources such as Greene and Wuts, Protective Groups in Organic Synthesis, 3rd Ed., John Wiley & Sons, New York, NY, 1999.

A "prodrug" refers to an agent that is converted into the parent drug *in vivo*. Prodrugs are often useful because, in some situations, they may be easier to administer than the parent drug. They may, for instance, be bioavailable by oral administration whereas the parent is not. The prodrug may also have improved solubility or stability in pharmaceutical compositions over the parent drug. An example, without limitation, of a prodrug would be a compound of the present invention which is administered as an ester (the "prodrug") to facilitate transmittal across a cell membrane where water solubility is detrimental to mobility but which then is metabolically hydrolyzed to the carboxylic acid, the active entity, once inside the cell where water-solubility is beneficial. A further example of a prodrug might be a short peptide (polyaminoacid) bonded to an acid group where the peptide is metabolized to reveal the active moiety. Conventional procedures for the selection and preparation of suitable prodrug derivatives are described, for example, in *Design of Prodrugs*, (ed. H. Bundgaard, Elsevier, 1985).

The term "aromatic" refers to an aromatic group which has at least one ring having a conjugated pi electron system and includes both carbocyclic aryl (*e.g.*, phenyl) and heterocyclic aryl groups (*e.g.*, pyridine). The term includes monocyclic or fused-ring polycyclic (*i.e.*, rings which share adjacent pairs of carbon atoms) groups. The term "carbocyclic" refers to a compound which contains one or more covalently closed ring structures, and that the atoms forming the backbone of the ring are all carbon atoms. The term thus distinguishes carbocyclic from heterocyclic rings in which the ring backbone contains at least one atom which is different from carbon. The term "heteroaromatic" refers to an aromatic group which contains at least one heterocyclic ring.

As used herein, the term "alkyl" refers to an aliphatic hydrocarbon group. The alkyl moiety may be a "saturated alkyl" group, which means that it does not contain any alkene or alkyne moieties. The alkyl moiety may also be an "unsaturated alkyl" moiety, which means that it contains at least one alkene or alkyne moiety. An "alkene" moiety refers to a group consisting of at least two carbon atoms and at least one carbon-carbon double bond, and an "alkyne" moiety refers to a group consisting of at least two carbon atoms and at least one carbon-carbon triple bond. The alkyl moiety, whether saturated or unsaturated, may be branched, straight chain, or cyclic.

The alkyl group may have 1 to 20 carbon atoms (whenever it appears herein, a numerical range such as "1 to 20" refers to each integer in the given range; *e.g.*, "1 to 20 carbon atoms" means that the alkyl group may consist of 1 carbon atom, 2 carbon atoms, 3 carbon atoms, *etc.*, up to and including 20 carbon atoms, although the present definition also covers the occurrence of the term "alkyl" where no numerical range is designated). The alkyl group may also be a medium size alkyl having 1 to 10 carbon atoms. The alkyl group could also be a lower alkyl having 1 to 5 carbon atoms. The alkyl group of the compounds of the invention may be designated as "C_{1-6} alkyl" or similar designations. By way of example only, "C_{1-6} alkyl" indicates that there are one to six carbon atoms in the alkyl chain, *i.e.*, the alkyl chain is selected from the group consisting of methyl, ethyl, propyl, iso-propyl, n-butyl, iso-butyl, sec-butyl, t-butyl, pentyl (straight chain or branched), and hexyl (straight chain or branched).

The alkyl group may be substituted or unsubstituted. When substituted, the substituent group(s) is(are) one or more group(s) individually and independently selected from cycloalkyl, aryl, heteroaryl, heteroalicyclic, hydroxy, alkoxy, aryloxy, mercapto, alkylthio, arylthio, cyano, halo, carbonyl, thiocarbonyl, O-carbamyl, N-carbamyl, O-thiocarbamyl, N-thiocarbamyl, C-amido, N-amido, S-sulfonamido, N-sulfonamido, C-carboxy, O-carboxy, isocyanato, thiocyanato, isothiocyanato, nitro, silyl, trihalomethanesulfonyl, and amino, including mono- and di-substituted amino groups, and the protected derivatives thereof. Typical alkyl groups include, but are in no way limited to, methyl, ethyl, propyl, isopropyl, butyl, isobutyl, tertiary butyl, pentyl, hexyl, ethenyl, propenyl, butenyl, cyclopropyl, cyclobutyl, cyclopentyl, cyclohexyl, and the like. Wherever a substituent is described as being "optionally substituted" that substitutent may be substituted with one of the above substituents.

The substituent "R" appearing by itself and without a number designation refers to a substituent selected from the group consisting of alkyl, cycloalkyl, aryl, heteroaryl (bonded through a ring carbon) and heteroalicyclic (bonded through a ring carbon).

An "O-carboxy" group refers to a RC(=O)O- group, where R is as defined herein.

A "C-carboxy" group refers to a -C(=O)OR groups where R is as defined herein.

An "acetyl" group refers to a $-C(=O)CH_3$, group.

A "trihalomethanesulfonyl" group refers to a $X_3CS(=O)_2$- group where X is a halogen.

A "cyano" group refers to a -CN group.

An "isocyanato" group refers to a -NCO group.

A "thiocyanato" group refers to a -CNS group.

An "isothiocyanato" group refers to a -NCS group.

A "sulfinyl" group refers to a -S(=O)-R group, with R as defined herein.

A "S-sulfonamido" group refers to a $-S(=O)_2NR$, group, with R as defined herein.

A "N-sulfonamido" group refers to a $RS(=O)_2NH$- group with R as defined herein.

A "trihalomethanesulfonarnido" group refers to a $X_3CS(=O)_2NR$- group with X and R as defined herein.

An "O-carbamyl" group refers to a -OC(=O)-NR, group-with R as defined herein.

An "N-carbamyl" group refers to a ROC(=O)NH- group, with R as defined herein.

An "O-thiocarbamyl" group refers to a -OC(=S)-NR, group with R as defined herein.

An "N-thiocarbamyl" group refers to an ROC(=S)NH- group, with R as defined herein.

A "C-amido" group refers to a $-C(=O)-NR_2$ group with R as defined herein.

An "N-amido" group refers to a RC(=O)NH- group, with R as defined herein.

The term "perhaloalkyl" refers to an alkyl group where all of the hydrogen atoms are replaced by halogen atoms.

In the present context the term "aryl" is intended to mean a carbocyclic aromatic ring or ring system. Moreover, the term "aryl" includes fused ring systems wherein at least two aryl rings, or at least one aryl and at least one C_{3-8}-cycloalkyl share at least one chemical bond. Some examples of "aryl" rings include optionally substituted phenyl, naphthalenyl, phenanthrenyl, anthracenyl, tetralinyl, fluorenyl, indenyl, and indanyl. The term "aryl" relates to aromatic, preferably benzenoid groups, connected via one of the ring-forming carbon atoms, and optionally carrying one or more substituents selected from heterocyclyl, heteroaryl, halo, hydroxy, amino, cyano, nitro, alkylamido, acyl, C_{1-6} alkoxy, C_{1-6} alkyl, C_{1-6} hydroxyalkyl, C_{1-6} aminoalkyl, C_{1-6} alkylamino, alkylsulfenyl, alkylsulfinyl, alkylsulfonyl, sulfamoyl, or trifluoromethyl. The aryl group may be substituted at the *para* and/or *meta* positions. Representative examples of aryl groups include, but are not limited to, phenyl, 3-halophenyl, 4-halophenyl, 3-hydroxyphenyl, 4-hydroxyphenyl, 3-aminophenyl, 4-aminophenyl, 3-methylphenyl, 4-methylphenyl, 3-methoxyphenyl, 4-methoxyphenyl, 4-trifluoromethoxyphenyl 3-cyanophenyl, 4-cyanophenyl, dimethylphenyl, naphthyl, hydroxynaphthyl, hydroxymethylphenyl, trifluoromethylphenyl, alkoxyphenyl, 4-morpholin-4-ylphenyl, 4-pyrrolidin-1-ylphenyl, 4-pyrazolylphenyl, 4-triazolylphenyl, and 4-(2-oxopyrrolidin-1-yl)phenyl.

In the present context, the term "heteroaryl" is intended to mean a heterocyclic aromatic group where one or more carbon atoms in an aromatic ring have been replaced with one or more heteroatoms selected from the group comprising nitrogen, sulfur, phosphorous, and oxygen.

Furthermore, in the present context, the term "heteroaryl" comprises fused ring systems wherein at least one aryl ring and at least one heteroaryl ring, at least two heteroaryl rings, at least one heteroaryl ring and at least one heterocyclyl ring, or at least one heteroaryl ring and at least one C_{3-8}-cycloalkyl ring share at least one chemical bond.

The term "heteroaryl" is understood to relate to aromatic, C_{3-8} cyclic groups further containing one oxygen or sulfur atom or up to four nitrogen atoms, or a combination of one oxygen or sulfur atom with up to two nitrogen atoms, and their substituted as well as benzo- and pyrido-fused derivatives, preferably connected via one of the ring-forming carbon atoms. Heteroaryl

groups may carry one or more substituents, selected from halo, hydroxy, amino, cyano, nitro, alkylamido, acyl, C_{1-6}-alkoxy, C_{1-6}-alkyl, C_{1-6}-hydroxyalkyl, C_{1-6}-aminoalkyl, C_{1-6}-alkylamino, alkylsulfenyl, alkylsulfinyl, alkylsulfonyl, sulfamoyl, or trifluoromethyl. In some embodiments, heteroaryl groups may be five- and six-membered aromatic heterocyclic systems carrying 0, 1, or 2 substituents, which may be the same as or different from one another, selected from the list above. Representative examples of heteroaryl groups include, but are not limited to, unsubstituted and mono- or di-substituted derivatives of furan, benzofuran, thiophene, benzothiophene, pyrrole, pyridine, indole, oxazole, benzoxazole, isoxazole, benzisoxazole, thiazole, benzothiazole, isothiazole, imidazole, benzimidazole, pyrazole, indazole, tetrazole, quionoline, isoquinoline, pyridazine, pyrimidine, purine and pyrazine, which are all preferred, as well as furazan, 1,2,3-oxadiazole, 1,2,3-thiadiazole, 1,2,4-thiadiazole, triazole, benzotriazole, pteridine, phenoxazole, oxadiazole, benzopyrazole, quinolizine, cinnoline, phthalazine, quinazoline, and quinoxaline. In some embodiments, the substituents are halo, hydroxy, cyano, O-C_{1-6}-alkyl, C_{1-6}-alkyl, hydroxy-C_{1-6}-alkyl, amino-C_{1-6}-alkyl.

In the present context, the term "alkyl" and "C_{1-6}-alkyl" are intended to mean a linear or branched saturated hydrocarbon chain wherein the longest chain has from one to six carbon atoms, such as methyl, ethyl, n-propyl, isopropyl, n-butyl, isobutyl, sec-butyl, tert-butyl, pentyl, isopentyl, neopentyl, and hexyl. An alkyl chain may be optionally substituted.

The term "heterocyclyl" is intended to mean three-, four-, five-, six-, seven-, and eight-membered rings wherein carbon atoms together with from 1 to 3 heteroatoms constitute said ring. A heterocyclyl may optionally contain one or more unsaturated bonds situated in such a way, however, that an aromatic π-electron system does not arise. The heteroatoms are independently selected from oxygen, sulfur, and nitrogen.

A heterocyclyl may further contain one or more carbonyl or thiocarbonyl functionalities, so as to make the definition include oxo-systems and thio-systems such as lactams, lactones, cyclic imides, cyclic thioimides, cyclic carbamates, and the like.

Heterocyclyl rings may optionally also be fused to aryl rings, such that the definition includes bicyclic structures. Preferred such fused heterocyclyl groups share one bond with an optionally substituted benzene ring. Examples of benzo-fused heterocyclyl groups include, but are not limited to, benzimidazolidinone, tetrahydroquinoline, and methylenedioxybenzene ring structures.

Some examples of "heterocyclyls" include, but are not limited to, tetrahydrothiopyran, 4*H*-pyran, tetrahydropyran, piperidine, 1,3-dioxin, 1,3-dioxane, 1,4-dioxin, 1,4-dioxane, piperazine, 1,3-oxathiane, 1,4-oxathiin, 1,4-oxathiane, tetrahydro-1,4-thiazine, 2*H*-1,2-oxazine , maleimide, succinimide, barbituric acid, thiobarbituric acid, dioxopiperazine, hydantoin, dihydrouracil, morpholine, trioxane, hexahydro-1,3,5-triazine, tetrahydrothiophene, tetrahydrofuran, pyrroline, pyrrolidine, pyrrolidone, pyrrolidione, pyrazoline, pyrazolidine, imidazoline, imidazolidine, 1,3-

dioxole, 1,3-dioxolane, 1,3-dithiole, 1,3-dithiolane, isoxazoline, isoxazolidine, oxazoline, oxazolidine, oxazolidinone, thiazoline, thiazolidine, and 1,3-oxathiolane. Binding to the heterocycle may be at the position of a heteroatom or via a carbon atom of the heterocycle, or, for benzo-fused derivatives, via a carbon of the benzenoid ring.

The term "(heterocyclyl)C_{1-6}-alkyl" is understood as heterocyclyl groups connected, as substituents, via an alkyl, each as defined herein. The heterocyclyl groups of (heterocyclyl)C_{1-6}-alkyl groups may be substituted or unsubstituted. The term "(heterocyclyl)C_{1-6}-alkyl" is intended to mean an alkyl chain substituted at least once with a heterocyclyl group, typically at the terminal position of the alkyl chain.

In the present context, the term "C_{2-8}-alkenyl" is intended to mean a linear or branched hydrocarbon group having from two to eight carbon atoms and containing one or more double bonds. Some examples of C_{2-8}-alkenyl groups include allyl, homo-allyl, vinyl, crotyl, butenyl, pentenyl, hexenyl, heptenyl and octenyl. Some examples of C_{2-8}-alkenyl groups with more than one double bond include butadienyl, pentadienyl, hexadienyl, heptadienyl, heptatrienyl and octatrienyl groups as well as branched forms of these. The position of the unsaturation (the double bond) may be at any position along the carbon chain.

In the present context the term "C_{2-8}-alkynyl" is intended to mean a linear or branched hydrocarbon group containing from two to eight carbon atoms and containing one or more triple bonds. Some examples of C_{2-8}-alkynyl groups include ethynyl, propynyl, butynyl, pentynyl, hexynyl, heptynyl and octynyl groups as well as branched forms of these. The position of unsaturation (the triple bond) may be at any position along the carbon chain. More than one bond may be unsaturated such that the "C_{2-8}-alkynyl" is a di-yne or enedi-yne as is known to the person skilled in the art.

In the present context, the term "C_{3-8}-cycloalkyl" is intended to cover three-, four-, five-, six-, seven-, and eight-membered rings comprising carbon atoms only. A C_{3-8}-cycloalkyl may optionally contain one or more unsaturated bonds situated in such a way, however, that an aromatic π-electron system does not arise.

Some examples of preferred "C_{3-8}-cycloalkyl" are the carbocycles cyclopropane, cyclobutane, cyclopentane, cyclopentene, cyclopentadiene, cyclohexane, cyclohexene, 1,3-cyclohexadiene, 1,4-cyclohexadiene, cycloheptane, cycloheptene.

The terms "(aryl)C_{1-6}-alkyl" is intended to mean an aryl group connected, as a substituent, via a C_{1-6}-alkyl, each as defined herein. The aryl groups of (aryl)C_{1-6}-alkyl may be substituted or unsubstituted. Examples include benzyl, substituted benzyl, 2-phenylethyl, 3-phenylpropyl, and naphthylalkyl.

The terms "(cycloalkyl)C_{1-6}-alkyl" is intended to mean a cycloalkyl groups connected, as substituents, via an alkyl, each as defined herein.

When used herein, the term "O-C_{1-6}-alkyl" is intended to mean C_{1-6}-alkyloxy, or alkoxy, such as methoxy, ethoxy, n-propoxy, isopropoxy, n-butoxy, isobutoxy, sec-butoxy, tert-butoxy, pentyloxy, isopentyloxy, neopentyloxy and hexyloxy

The term "halogen" includes fluorine, chlorine, bromine and iodine.

In the present context, i.e. in connection with the terms "C_{1-6}-alkyl", "aryl", "heteroaryl", "heterocyclyl", "C_{3-8}-cycloalkyl", "heterocyclyl(C_{1-6}-alkyl)", "(cycloalkyl)alkyl", "O-C_{1-6}-alkyl", "C_{2-8}-alkenyl", and "C_{2-8}-alkynyl", the term "optionally substituted" is intended to mean that the group in question may be substituted one or several times, such as 1 to 5 times, or 1 to 3 times, or 1 to 2 times, with one or more groups selected from C_{1-6}-alkyl, C_{1-6}-alkoxy, oxo (which may be represented in the tautomeric enol form), carboxyl, amino, hydroxy (which when present in an enol system may be represented in the tautomeric keto form), nitro, alkylsulfonyl, alkylsulfenyl, alkylsulfinyl,C_{1-6}-alkoxycarbonyl, C_{1-6}-alkylcarbonyl, formyl, amino, mono- and di(C_{1-6}-alkyl)amino; carbamoyl, mono- and di(C_{1-6}-alkyl)aminocarbonyl, amino-C_{1-6}-alkyl-aminocarbonyl, mono- and di(C_{1-6}-alkyl)amino-C_{1-6}-alkyl-aminocarbonyl, C_{1-6}-alkylcarbonylamino, C_{1-6}-alkylhydroxyimino, cyano, guanidino, carbamido, C_{1-6}-alkanoyloxy, C_{1-6}-alkylsulphonyloxy, dihalogen-C_{1-6}-alkyl, trihalogen-C_{1-6}-alkyl, heterocyclyl, heteroaryl, and halo. In general, the above substituents may be susceptible to further optional substitution.

Unless otherwise indicated, when a substituent is deemed to be "optionally subsituted," it is meant that the subsitutent is a group that may be substituted with one or more group(s) individually and independently selected from cycloalkyl, aryl, heteroaryl, heteroalicyclic, hydroxy, alkoxy, aryloxy, mercapto, alkylthio, arylthio, cyano, halo, carbonyl, thiocarbonyl, O-carbamyl, N-carbamyl, O-thiocarbamyl, N-thiocarbamyl, C-amido, N-amido, S-sulfonamido, N-sulfonamido, C-carboxy, O-carboxy, isocyanato, thiocyanato, isothiocyanato, nitro, silyl, trihalomethanesulfonyl, and amino, including mono- and di-substituted amino groups, and the protected derivatives thereof. The protecting groups that may form the protective derivatives of the above substituents are known to those of skill in the art and may be found in references such as Greene and Wuts, above.

In certain embodiments, in the compound of formula A, E is oxygen. In some embodiments, T is also oxygen.

In some embodiments, the term "heterocyclyl" refers to a substituent selected from the group consisting of tetrahydrothiopyran, 4*H*-pyran, tetrahydropyran, piperidine, 1,3-dioxin, 1,3-dioxane, 1,4-dioxin, 1,4-dioxane, piperazine, 1,3-oxathiane, 1,4-oxathiin, 1,4-oxathiane, tetrahydro-1,4-thiazine, 2*H*-1,2-oxazine , maleimide, succinimide, barbituric acid, thiobarbituric acid, dioxopiperazine, hydantoin, dihydrouracil, morpholine, trioxane, hexahydro-1,3,5-triazine, tetrahydrothiophene, tetrahydrofuran, pyrroline, pyrrolidine, pyrrolidone, pyrrolidione, pyrazoline, pyrazolidine, imidazoline, imidazolidine, 1,3-dioxole, 1,3-dioxolane, 1,3-dithiole, 1,3-dithiolane, isoxazoline, isoxazolidine, oxazoline, oxazolidine, oxazolidinone, thiazoline, thiazolidine, and 1,3-oxathiolane.

In certain embodiments, the term "heteroaryl" refers to a substituent selected from the group consisting of furan, benzofuran, thiophene, benzothiophene, pyrrole, pyridine, indole, oxazole, benzoxazole, isoxazole, benzisoxazole, thiazole, benzothiazole, isothiazole, imidazole, benzimidazole, pyrazole, indazole, tetrazole, quionoline, isoquinoline, pyridazine, pyrimidine, purine, pyrazine, furazan, 1,2,3-oxadiazole, 1,2,3-thiadiazole, 1,2,4-thiadiazole, triazole, benzotriazole, pteridine, phenoxazole, oxadiazole, benzopyrazole, quinolizine, cinnoline, phthalazine, quinazoline, and quinoxaline.

In some embodiments, the term "aryl" refers to a substituent selected from the group consisting of phenyl, naphthalenyl, phenanthrenyl, anthracenyl, tetralinyl, fluorenyl, indenyl, and indanyl.

In other embodiments, the term "cycloalkyl" refers to a substituent selected from the group consisting of cyclopropane, cyclobutane, cyclopentane, cyclopentene, cyclopentadiene, cyclohexane, cyclohexene, 1,3-cyclohexadiene, 1,4-cyclohexadiene, cycloheptane, cycloheptene.

Some embodiments of the compounds of formula A include those in which R_1 is selected from the group consisting of hydrogen; C_{1-6} alkyl; C_{2-6} alkenyl; C_{2-6} alkynyl; C_{3-8} cycloalkyl; C_{3-8} heterocyclyl; cycloalkyl(C_{1-6})alkyl; heterocyclyl(C_{1-6})alkyl; aryl; heteroaryl; (C_{1-6})alkylcarbonyl; (C_{1-6})alkoxy(C_{1-6})alkyl; and perhalo(C_{1-6})alkyl. In some of these embodiments, the alkyl group of the various substituents listed above is selected from the group consisting of methyl, ethyl, propyl, n-butyl, sec-butyl, and tert-butyl.

In certain embodiments, however, R_1 is hydrogen.

In some embodiments, R_2 is selected from the group consisting of hydrogen; C_{1-6} alkyl; C_{2-6} alkenyl; C_{2-6} alkynyl; C_{3-8} cycloalkyl; C_{3-8} heterocyclyl; cycloalkyl(C_{1-6})alkyl; heterocyclyl(C_{1-6})alkyl; aryl; heteroaryl; (C_{1-6})alkylcarbonyl; (C_{1-6})alkoxy(C_{1-6})alkyl; and perhalo(C_{1-6})alkyl. In some of these embodiments, the alkyl group of the various substituents listed above is selected from the group consisting of methyl, ethyl, propyl, n-butyl, sec-butyl, and tert-butyl.

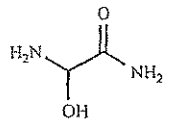
In certain embodiments, however, R_2 is hydrogen.

In some embodiments, R_3-R_6 are each independently selected from the group consisting of hydrogen; C_{1-6} alkyl; C_{2-6} alkenyl; C_{2-6} alkynyl; C_{3-8} cycloalkyl; C_{3-8} heterocyclyl; cycloalkyl(C_{1-6})alkyl; heterocyclyl(C_{1-6})alkyl; aryl; heteroaryl; (C_{1-6})alkylcarbonyl; (C_{1-6})alkoxy(C_{1-6})alkyl; and perhalo(C_{1-6})alkyl. In some of these embodiments, the alkyl group of the various substituents listed above is selected from the group consisting of methyl, ethyl, propyl, n-butyl, sec-butyl, and tert-butyl.

In certain embodiments, however, R_3-R_6 are hydrogen.

In further embodiments, R_7 and R_8 are each independently selected from hydrogen and C_{1-6} alkyl. In some of these embodiments, R_7 and R_8 are hydrogen.

Preferred pharmaceuticals or medicaments consist of, consist essentially of, or comprise a compound of formula C:

(C) 

or a pharmaceutically acceptable salt, amide, ester, or prodrug thereof. This compound was isolated using cation exchange HPLC after incubating unmodified G-NH_2 in cofactor-containing serum, as described herein (*See* **EXAMPLE 6**). The compound of formula C was identified as modified G-NH_2 (Metabolite X) after the chromatography isolate described above using its NMR spectra.

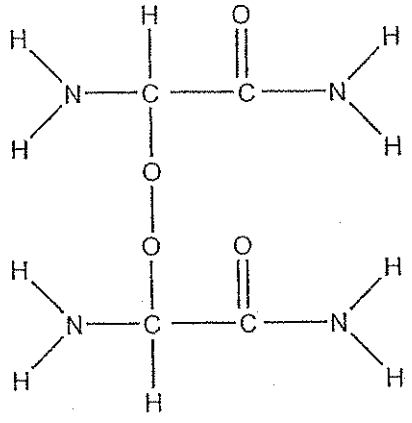
The analysis was based on a doubly labeled *i.e.*, $^{13}C/^{15}N$, sample. The ^{1}H NMR spectrum consisted of two broad NH-amide signals located at 7.65 and 7.15 ppm and a CH-proton doublet (J=163 Hz) centered at 5.21 ppm. The intensity ratios of all three signals were close to 1:1:1. In the spectrum taken without presaturation of water solvent signal, it was possible to observe extra NH_3^+ group signal at ~7.4 ppm. This indicated that one proton in glycine methylene group was replaced by electronegative substituent causing significant downfield shift in ^{1}H NMR spectrum, as compared to the original glycine amide.

The ^{13}C NMR spectrum showed two signals of equal intensity: a doublet for ^{13}C=O (J=62 Hz) at 177.6 ppm and eight lines for the aliphatic carbon signal at 89.0 ppm with three different coupling constants (J=7.1; 62 and 163 Hz). J=163 Hz is the one bond ^{13}C-^{1}H coupling, J=62 Hz is the one bond ^{13}C-^{13}C coupling, while the third coupling 7.1 Hz was in agreement with a one bond ^{15}N-^{13}C coupling. All possible two bond couplings were close to zero as expected from theoretical considerations. Both ^{1}H-^{13}C and ^{13}C-^{13}C couplings were relatively large, in agreement with the introduction of a strongly electronegative substituent at the glycine aliphatic carbon. The same conclusion came from analysis of the ^{13}C chemical shift of that aliphatic carbon, using the existing additive schemes for chemical shift prediction.

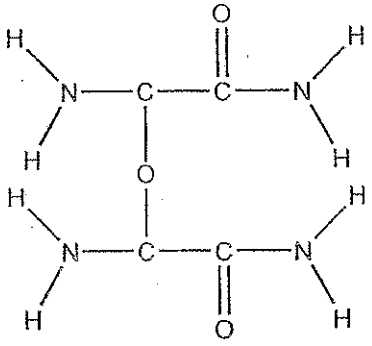
^{15}N-^{1}H HSQC spectrum consisted of a strong signal from the ^{15}N labeled amine located ~20 ppm and a weak signal from unlabelled amide nitrogen at ~105 ppm. These are expected typical values for NH_3^+ and $CONH_2$ nitrogen resonances. The total measurement time for the doubly labeled sample was ~10 hours.

Thus, the best agreement between the ^{1}H and ^{13}C spectra was obtained for the structure of the compound of formula C. Accordingly, preferred embodiments include pharmaceuticals and medicaments that consist of, consist essentially of (*e.g.*, an enriched or isolated preparation containing the compound of formula C in either enatiomer (D or L) and/or isomer (R or S)), or comprise the compound of formula C and derivatives thereof, in particular, derivatives wherein the hydroxyl group is replaced by a methoxy, ethoxy or alkoxy.

Additional preferred embodiments include pharamceutical and medicaments that consist of, consist essentially of, or comprise α-peroxyglycinamide dimer (NH_2-gly-O-O-gly-NH_2), having the structure set forth in formula E or diglycinamide ether (NH_2-gly-O-gly-NH_2) having the structure set forth in formula F:

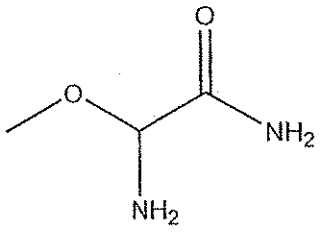


(E)



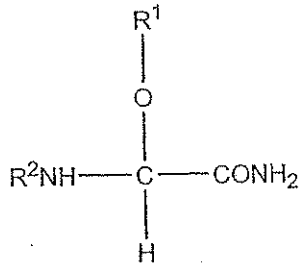
(F)

Preferred compositions also include pharmaceuticals and medicaments that consist of, consist essentially of, or comprise alpha-methoxyglycinamide (alpha-MeO-gly-NH_2) having the structure set forth in formula (G):



(G)

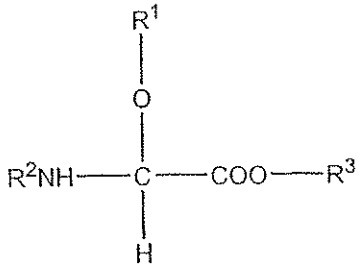
Various approaches to synthesize modified glycinamides are known in the art. (*See e.g.*, JP 5097789A2 to Hayakawa *et al.*, entitled "Alpha-hydroxyglycinamide Derivative and its Preparation," filed October 3, 1991). By one approach, an α-hydroxyglycinamide derivative represented by the following formula (B) is prepared:



(B)

(wherein R^1 is a hydrogen atom, a lower alkyl group, a lower alkenyl group, a lower alkynyl group, a benzyl group, or a silyl group substituted with an alkyl group or an alkyl group and an aromatic group; R^2 is a hydrogen atom or an amino protecting group) and a salt thereof.

By another approach, an α-hydroxyglycinamide derivative or salt thereof represented by the following formula (H):



(H)

(wherein R^1 and R^2 are defined in formula (B); R^3 is a hydrogen atom or a carboxyl protecting group) is treated with ammonia in a solvent, the amino protecting group is removed if desired, and the compound obtained is further converted into a salt thereof if desired.

In accordance with some of the preferred embodiments described herein, the lower alkyl group represented by reference symbol R_1 is an alkyl group containing no more than 6, preferably no more than 4 carbon atoms. Examples of such groups include methyl group, ethyl group, n-propyl group, isopropyl group, n-butyl group, isobutyl group, tert-butyl group, pentyl group that may be branched, and hexyl group that may be branched.

The lower alkenyl group represented by reference symbol R_1 is an alkenyl group containing no more than 6, preferably no more than 4 carbon atoms. Examples of such groups include ethenyl group, allyl group, and butenyl group having a double bond in any position. The lower alkynyl group represented by reference symbol R_1 is an alkynyl group containing no more than 6,

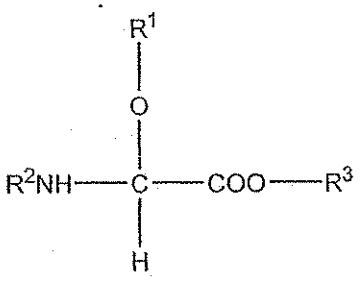
preferably no more than 4 carbon atoms. Examples of such groups include ethynyl group and the like.

The silyl group substituted with a lower alkyl group, which is represented by reference symbol R_1, is a silyl group substituted with 1 to 3 lower alkyl groups. The lower alkyl substituents used in this case are any of the lower alkyl groups described hereinabove with reference to R_1 or combinations thereof. The silyl group substituted with a lower alkyl group is preferably a tert-butyldimethylsilyl group. The silyl group substituted with an alkyl and an aromatic group is a silyl group substituted with the above-described alkyl group and phenyl group, for example, tert-butyldiphenylsilyl group.

Protecting groups that have been used in the field of amino acid or peptide chemistry can be used as the amino protecting group represented by R_2. Examples of such groups include oxycarbonyl-type protecting groups, for example, benzyloxycarbonyl (Cbz-), p-methoxybenzyloxycarbonyl [Z(OMe)-], tert-butoxycarbonyl (Boc-), or 2-biphenylisopropoxycarbonyl (Bpoc-), and the like; acyl protecting groups, for example, HCO-, phthalate group (Pht-), or o-nitrophenylthio group (Nps-), and the like; and alkyl protecting groups, for example, triphenylmethyl group (Trt-), and the like.

Salts of the α-hydroxyglycinamide derivative in accordance with some of the embodiments described herein are acid-added salts, for example, inorganic salts such as hydrohalides, *e.g.*, hydrofluorides, hydrochlorides, hydrobromides, nitrates, sulfates, or phosphates, or organic acid salts such as fumarates, acetates, and the like.

The compounds represented by formula (C) can be prepared by treating an α-hydroxyglycine derivative represented by the following formula (H):



(H)

(wherein R^1 and R^2 are defined in formula (B); R^3 is a hydrogen atom or a carboxyl protecting group) with ammonia in a solvent and optionally removing the amino protecting group.

The carbonyl protecting group R^3 is an ordinary carboxy protecting group that can be substituted with amino group by treatment with ammonia. Examples of such groups include lower alkyloxy groups, for example, methoxy group (-OMe), ethoxy group (-OEt), benzyloxy group (-OBzl), or tert-butoxy group (-OtBu), or aryloxy group, such as p-nitrophenoxy group (-ONp), and the like.

Ordinary organic solvents such as lower alcohols, for example methanol, ethanol, propanol, ethers such as methyl ethyl ether, diethyl ether, isopropyl ether, and the like can be used as the solvents for the reaction. The reaction can be conducted by dissolving the compound represented by formula (H) in the above-mentioned solvent and blowing ammonia under reduced, normal, or increased pressure at a temperature, for example, from -78°C to 40°C, preferably from 0°C to 25°C, e.g. at room temperature.

This reaction makes it possible to obtain the compound (B), in which R^2 is an amino protecting group. In order to remove the amino protecting group R^2 from this compound and to obtain the compound (B), in which R^2 is hydrogen, usual deprotecting treatment may be conducted according to the type of the amino protecting group R^2. For example, when the protecting group R^2 is benzyloxycarbonyl, P-methoxybenzyloxycarbonyl, and the like, deprotecting can be carried out by conducting treatment with hydrogen gas in the presence of a hydrogenation catalyst, for example, palladium/carbon or the like. Furthermore, when the protecting group R^2 is tert-butoxycarbonyl, deprotecting can be conducted with hydrochloric acid – dioxane. A salt of the compound (B) can be produced, for example, by conducting the above-described deprotecting treatment in the presence of an acid such as hydrochloric acid.

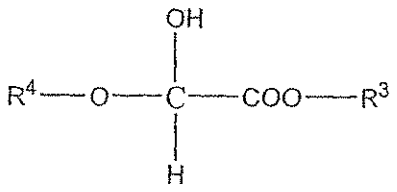
A compound according to formula (H), in which R^1 is not a hydrogen atom, can be produced, for example, by the following two methods. With the first method, it can be produced by introducing R^1 other than hydrogen into the compound among the compounds represented by formula (H), in which R^1 is hydrogen. The introduction of the group R^1 other than hydrogen can be conducted with the respective functional derivative of the group, for example, a halogen derivative. For example, for introducing a lower alkyl substituted silyl group, a halide of silyl group can be used, for example, tert-butyldimethylsilyl chloride can be used for introducing a tert-butoxydimethylsilyl group. This reaction can be conducted at a temperature of from 0°C to 30°C in a solvent such as dimethylformamide.

Furthermore, in order to introduce a lower alkenyl or lower alkynyl group, a halogen derivative of alkene or alkyl respectively can be used. For example, an allyl group can be introduced by using an allyl halide such as allyl iodide in the presence of a catalyst such as silver oxide. This reaction can be conducted at a temperature from -10 to 50°C, preferably from 0°C to 25°C, in a solvent such as dimethylformamide.

With the other method for producing the compound of formula (H) in which R^1 is not hydrogen, the compound represented by formula (H) in which both R^1 and R^2 are hydrogen atoms is treated with thionyl chloride by using a lower alcohol, for example methanol or ethanol as a solvent. In this case, a compound represented by formula (H) in which R^1 and R^2 are the same lower alkyl group corresponding to the lower alcohol solvent can be obtained. The reaction can be conducted at a temperature from -10°C to 40°C, preferably from 0°C to 25°C.

The compound represented by formula (H) in which R^1 is hydrogen can be produced, for example, by the following two methods. With the first method, it can be obtained by reacting glyceraldehydes CHO-COOH with an amine R^2NH_2 protected with amino protecting group R^2. This reaction can be conducted at a temperature of 20°C to 75°C in a solvent such as acetone, ether, and the like, for example, by a method described in US Patent No. 3,668,121 issued to Philip X. Masciantonio *et al.*, and by Stanlen D. Young *et al.*, J. Am. Chem. Soc. 111, 1933 (1989). In this case, a compound represented by formula (H) in which both the R^1 and the R^3 are hydrogen atoms can be obtained.

With the other method for the preparation of the compound represented by formula (H) in which R^1 is hydrogen, a compound represented by the following formula (I):



(I)

(wherein R^3 is defined as described with reference to formula (H), and R^4 is a lower alkyl group) is reacted with an amine R^2NH_2 protected with amino protecting group R^2. This reaction can be conducted in a solvent such as tetrahydrofuran at a temperature of 20°C to 80°C, for example, at the reflux temperature of the solvent used. The lower alkyl group R^4 is defined as the lower alkyl group R^1. The following examples describe some of these synthetic approaches in greater detail.

EXAMPLE 12

12-1

α-Hydroxy-N-tert-butoxycarbonylglycine methyl ester (4.11 g, 20mmol) and imidazole are dissolved in DMF at room temperature and cooled to a temperature of 0°C. Then chlorinated tert-butyldimethylsilyl is added to the solution at this temperature and the components are stirred for 10 min. The solution is returned to room temperature and stirring is continued for 1 hour. Then, saturated brine is added and extraction is conducted with ethyl acetate. The organic layer is dried with anhydrous magnesium sulfate and the solvent is distilled off.

The oily substance obtained is then dissolved in ethanol (50 mL) and excess ammonia is blown into the solution at a temperature of 0°C. Next, the excess ammonia is removed under reduced pressure and ethanol is distilled off. The crude product thus obtained is purified by silica gel column chromatography and α-tert-butyldimethylsilyloxy-N-tert-butoxycarbonylglycinamide (6.10 g, quant.) is obtained. An expected profile includes: ^{1}HNMR δ($CDCl_3$) 0.16(s, 3H), 0.21(s, 3H), 0.92(s, 9H), 5.46(d, 1H, J=9Hz), 5.63(d, 1H, J=9Hz), 6.22-6.82 (br, 2H).

12-2

The α-hydroxy-N-tert-butoxycarbonylglycine methyl ester that is a starting substance in 12-1 above is prepared in the manner as follows: tert-Butyl carbamate(2.83 g, 23.6 mmol) and glyoxylic acid monohydrate (2.02 g, 21.5 mmol) are dissolved in acetone (50 mL) and refluxed overnight. The solution is then cooled to a temperature of 0°C and treated with excess diazomethane-ether solution at this temperature. The solvent is then distilled off.

Saturated brine is then added, extraction is conducted with chloroform, the organic layer is dried with anhydrous magnesium sulfate and the solvent is distilled off. The crude product thus obtained is purified by silica gel column chromatography and α-hydroxy-N-tert-butoxycarbonylglycine methyl ester (2.56 g, 58%) is obtained. An expected profile includes: ^{1}HNMR δ($CDCl_3$) 1.46 (s, 9H), 1.65 (br s, 1H), 3.84 (s, 3H), 5.27-5.52 (br, 1H), 5.59-5.90 (br, 1H). IR(NaCl) 1755(s), 1690(s), 1528(s)cm^{-1}.

12-3

The α-hydroxy-N-tert-butoxycarbonylglycine methyl ester that is a starting substance in 12-1 above can be prepared by a method other than that of 12-2. Accordingly, tert-Butyl carbamate (11.35 g, 95.0 mmol) and 1-hydroxy-1-methoxyacetic acid methyl ester (14.35 g, 119.5 mmol) are dissolved in anhydrous THF (50 mL) and refluxed overnight. The temperature is then returned to room temperature, 1-hydroxy-1-methoxyacetic acid methyl ester (1.15 g, 9.6 mmol) is then added and the components are further refluxed for 8 h. The reaction liquid is allowed to sit until the temperature returns to room temperature and the solvent is then distilled off. The crude product thus obtained is recrystallized from a chloroform-hexane solution and pure α-hydroxy-N-tert-butoxycarbonylglycine methyl ester (16.42 g, 84%) is obtained.

EXAMPLE 13

The α-hydroxy-N-tert-butoxycarbonylglycine methyl ester (1.21 g, 5.9 mmol) obtained in 12-2 or 12-3 above is dissolved in DMF (10 mL), and then silver oxide (1.04 g, 4.5 mmol) and benzene iodide (1.99 g, 9.1 mmol) are added at room temperature. The components are stirred overnight at room temperature, the precipitate is filtered, water is added to the mother liquor, and extraction is conducted with ethyl acetate. The extracted solution is dried with anhydrous magnesium sulfate, then the solvent is distilled off and crude purification is conducted with silica gel column chromatography.

The oily substance thus obtained is dissolved in ethanol (50 mL) and excess ammonia is blown into the solution at a temperature of 0°C. The excess ammonia is then removed under reduced pressure and the solvent is distilled off. The crude product thus obtained is purified by silica gel column chromatography and α-benzyloxy-N-tert-butoxycarbonylglycinamide (0.397 g, 22%) is obtained. An expected profile includes: m.p. 115-120°C, ^{1}HNMR δ($CDCl_3$) 1.44 (s, 9H),

4.61 (d, 1H, J=11.3Hz), 4.79 (d, 1H, J=11.3Hz), 5.4 (d, 1H, J=9.0Hz), 5.75 (brd, 1H, J=9.0Hz), 6.00 (br, 1H), 6.52 (br, 1H), 7.35 (s, 5H). IR(NaCl) 1698(s), 1664(s), 1502(s), 732(m), 695(m) cm^{-1}. Analytical values for elements ($C_{14}H_{20}O_4N_2$): Calcd. C:59.99, H:7.19, N:9.99 Obsd. C:59.94, H:7.33, N:10.28 are expected.

EXAMPLE 14

The α-hydroxy-N-tert-buthoxycarbonylglycinemethyl ester (2.07 g, 10.1 mmol) prepared according to 12-2 or 12-3 above is dissolved in DMF (20 mL), and silver oxide (1.39 g, 6.0 mmol) and allyl iodide (1.2 mL, 12.9 mmol) are added at room temperature. After overnight stirring at room temperature, the precipitate is filtered out, water is added to the mother liquor, and extraction with ethyl acetate is conducted. The extracted solution is dried with anhydrous magnesium sulfate, then the solvent is distilled off, and an aqueous solution of sodium thiosulfate is added, followed by extraction with ethyl acetate and removal of iodine as a reaction byproduct.

The oily substance thus obtained is dissolved in ethanol, excess ammonia is blown into the solution at a temperature of 0°C, the excess ammonia is thereafter removed under reduced pressure, and the solvent is distilled off. The crude produt obtained is purified with silica gel column chromatography to obtain α-allyloxy-N-tert-butoxycarbonylglycinamide (0.625 g, 27%). An expected profile includes: ^{1}HNMR δ($CDCl_3$) 1.45 (s, 9H), 4.14 (dd, 2H, J=7.2, 1.8Hz), 5.11-5.56 (m, 3H), 5.70-6.20 (m, 2H), 6.33-7.01 (m, 2H). IR($CDCl_3$) 2975(w), 1705(s, br), 1498(m), 990(sh.w) cm^{-1}.

EXAMPLE 15

15-1

α-Hydroxy-N-benzyloxycarbonylglycine (4.44 g, 19.7 mmol) is dissolved in methanol (20 mL). Thionyl chloride (2.9 mL, 40.0 mmol) is dropwise added to the solution at a temperature of 0°C, and stirring is conducted for 30 minutes at this temperature and then for 2 hours at room temperature. The solvent is then distilled off and the crude product obtained is dissolved in methanol (50 mL). The solution is cooled to 0°C, and excess ammonia is blown therein.

Upon completion of the reaction, the excess ammonia is removed under reduced pressure, the solvent is distilled off, and the white crystals obtained are purified with silica gel column chromatography to obtain α-methoxy-N-benzyloxycarbonylglycinamide (3.42 g, 73%). An expected profile includes: m.p. 110-112°C, ^{1}HNMR δ($CDCl_3$) 3.44 (s, 3H), 5.16 (s, 2H), 5.31 (d, 1H, J=8.8Hz), 5.45-5.98 (br, 2H), 6.28-6.68 (br, 1H), 7.36 (s, 5H). IR(NaCl) 1680(s. br), 1540(s), 1520(s), 860(m), 700(m) cm^{-1}. Analytical values of elements ($C_{11}H_{14}O_4N_2$); Calcd. C:55.46, H:5.92, N:11.76 Obsd. C:55.70, H:5.94, N:11.58 are expected.

15-2

The α-hydroxy-N-benzyloxycarbonylglycine that is the starting material in 12-4 above is prepared in the manner as follows. Benzyl carbamate (30.24 g, 0.2 mol) and glyoxylic acid monohydrate (20.26 g, 0.22 mol) are dissolved in diethyl ether (200 mL) and the solution is stirred overnight at room temperature. The crystals produced are filtered and then washed with ether to obtain pure α-hydroxy-N-benzyloxycarbonylglycine (33.78 g, 75%). An expected profile includes: m.p. 200-205°C, ^{1}HNMR δ(CD_3OD) 5.12 (s, 2H), 5.40 (s, 1H), 7.34 (s, 5H).

EXAMPLE 16

The α-hydroxy-N-benzyloxycarbonylglycine (2.26 g, 10.0 mmol) produced according to 15-2 above is dissolved in ethanol (20 mL). Thionyl chloride (2 mL, 27.4 mmol) is dropwise added to the solution at a temperature of -10°C, and stirring is conducted overnight at room temperature. The solvent is then distilled off and the crude product thus obtained is purified with silica gel column chromatography to obtain α-ethoxy-N-benzyloxycarbonylglycine ethyl ester (2.81 g, quant.). An expected profile includes: m.p. 66-68°C, ^{1}HNMR δ($CDCL_3$) 1.22 (t, 3H, J=7.2 Hz), 1.30 (t, 3H, J=7.2 Hz), 3.70 (q, 2H, J=7.2 Hz), 4.24(q, 2H, J=7.2 Hz), 5.15 (s, 2H), 5.33 (d, 1H, J=9.7 Hz), 5.93 (brd, 1H, J=9.7 Hz), 7.35 (s, 5H). IR(NaCl) 1740(s), 1700(s), 1540(s), 760(m), 700(m) cm^{-1}. Analytical values of elements ($C_{14}H_{19}O_5N$); Calcd. C:59.78, H:6.81, N:4.98,Obsd. C:60.03, H:6.88, N:4.89 are expected.

EXAMPLE 17

The α-hydroxy-N-benzyloxycarbonylglycine (2.26 g, 10.0 mmol) produced according to 15-2 above is dissolved in isopropyl alcohol (20 mL). Thionyl chloride (2 mL, 27.4 mmol) is dropwise added to the solution at a temperature of -10°C, and stirring is conducted overnight at room temperature. The solvent is then distilled off and the crude product thus obtained is purified with silica gel column chromatography to obtain α-isopropoxy-N-benzyloxycarbonylglycine isopropyl ester (3.10 g, quant.). An expected profile includes: ^{1}HNMR δ($CDCL_3$) 1.16-1.37 (m, 12H), 3.87-4.22 (m, 1H), 4.57-5.20 (m, 1H), 5.14 (s, 2H), 5.33 (d, 1H, J=9.7 Hz), 5.93 (brd, 1H, J=9.7 Hz), 7.35 (s, 5H). IR(Neat) 1728(s, br), 1508(m), 740(m) cm^{-1}.

EXAMPLE 18

The α-ethoxy-N-benzyloxycarbonylglycine ethyl ester (2.29 g, 8.1 mmol) produced according to **EXAMPLE 16** is dissolved in ethanol (80 mL) and cooled to 0°C. Excess ammonia is then blown into the solution at this temperature. Upon completion of the reaction, the excess ammonia is removed under reduced pressure, the solvent is distilled off, and the white crystals thus obtained are washed with a hexane-ethyl acetate mixed solution to obtain pure α-ethoxy-N-

benzyloxycarbonylglycinamide (1.51 g, 77%). An expected profile includes: m.p 119-121°C, ^{1}HNMR δ($CDCL_3$) 1.23 (t, 3H, J=7.1 Hz), 3.50-3.90 (m, 2H), 5.14 (s, 2H), 5.37 (d, 1H, J=9.0 Hz), 5.65-5.96 (br, 2H), 6.41-6.71 (br, 1H), 7.35 (s, 5H). IR(NaCl) 1680(s), 1664(s), 1542(m), 1524(m), 760(w), 740(w), 700(m) cm^{-1}. Analytical values of elements ($C_{12}H_{16}O_4N_2$); Calcd. C:57.13, H:6.39, N:11.10, Obsd. C:57.09, H:6.34, N:11.37 are expected.

EXAMPLE 19

The α-isopropoxy-N-benzyloxycarbonylglycine isopropyl ester (2.48 g, 8.0 mmol) produced according to **EXAMPLE 16** is dissolved in ethanol (40 mL) and cooled to 0°C. Then, excess ammonia is blown into the solution for 5 hours at this temperature and stirring is further conducted for 2 days in the ammonia saturated state. Upon completion of the reaction, the excess ammonia is removed under reduced pressure, the solvent is distilled off, and the white crystals thus obtained are washed with a hexane - ethyl acetate mixed solution to obtain pure α-isopropoxy-N-benzyloxycarbonylglycinamide (1.64 g, 77%). An expected profile includes: m.p 111-113°C, ^{1}HNMR δ($CDCL_3$) 1.18 (d, 3H, J=4.4 Hz), 1.25 (d, 3H, J=4.4 Hz), 3.81-4.20(m, 1H), 5.15 (s, 2H), 5.44 (d, 1H, J=9.0Hz), 5.53-5.86 (br, 2H), 6.37-6.73 (br, 1H), 7.35 (s, 5H). IR(NaCl) 1668(s), 1660(s), 1538(m), 1530(m), 760(w), 740(w), 700(m) cm^{-1}. Analytical values of elements ($C_{13}H_{18}O_4N_2$); Calcd. C:58.63, H:6.81, N:10.52. Obsd. C:58.60, H:6.82, N:10.54 are expected..

EXAMPLE 20

The α-tert-butyldimethylsilyloxy-N-tert-buthoxycarbonylglycinamide (5.08 g, 16.7 mmol) produced according to (12-1) of **EXAMPLE 12** is dissolved in dioxane (10 mL) and cooled to 0°C. Then, a 4N hydrochloric acid – dioxane solution (17 mL) is added and stirring is conducted for 1 hour at this temperature.

In order to complete the reaction, a 4N hydrochloric acid – dioxane solution is further added, the temperature is raised to room temperature and stirring is conducted for 1 hour. Diethyl ether is then added to the solution, as large an amount of the product as possible is precipitated, filtered, and washed with ether. The precipitate is then dried under reduced pressure to obtain pure α-hydroxyglycinamide hydrochloride (1.86 g, 88%). An expected profile includes: ^{1}HNMR δ(DMSO-d_6) 4.99 (br sd, 1H), 7.62-8.03 (br, 2H), 8.32-8.85 (br, 3H). IR (KBr) 1686 (s), 1581(m), 1546 (m), 1477 (s), 843 (m) cm^{-1}

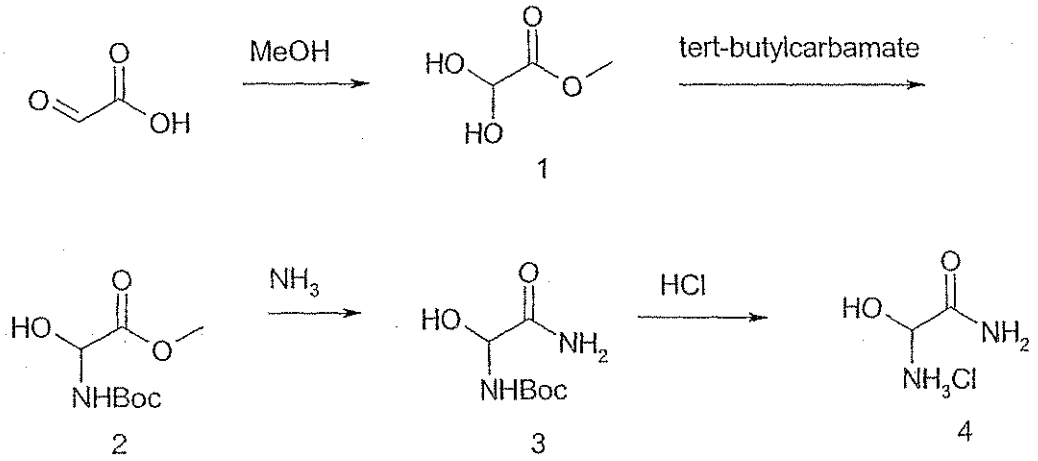
EXAMPLE 21

The α-methoxy-N-benzyloxycarbonylglycinamide (0.24 g, 1.0 mmol) prepared according to **EXAMPLE 15** (15-1) is dissolved in methanol, 12N hydrochloric acid (0.1 mL) and palladium-carbon (50 mg) are added to the solution at room temperature, and stirring is conducted for 30

minutes under hydrogen atmosphere. The palladium-carbon is then filtered out and the solvent of the mother liquor is distilled off to obtain α-methoxyglycinamide hydrochloride (0.14 g, quant). An expected profile includes: ^{1}HNMR δ(CD_3OD) 3.35 (s, 3H), 5.01 (s, 1H), ^{13}CNMR δ(CD_3OD) 42.1, 84.3 (d, J= 159.8 Hz), 170.3. The next Example describes an approach that was used to synthesize α-hydroxy-glycinamide hydrochloride for formulation into a pharmaceutical or medicament.

EXAMPLE 22

Preparation of α-hydroxy-glycinamide hydrochloride



22.1 Methyl glyoxylate hemiacetal

A solution of glyoxylic acid monohydrate (7.0 g, 76 mmol) in methanol (35 mL) was refluxed overnight. The solution was then neutralized with saturated $NaHCO_3$ and evaporated. The residue was dissolved in CH_2Cl_2 and dried over Na_2SO_4. Evaporation afforded 3.23 g (40.0 %) of crude oil that was used in the following reaction without further purification.

22.2 Methyl N-tert-butoxycarbonyl-α-hydroxyglycinate

A solution of methyl glyoxylate hemiacetal (2.0 g, 18.9 mmol) and tert-butyl carbamate (2.0 g, 17.18 mmol) in toluene (45 mL) was refluxed overnight. Evaporation afforded oil. This crude oil was purified by silica gel chromatography EtOAc/heptane 1/9 to 2/8 as eluent. The pure fractions gave 0.6 g oily product that was then crystallized with diethyl ether/heptane. The yield 0.39 g (10.1 %). The NMR spectra observed were:

^{1}H NMR (300 MHz, $CDCl_3$)δ 5.74 (br s, 1H), 5.44 (br s, 1H), 3.84 (s, 3H), 1.46 (s, 9H).

^{13}C NMR (300 MHz, DMSO-d_6)δ 170.3, 154.7, 78.6, 72.8, 51.9, 28.1.

22.3 N-tert-butoxycarbonyl-α-hydroxyglycinamide

Methyl N-tert-butoxycarbonyl-α-hydroxyglycinate (0.34 g, 1.66 mmol) was solved in 7N NH_3 in methanol (4 mL). The solution was stirred at room temperature overnight, evaporated and then co-evaporated twice with acetonitrile. The product was purified by silica gel chromatography EtOAc/heptane 3/7 to 5/5 as eluent. The yield 0.1 g (31.7 %). The NMR spectra observed were:

^{1}H NMR (300 MHz, DMSO-d_6)δ 7.28 (br d, 2H), 6.20 (d, 1H), 5.09 (t, 1H), 1.39 (s, 9H).

^{13}C NMR (300 MHz, DMSO-d_6)δ 171.7, 155.0, 78.3, 73.4, 28.2.

22.4 α-Hydroxy-glycinamide hydrochloride

N-tert-butoxycarbonyl-α-hydroxyglycinamide (40 mg, 0.2 mmol) was solved in dioxane (1.5 mL). 4N HCl in dioxane (0.5 mL) was added to the solution at 0°C. The cooling bath was removed and the solution was stirred for 40 min. at room temperature. Diethyl ether was added and the solution was stirred. Ether was decanted and the residue was evaporated. The yield was approximately ~40 mg. The NMR spectra observed were:

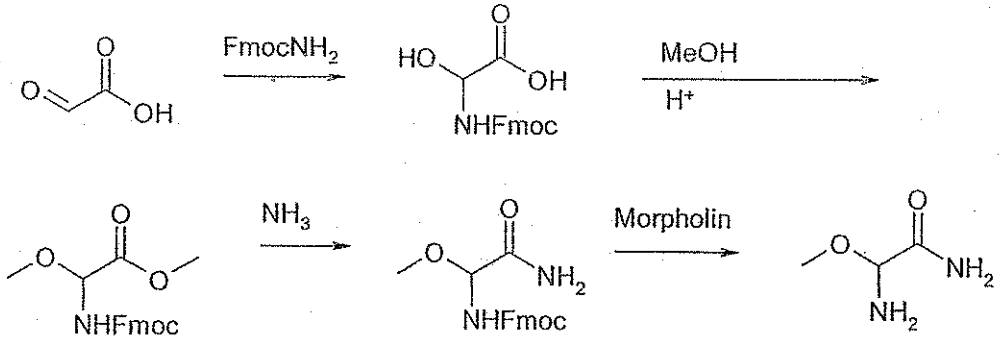
^{1}H NMR (500 MHz, DMSO-d_6)δ 8.5-7.1 (m, 5H), 4.85 (s, 1H).

^{13}C NMR (500 MHz, DMSO-d_6)δ 173.1, 87.4.

The following Example describes an approach that was used to prepare α-methoxy-glycinamide.

EXAMPLE 23

Preparation of α-Methoxy-glycinamide



23-1 Methyl N-(9H-Fluoren-9-ylmethoxycarbonyl)-α-methoxyglycinate

Glyoxylic acid monohydrate (276 mg, 3 mmol) and 9H-fluoren-9-ylmethyl carbamate (320 mg, 1.33 mmol) were solved in dry diethylether (10 mL). The mixture was stirred at room temperature overnight. The solvent was evaporated and the residue was solved in methanol (20 mL) and 1 drop of sulfuric acid was added. The reaction mixture was stirred 3 days at room temperature. Sat. $NaHCO_3$ (100 mL) was added to the mixture and it was extracted with ethyl

acetate, dried over Na_2SO_4 and evaporated. The residue was purified on silica gel column to give 250 mg (55 %) of the titled compound. The NMR spectra observed were:

^{1}H NMR (300 MHz, $CDCl_3$)δ 7.76 (d, 2H), 7.59 (d, 2H), 7.40 (t, 2H), 7.31 (t, 2H), 5.90 (br d, 1H), 5.35 (d, 1H), 4.46 (m, 2H), 4.24 (t, 1H), 3.82 (s, 3H), 3.43 (s, 3H).

^{13}C NMR (300 MHz, $CDCl_3$)δ 143.6, 143.5, 141.2, 127.7, 127.1, 124.9, 120.0, 80.5, 67.2, 56.2, 52.9.

23-2 α-Methoxyglycinamide

Methyl N-(9H-Fluoren-9-ylmethoxycarbonyl)-α-methoxyglycinate (240 mg, 0.7 mmol) was treated with 3N NH_3 in methanol (20 mL) at room temperature overnight. Methanol was removed by evaporation. The solid was solved in THF (30 mL) and morpholine (305 mg, 3.5 mmol) was added. The mixture was stirred at room temperature for 5 h. The solvent was evaporated and the product was purified on silica gel column to give 5 mg (6 %) of the titled compound. The NMR spectrum observed was:

^{1}H NMR (300 MHz, $CDCl_3$)δ 4.40 (br s, 1H), 3.35 (s, 3H).

The modified glycinamide compounds described herein are suitable for use as a biotechnological tool to study the interaction of the compound with HIV and also as a pharmaceutical or medicament for the treatment of subjects already infected with HIV, or as a preventive preparation to avoid HIV infection. The cofactor(s) obtainable by the methods described herein (either alone or in conjunction or combination with G-NH_2 or a G-NH_2 containing peptide, such as GPG-NH_2) are also suitable for use as biotechnological tools and as medicaments for the treatment and prevention of HIV replication. By one approach, for example, a prodrug therapy is contemplated, wherein G-NH_2 or a G-NH_2 containing peptide, such as GPG-NH_2, is provided to a subject in need and the cofactor is provided by co-administration. Alternatively, the G-NH_2 or a G-NH_2 containing peptide, such as GPG-NH_2 and the cofactor can be combined in a pharmaceutical (*e.g.*, a pharmaceutical composition comprising G-NH_2 or a G-NH_2 containing peptide, such as GPG-NH_2, and the cofactor). In this vein, cofactor and/or G-NH_2 and/or GPG-NH_2 and/or other glycinamide containing peptides can be administered as prodrugs when, for example, time release or long term treatments are desired.

Although anyone could be treated with these anti-HIV compositions as a prophylactic, the most suitable subjects are people at risk for viral infection. Such subjects include, but are not limited to, the elderly, the chronically ill, homosexuals, prostitutes, intravenous drug users, hemophiliacs, children, and those in the medical profession who have contact with patients or biological samples.

Methods of making and using medicaments comprising modified G-NH_2 (*e.g.*, Metabolite X or AlphaHGA) are also embodiments of the present invention. The modified G-NH_2 obtainable by the methods described herein can be processed in accordance with conventional methods of

galenic pharmacy to produce medicinal agents for administration to patients, *e.g.*, mammals including humans. The modified G-NH_2 can be incorporated into a pharmaceutical product with and without modification. Further, the manufacture of pharmaceuticals or therapeutic agents that deliver modified G-NH_2 by several routes is included within the scope of the present invention.

The modified G-NH_2 described herein can be employed in admixture with conventional excipients, *i.e.*, pharmaceutically acceptable organic or inorganic carrier substances suitable for parenteral, enteral (*e.g.*, oral) or topical application that do not deleteriously react with the peptide agents. Suitable pharmaceutically acceptable carriers include, but are not limited to, water, salt solutions, alcohols, gum arabic, vegetable oils, benzyl alcohols, polyethylene glycols, gelatine, carbohydrates such as lactose, amylose or starch, magnesium stearate, talc, sialicic acid, viscous paraffin, perfume oil, fatty acid monoglycerides and diglycerides, pentaerythritol fatty acid esters, hydroxy methylcellulose, polyvinyl pyrrolidone, etc. The pharmaceutical preparations can be sterilized and if desired mixed with auxiliary agents, *e.g.*, lubricants, preservatives, stabilizers, wetting agents, emulsifiers, salts for influencing osmotic pressure, buffers, coloring, flavoring and/or aromatic substances and the like that do not deleteriously react with the modified G-NH_2.

In some embodiments, medicaments comprising modified G-NH_2 are formulated with or administered in conjunction with other agents that inhibit viral infections, such as HIV infection, so as to achieve a better viral response. At present four different classes of drugs are in clinical use in the antiviral treatment of HIV-1 infection in humans. These are (i) nucleoside analogue reverse transcriptase inhibitors (NRTIs), such as zidovudine, lamivudine, stavudine, didanosine, abacavir, and zalcitabine; (ii) nucleotide analogue reverse transcriptase inhibitors, such as tenofovir; (iii) non-nucleoside reverse transcriptase inhibitors (NNRTIs), such as efavirenz, nevirapine, and delavirdine; and (iv) protease inhibitors, such as indinavir, nelfinavir, ritonavir, saquinavir and amprenavir. By simultaneously using two, three, or four different classes of drugs in conjunction with administration of the modified G-NH_2, HIV is less likely to develop resistance, since it is less probable that multiple mutations that overcome the different classes of drugs and the modified G-NH_2 will appear in the same virus particle.

It is thus preferred that medicaments comprising modified G-NH_2 are formulated with or given in combination with nucleoside analogue reverse transcriptase inhibitors, nucleotide analogue reverse transcriptase inhibitors, non-nucleoside reverse transcriptase inhibitors, and protease inhibitors at doses and by methods known to those of skill in the art. Medicaments comprising the modified G-NH_2 and nucleoside analogue reverse transcriptase inhibitors, nucleotide analogue reverse transcriptase inhibitors, non-nucleoside reverse transcriptase inhibitors, and protease inhibitors can be formulated to contain other ingredients to aid in delivery, retention, or stability of the modified G-NH_2.

The effective dose and method of administration of a particular modified G-NH_2 formulation can vary based on the individual patient and the stage of the disease, as well as other

factors known to those of skill in the art. Therapeutic efficacy and toxicity of such compounds can be determined by standard pharmaceutical procedures in cell cultures or experimental animals, *e.g.*, ED_{50} and LD_{50} (the dose lethal to 50% of the population). The dose ratio of toxic to therapeutic effects is the therapeutic index, and it can be expressed as the ratio, LD_{50}/ED_{50}. Pharmaceutical compositions that exhibit large therapeutic indices are preferred. The data obtained from cell culture assays and animal studies is used in formulating a range of dosage for human use. The dosage of such compounds lies preferably within a range of circulating concentrations that include the ED50 with little or no toxicity. The dosage varies within this range depending upon the dosage form employed, sensitivity of the patient, and the route of administration.

The exact dosage is chosen by the individual physician in view of the patient to be treated. Dosage and administration are adjusted to provide sufficient levels of the active moiety or to maintain the desired effect. Additional factors that may be taken into account include the severity of the disease state, age, weight and gender of the patient; diet, time and frequency of administration, drug combination(s), reaction sensitivities, and tolerance/response to therapy. Short acting pharmaceutical compositions are administered daily whereas long acting pharmaceutical compositions are administered every 2, 3 to 4 days, every week, or once every two weeks. Depending on half-life and clearance rate of the particular formulation, the pharmaceutical compositions of the invention are administered once, twice, three, four, five, six, seven, eight, nine, ten or more times per day.

Normal dosage amounts may vary from approximately 1 to 100,000 micrograms, up to a total dose of about 20 grams, depending upon the route of administration. Desirable dosages include 250µg, 500µg, 1mg, 50mg, 100mg, 150mg, 200mg, 250mg, 300mg, 350mg, 400mg, 450mg, 500mg, 550mg, 600mg, 650mg, 700mg, 750mg, 800mg, 850mg, 900mg, 1g, 1.1g, 1.2g, 1.3g, 1.4g, 1.5g, 1.6g, 1.7g, 1.8g, 1.9g, 2g, 3g, 4g, 5, 6g, 7g, 8g, 9g, 10g, 11g, 12g, 13g, 14g, 15g, 16g, 17g, 18g, 19g, and 20g. Additionally, the concentrations of the modified G-NH_2 can be quite high in embodiments that administer the agents in a topical form. Molar concentrations of peptide agents can be used with some embodiments. Desirable concentrations for topical administration and/or for coating medical equipment range from 100:M to 800mM. Preferable concentrations for these embodiments range from 500:M to 500mM. For example, preferred concentrations for use in topical applications and/or for coating medical equipment include 500µM, 550µM, 600µM, 650µM, 700µM, 750µM, 800µM, 850µM, 900µM, 1mM, 5mM, 10mM, 15mM, 20mM, 25mM, 30mM, 35mM, 40mM, 45mM, 50mM, 60mM, 70mM, 80mM, 90mM, 100mM, 120mM, 130mM, 140mM, 150mM, 160mM, 170mM, 180mM, 190mM, 200mM, 300mM, 325mM, 350mM, 375mM, 400mM, 425mM, 450mM, 475mM, and 500mM. Guidance as to particular dosages and methods of delivery is provided in the literature and below. (*See e.g.*, U.S. Pat. Nos. 4,657,760; 5,206,344; or 5,225,212).

More specifically, the dosage of the modified G-NH_2 is one that provides sufficient modified G-NH_2 to attain a desirable effect including inhibition of proper viral release and/or inhibition of HIV replication. Accordingly, the dose of modified G-NH_2 preferably produces a tissue or blood concentration or both from approximately 0.1nM to 500mM. Desirable doses produce a tissue or blood concentration or both of about 0.1nM to 800 μM. Preferable doses produce a tissue or blood concentration of greater than about 10 nM to about 300:M. Preferable doses are, for example, the amount of modified G-NH_2 required to achieve a tissue or blood concentration or both of 10nM, 15nM, 20nM, 25nM, 30nM, 35nM, 40nM, 45nM, 50nM, 55nM, 60nM, 65nM, 70nM, 75nM, 80nM, 85nM, 90nM, 95nM, 100nM, 200nM, 300nM, 400nM, 500nM, 600nM, 700nM, 800nM, 900nM, 1μM, 10μM, 15μM, 20μM, 25μM, 30μM, 50μM, 100μM, 200μM, and 300μM. Although doses that produce a tissue concentration of greater than 800μM are not preferred, they can be used with some embodiments. A constant infusion of the modified G-NH_2 can also be provided so as to maintain a stable concentration in the tissues as measured by blood levels.

Routes of administration of the modified G-NH_2 include, but are not limited to, topical, transdermal, parenteral, gastrointestinal, transbronchial, and transalveolar. Topical administration is accomplished via a topically applied cream, gel, rinse, etc. containing modified G-NH_2. Transdermal administration is accomplished by application of a cream, rinse, gel, etc. capable of allowing the modified G-NH_2 to penetrate the skin and enter the blood stream. Parenteral routes of administration include, but are not limited to, electrical or direct injection such as direct injection into a central venous line, intravenous, intramuscular, intraperitoneal or subcutaneous injection. Gastrointestinal routes of administration include, but are not limited to, ingestion and rectal. Transbronchial and transalveolar routes of administration include, but are not limited to, inhalation, either via the mouth or intranasally.

Compositions of modified G-NH_2 containing compounds suitable for topical application include, but are not limited to, physiologically acceptable implants, ointments, creams, rinses, and gels. Any liquid, gel, or solid pharmaceutically acceptable base in which the compounds are at least minimally soluble is suitable for topical use in the present invention. Compositions for topical application are particularly useful during sexual intercourse to prevent transmission of HIV. Suitable compositions for such use include, but are not limited to, vaginal or anal suppositories, creams, jellies, lubricants, oils, and douches.

Compositions of the modified G-NH_2 suitable for transdermal administration include, but are not limited to, pharmaceutically acceptable suspensions, oils, creams, and ointments applied directly to the skin or incorporated into a protective carrier such as a transdermal device ("transdermal patch"). Examples of suitable creams, ointments, etc. can be found, for instance, in the Physician's Desk Reference and are well known in the art. Examples of suitable transdermal

devices are described, for instance, in U.S. Patent No. 4,818,540, issued April 4, 1989 to Chinen, *et al.*

Compositions of the modified G-NH_2 suitable for parenteral administration include, but are not limited to, pharmaceutically acceptable sterile isotonic solutions. Such solutions include, but are not limited to, saline and phosphate buffered saline for injection into a central venous line, intravenous, intramuscular, intraperitoneal, or subcutaneous injection of the modified G-NH_2.

Compositions of the modified G-NH_2 suitable for transbronchial and transalveolar administration include, but are not limited to, various types of aerosols for inhalation. For instance, pentamidine is administered intranasally via aerosol to AIDS patients to prevent pneumonia caused by *pneumocystis carinii*. Devices suitable for transbronchial and transalveolar administration of the modified G-NH_2, including but not limited to atomizers and vaporizers, are also included within the scope of the present invention. Many forms of currently available atomizers and vaporizers can be readily adapted to deliver modified G-NH_2.

Compositions of the modified G-NH_2 suitable for gastrointestinal administration include, but not limited to, pharmaceutically acceptable powders, pills, sachets, or liquids for ingestion and suppositories for rectal administration. Due to the most common routes of HIV infection and the ease of use, gastrointestinal administration, particularly oral, is preferred. Pharmaceuticals for gastorintestinal administration, for example, are formulated in capsule, pill, or tablet form, wherein the active ingredient, modified glycinamide (*e.g.*, α-hydroxyglycinamide, α-peroxyglycinamide dimer, diglycinamide ether, or α-methoxyglycinamide), is in an amount effective to inhibit HIV replication.

The modified G-NH_2 is also suitable for use in situations where prevention of HIV infection is important. For instances, medical personnel are constantly exposed to patients who may be HIV positive and whose secretions and body fluids contain the HIV virus. Further, the modified G-NH_2 can be formulated into antiviral compositions for use during sexual intercourse so as to prevent transmission of HIV. Such compositions are known in the art and also described in the international application published under the PCT publication number WO90/04390 on May 3, 1990 to Modak *et al.*

Embodiments of the invention also include a coating for medical equipment such as gloves, sheets, and work surfaces that protects against viral transmission. Alternatively, the modified G-NH_2 can be impregnated into a polymeric medical device. Particularly preferred are coatings for medical gloves and condoms. Coatings suitable for use in medical devices can be provided by a powder containing the peptides or by polymeric coating into which the peptide agents are suspended. Suitable polymeric materials for coatings or devices are those that are physiologically acceptable and through which a therapeutically effective amount of the modified G-NH_2 can diffuse. Suitable polymers include, but are not limited to, polyurethane, polymethacrylate,

polyamide, polyester, polyethylene, polypropylene, polystyrene, polytetrafluoroethylene, polyvinyl-chloride, cellulose acetate, silicone elastomers, collagen, silk, etc. Such coatings are described, for instance, in U.S. Patent No. 4,612,337, issued September 16, 1986 to Fox *et al.* Accordingly, methods of making a medicament that inhibits HIV replication involve providing modified G-NH_2 and formulating said medicament for delivery to a subject, including a human, as described above.

Methods of identification of compounds that inhibit HIV replication are also provided. By one method, for example, a compound for incorporation into an anti-HIV pharmaceutical is identified by incubating G-NH_2 with serum, plasma, or a cell extract for a time sufficient to metabolize modified G-NH_2 and isolating the modified G-NH_2 by cation exchange HPLC. Preferably, human sera, pig sera, bovine sera, cat sera, dog sera, horse sera, monkey sera, or pig plasma is used. By this approach, modified G-NH_2 rapidly elutes from the column, whereas unreacted G-NH_2 is retained on the column for a considerably longer period of time. The isolation of modified G-NH_2 can be further confirmed by conducting HIV infectivity studies in the presence of the isolated compound, as described above. Similarly, synthetic compounds that are related to α-hydroxyglycinamide, α-peroxyglycinamide dimer, diglycinamide ether, methoxyglycinamide, α-ethoxyglycinamide, and derivatives of these compounds can be screened using the HIV infectivity studies presented herein. Depending on the purity of the modified G-NH_2 isolated or the structure of the synthetic modified glycinamide, the ED_{50} of the compound is between less than 1μM and less than 30μM. That is, the ED_{50} of pure modified G-NH_2 is less than 100nM, 200nM, 300nM, 400nM, 500nM, 600nM, 700nM, 800nM, 900nM, 1μM, 2μM, 3μM, 4μM, 5μM, 6μM, 7μM, 8μM, 9μM, 10μM, 11μM, 12μM, 13μM, 14μM, 15μM, 16μM, 17μM, 18μM, 19μM, 20μM, 21μM, 22μM, 23μM, 24μM, 25μM, 26μM, 27μM, 28μM, 29μM, or 30μM. Thus, in some embodiments, the modified G-NH_2 identified by the methods above is incorporated in a pharmaceutical. Furthermore, the methods above can be supplemented by providing an antiviral compound selected from the group consisting of nucleoside analogue reverse transcriptase inhibitors, nucleotide analogue reverse transcriptase inhibitors, non-nucleoside reverse transcriptase inhibitors, and protease inhibitors into the pharmaceutical. Additionally, the methods above can be supplemented by incorporating a carrier into the pharmaceutical.

Although the modified G-NH_2 can be used as a research tool to analyze the inhibition of HIV, desirably modified G-NH_2 is used to inhibit HIV replication and infection in a subject. By one method, for example, a subject at risk of becoming infected by HIV or who is already infected with HIV is identified and said subject is provided modified G-NH_2. By an additional method, a subject is provided modified G-NH_2 and the effect on HIV replication or infection, is determined (*e.g.*, by analyzing the amount of p24 or reverse transcriptase activity in a biological sample).

It is contemplated that modified glycinamide inhibits replication of HIV by a mechanism that is different than conventional nucleoside analogues and protease inhibitors. (*See* U.S. Pat. Nos.

US6258932; US6455670; US6537967). Accordingly, preferred subjects to receive pharmaceuticals containing modified glycinamide are HIV infected individuals that have developed resistance to nucleoside analogues and protease inhibitors.

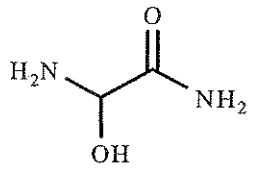
By one approach, nine HIV infected patients are provided differing amounts of modified glycinamide (*e.g.*, alpha-hydroxyglycinamide, alpha-peroxyglycinamide dimer, diglycinamide ether or alpha-methoxyglycinamide) and the inhibition of HIV replication is analyzed. Group I, which contains three individuals, is provided 1.0g of modified glycinamide by capsule form three times a day; whereas Group II, which contains three individuals, is provided 1.5g of modified glycinamide by capsule form three times a day; and Group III, which contains three individuals is provided 2.0g of modified glycinamide by capsule form throughout the day. The reduction in viral lode is monitored daily by conventional techniques that detect the amount of HIV RNA (*e.g.*, Roche AMPLICOR MONITOR™). A reduction in viral lode will be observed, as indicated by a reduction in the amount of HIV RNA detected.

The methods above can be supplemented with administration of an antiviral treatment selected from the group consisting of nucleoside analogue reverse transcriptase inhibitors, nucleotide analogue reverse transcriptase inhibitors, non-nucleoside reverse transcriptase inhibitors, and protease inhibitors. Further, the modified G-NH_2 used in these methods can be joined to a support or can be administered in a pharmaceutical comprising a pharmaceutically acceptable carrier.

While the present invention has been described in some detail for purposes of clarity and understanding, one skilled in the art will appreciate that various changes in form and detail can be made without departing from the true scope of the invention.

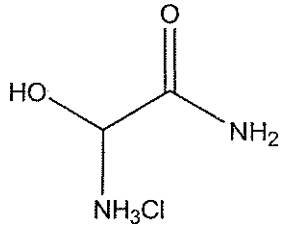
WHAT IS CLAIMED IS:

1. Use of a composition comprising α-hydroxyglycinamide (formula C) or a pharmaceutical salt thereof, in the manufacture of a medicament used to treat or prevent HIV infection.



(C)

2. The use of Claim 1, wherein said composition comprises the α-hydroxyglycinamide salt of formula D.



(D)

3. The use of Claim 1, wherein said α-hydroxyglycinamide (formula C) is a L-α-hydroxyglycinamide.

4. The use of Claim 1, wherein said α-hydroxyglycinamide (formula C) is a D-α-hydroxyglycinamide.

5. The use of Claim 1, wherein said α-hydroxyglycinamide (formula C) is a S-α-hydroxyglycinamide.

6. The use of Claim 1, wherein said α-hydroxyglycinamide (formula C) is a R-α-hydroxyglycinamide.

7. The use of Claim 1, wherein said composition is an oral formulation.

8. The use of Claim 1, wherein said composition is an intravenous formulation.

9. The use of Claim 1, wherein said composition is an oral formulation.

10. The use of Claim 1, wherein said composition is an intranasal formulation.

11. Use of α-hydroxyglycinamide (formula C) or a salt of α-hydroxyglycinamide (formula D) to prepare a medicament to treat or prevent HIV infection.

12. The use of Claim 10, wherein the salt of α-hydroxyglycinamide (formula D) is used.

13. The use of Claim 10, wherein an L-α-hydroxyglycinamide is used.

14. The use of Claim 10, wherein an D-α-hydroxyglycinamide is used.

15. The use of Claim 10, wherein an S-α-hydroxyglycinamide is used.

16. The use of Claim 10, wherein an R-α-hydroxyglycinamide is used.

17. The use of Claim 10, wherein said medicament is an oral formulation.

18. The use of Claim 1, wherein said medicament is an intravenous formulation.

19. The use of Claim 1, wherein said medicament is an oral formulation.

20. The use of Claim 1, wherein said medicament is an intranasal formulation.