

THERAPEUTIC METHODS AND COMPOSITIONS

FIELD OF THE INVENTION

[0001] The present invention relates to compositions and methods for modulating
5 the immune system in a subject in need thereof. The invention more particularly discloses
the existence and characterization of a key endogenous factor of the immune response and
provides novel therapeutic and diagnostic methods and compositions based on a
modulation of this factor. The invention particularly provides compositions and methods
10 suitable to stimulate or inhibit CD4 T cell-mediated immune responses in a subject, as well
as methods and compositions for monitoring immunodeficiency, including
immunodeficiency associated with human immunodeficiency virus (HIV) infection. Also
provided are methods and compositions to diagnose and assay CD4 T-cell-defects that
persist after antiretroviral therapy, as well as methods to develop drugs able to specifically
15 treat this immunodeficiency.

INTRODUCTION

[0002] CD4 T lymphocytes play a pre-eminent role in controlling the immune
system (both cellular and humoral responses) and are critical in various disease conditions.

[0003] During the immunological disease associated with HIV pathogenesis, less
20 than 0.5% of all CD4 T cells are actually infected (as measured in the peripheral blood), but
the great majority of CD4 T cells shows major regulatory dysfunction. Uninfected CD4 T
lymphocytes progressively lose their function, become anergic, and their numbers
decrease resulting in CD4 lymphopenia. Anergy and lymphopenia are the hallmarks of the
immunodeficiency characterizing HIV-infected patients. The mechanisms behind these
25 phenomena have never been fully elucidated (1).

[0004] Immune activation and inflammation also play a critical role in HIV pathogenesis (2, 3). The inventors have previously demonstrated that a decrease in responsiveness to interleukin-2 (IL-2), leading to CD4 anergy (4), and a reduction in responsiveness to interleukin-7 (IL-7) which, by disrupting the IL-7/CD4 regulatory loop, participates in the mechanisms leading to CD4 lymphopenia (5). The mechanisms involved have been attributed to defects in the Janus kinase (Jak) / Signal Transducer and Activator of Transcription (STAT) pathway (6, 7). Similar results have been obtained by other laboratories (8, 9). In this regard, compartmentalization of the IL-7 receptor (IL-7R) is required to initiate normal CD4 T cell responses (10). Upon IL-7 binding, the two chains of the IL-7R (IL-7R alpha and gamma-c) are first driven into membrane microdomains (MMD). These are cellular compartments which, like lipid rafts, are rich in cholesterol and sphingomyelin, but they also contain very significant amounts of structural and functional proteins (11). IL-7R complexes induce a reorganization of the cytoskeleton which then interacts with its meshwork. These two successive steps would be required for initiation of the Jak/STAT pathway (12).

[0005] The present inventors have investigated the mechanisms behind the unresponsiveness of CD4 T lymphocytes in viremic HIV-infected patients (VP). The experiments provided herein demonstrate that chronic activation of CD4 T lymphocytes drives them into an aberrant state of activation/differentiation which renders them refractory to certain physiological signals such as those delivered by interleukin-7. Furthermore, the present invention reports the identification, isolation and characterization, from human plasma, of the protein responsible for this aberrant state of CD4 T cell activation. For the first time, the invention thus discloses that immunosuppression can be mediated by an endogenous circulating protein which, upon expression, is able to induce alteration and inactivation of CD4-T cells and, upon inhibition, can stimulate the immune system in a subject.

[0006] Based in part on these remarkable findings, the invention now provides new methods, compositions and compounds for modulating the immune system, particularly for modulating the immune system in subjects having altered immunity (e.g.; immuno-

depressed or pathologic immune reactions). The invention further provides novel methods for treating immune disorders by modulating CD4 T cells. The invention is particularly suited for treating immunodeficiencies linked to CD4 T cell impairment, such as immunodeficiency syndrome associated with HIV-infection. The invention also provides
5 reagents and methods for characterizing the aberrant activation state, reactivity to IL7 and/or for monitoring immunoresponse impaired in HIV infected patients. Response of CD4 T cells can be evaluated in untreated or treated patients with antiretroviral drugs, and qualify their response to treatment and evaluate the competency of their CD4 T cells.

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SUMMARY OF THE INVENTION

[0007] An object of the invention relates to a method for modulating an immune response in a subject, comprising exposing the subject to a compound that modulates the amount (e.g., expression) or activity of GIBsPLA2.

[0008] A further object of the invention relates to a method of treatment of an
15 immune disorder in a subject, comprising exposing the subject to a compound that modulates the amount (e.g., expression) or activity of GIBsPLA2.

[0009] A further object of the invention relates to a method of treatment of an immune disorder in a subject, comprising modulating the amount (e.g., expression) or activity of GIBsPLA2 in the subject.

[0010] Another object of the invention relates to the use of a compound that
20 modulates the amount (e.g., expression) or activity of GIBsPLA2 for the manufacture of a medicament for modulating an immune response or for treating an immune disorder in a subject.

[0011] Another object of the invention relates to a GIBsPLA2 modulator for use in
25 a method of modulating an immune response or of treating an immune disorder in a subject.

[0012] Another object of the invention relates to a GIBsPLA2 modulator for use to modulate white blood cells in a subject.

[0013] In a first embodiment, the invention is used to induce or stimulate an immune response in the subject, and comprises inhibiting GIBsPLA2 in said subject, or
5 exposing the subject to a GIBsPLA2 inhibitor. Such embodiment is particularly suited to treat immuno-deficient subjects or subject in need of stimulated immunity (e.g., infectious diseases, cancer, etc.).

[0014] A particular object of the invention thus resides in a method of stimulating an immune response in a subject, comprising inhibiting GIBsPLA2 in said subject or
10 exposing the subject to a GIBsPLA2 inhibitor.

[0015] A further object of the invention relates to a method of treating an infectious disease in a subject, comprising inhibiting GIBsPLA2 in said subject or exposing the subject to a GIBsPLA2 inhibitor.

[0016] A more particular embodiment of the invention relates to a method of
15 treating AIDS in a HIV-infected subject, comprising inhibiting GIBsPLA2 in said subject or exposing the subject to a GIBsPLA2 inhibitor.

[0017] In a particular embodiment, exposing the subject to an inhibitor comprises administering the inhibitor to the subject. In another embodiment, exposing the subject to an inhibitor comprises vaccinating the subject against GIBsPLA2.

[0018] In this regard, in a particular embodiment, the invention relates to a method
20 for stimulating the immune system of a subject in need thereof, the method comprising vaccinating the subject against GIBsPLA2.

[0019] In another particular embodiment, the invention relates to a GIBsPLA2 antigen for use to vaccinate a subject in need thereof.

[0020] In another aspect, the invention is used to reduce or suppress an unwanted or deleterious immune response in the subject, and comprises causing or increasing GIBsPLA2 in said subject, or exposing the subject to a GIBsPLA2 agonist or activator. Such embodiment is particularly suited to treat subjects having abnormal and/or pathologic
5 immune responses (e.g., auto-immune diseases, inflammation, urticaria, eczema, allergies, asthma, etc.).

[0021] In a further aspect, the invention provides methods for diagnosing human immunodeficiency associated with CD4 T cell alteration. In some embodiments the methods comprise (a) providing a sample containing a body fluid, preferably plasma from a
10 subject, and (b) detecting the presence of GIBsPLA2 in the sample. In some embodiments of the methods the immunodeficiency is immunodeficiency associated with human immunodeficiency virus (HIV) infection. In some embodiments the method comprises contacting the sample with an antibody specific for GIBsPLA2. In some embodiments of the methods the presence of GIBsPLA2 in the sample is detected by an enzyme-linked
15 immunosorbent assay (ELISA).

[0022] In another aspect, the invention provides methods for identifying candidate immunodeficiency therapeutic agents. In some embodiments the immunodeficiency is associated with CD4 T cell alteration. In some embodiments of the methods, the human immunodeficiency associated with CD4 T cell alteration is caused by viral infection,
20 particularly human immunodeficiency virus (HIV) infection. In some embodiments the methods comprise: (a) contacting CD4 T lymphocytes with GIBsPLA2 in the presence of an agent, (b) measuring GIBsPLA2-induced CD4 T cell activation, and (c) comparing the level of GIBsPLA2-induced CD4 T cell activation in the presence of the agent with the level of GIBsPLA2-induced CD4 T cell activation in the absence of the agent. In some
25 embodiments of the methods, if the level of GIBsPLA2-induced CD4 T cell activation in the presence of the agent is lower than the level of GIBsPLA2-induced CD4 T cell activation in the absence of the agent, then the agent is identified as a candidate immunodeficiency therapeutic agent. In some embodiments of the methods, if the level of GIBsPLA2-induced CD4 T cell activation in the presence of the agent is not lower than the

level of GIBsPLA2-induced CD4 T cell activation in the absence of the agent, then the agent is identified as a candidate immunosuppressing therapeutic agent. In some embodiments the methods comprise measuring GIBsPLA2-induced CD4 T cell activation by determining the number of MMD per CD4 T cell. In some embodiments the methods
5 comprise measuring GIBsPLA2-induced CD4 T cell activation by determining the mean diameter of MMD on CD4 T cells. In some embodiments the methods comprise measuring GIBsPLA2-induced CD4 T cell activation by determining the IL-7 responsiveness of CD4 T cells.

[0023] In another aspect, the invention relates to a pharmaceutical composition
10 comprising a GIBsPLA2 modulator and a pharmaceutically acceptable carrier or excipient. In a preferred embodiment, the GIBsPLA2 modulator is a GIBsPLA2 inhibitor, more preferably selected from an antibody or a fragment or derivative thereof, an inhibitory nucleic acid, a peptide or a small drug. In another particular embodiment, the GIBsPLA2 modulator is a GIBsPLA2 agonist or activator, more particularly a GIBsPLA2 protein.

[0024] In another aspect, the invention relates to a vaccine composition comprising
15 a GIBsPLA2 antigen (e.g., an immunogenic GIBsPLA2 protein or an epitope-containing fragment thereof), a pharmaceutically acceptable carrier or excipient and, optionally, an adjuvant. In a preferred embodiment, the GIBsPLA2 antigen is a GIBsPLA2 protein or a fragment thereof treated to (i) increase its immunogenicity in human subjects and/or to (ii)
20 reduce its biological activity.

[0025] The invention may be used in any mammal. It is particularly suited for use in human subjects. It may be used to increase the immune response in any mammal, and it is particularly adapted to induce potent CD4-T cell activity in immuno-depressed subjects.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] **Figures 1a to 1e** shows that, before any stimulation, CD4 T cells from VP show an aberrant state of activation with many large membrane microdomains that are unaffected by IL-7.

5 [0027] **(a)** Membrane microdomains (MMD) were labelled with cholera toxin subunit B (CtxB-AF488) and analyzed by STED microscopy. From top to bottom, purified CD4 T cells from HD, VP and PHA-activated (40 µg/ml, 30 min) HD T cells. For each group the top half of a representative CD4 T-cell before and after IL-7 stimulation (2 nM, 15 min) is shown from Z-stack image series. CD4 T lymphocytes were also treated with
10 cholesterol oxidase (COase, 31µM, 25min) plus sphingomyelinase (SMase, 2.7µM, 5min) before stimulation by IL-7.

[0028] **(b, c)** MMD were counted on the entire surface of the purified CD4 T cells. An average of 50 cells were examined. **(b)** HD cells before (HDc: NS) and after IL-7 stimulation (HDc: IL-7). **(c)** VP cells before (VPc: NS) and after IL-7 stimulation VP (VPc: IL-7), PHA-activated HD cells before (HDc: PHA) and after IL-7 stimulation (HDc: PHA/IL-7).
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[0029] **(d, e)** MMD size was measured at the surface of purified CD4 T cells (d) IL-7-stimulated HD cells (HDc: IL-7), (e) IL-7-stimulated VP cells (VPc: IL-7) and IL-7-stimulated PHA- pre-activated HD cells (HDc: IL-7).

20 [0030] **Figures 2a to 2c** show that IL-7R chains from VP CD4 T-cells are embedded in detergent-resistant microdomains (DRM) that are unaffected by IL-7. Purified CD4 T lymphocytes were lysed (0.5% Triton X-100) and 200µl of the lysate was loaded on a 5-40% sucrose gradient. After 16h of centrifugation (50krpm) at 4°C, 18 fractions were collected (#1 left = tube top = 5% sucrose; #18 right = tube bottom = 40%
25 sucrose). Each fraction was analyzed on SDS-PAGE (7% acrylamide-bis). Flotillin, IL-7R alpha and gamma-c were detected by immunoblotting (10).

[0031] (a) Flotillin was used as a marker to indicate low density fractions corresponding to DRM and high-density fractions outside rafts.

[0032] (b) IL-7R α and (c) gamma-c bands are shown for purified non-stimulated HD CD4 T-cells (HDc: NS), IL-7-stimulated HD cells (HDc:IL-7), non
5 stimulated VP cells (VPc:NS) and PHA-activated HD cells (HDc:PHA).

[0033] Figures 3a to 3e show that IL-7R function is altered in membrane microdomains of VP CD4 T-cells.

[0034] (a) Two-dimensional effective diffusion rates D_{eff} for IL-7R α were measured as developed in Figure 7. Diffusion rates were also measured after adding various
10 drugs: COase (31 μ M, 30min) plus SMase (2.7 μ M, 5min) (CO/SM), Col (10 μ M, 30min) plus CytD (20 μ M, 30min) (CytD/Col), or in the presence of all these inhibitors (all). CD4 T cells from HD (HDc) and VP (VPc) were studied, as were PHA-activated HD CD4 T cells (HDc: PHA). Bars indicate SEM from 5 independent experiments. More experimental data are given in Figure 8.

15 [0035] (b) IL-7-induced phosphorylation and nuclear translocation of STAT5 were followed using rabbit phospho-STAT5 labelled with goat anti-rabbit-Atto642 and analyzed by pulsed-STED microscopy (0.5 μ m slices). The experiments involved purified non stimulated HD CD4 T cells (HDc: NS), IL-7-stimulated HD CD4 T cells (HDc: IL-7), non
20 stimulated VP CD4 T cells (VPc: NS), IL-7-stimulated VP CD4 T cells (VPc:IL-7), PHA-activated HD CD4 T cells (HDc:PHA) and PHA-activated HD CD4 T cells stimulated by IL-7 (HDc:PHA/IL-7). The effects of colchicin plus cytochalasin D are shown in the left panel.

[0036] (c, d, e) After IL-7 stimulation, the kinetics of phospho-STAT5 appearance in the cytoplasm and accumulation in the nucleus were measured using ImageJ software.
25 (c) HD CD4 T cells (black line) and HD CD4 T cells treated with Col plus CytD (blue line), (d) VP CD4 T cells (red line) and (e) PHA-activated HD CD4 T cells (green line).

[0037] **Figures 4a to 4d** show that plasma from VP induces an aberrant activation pattern in HD CD4 T cells as measured by the number of MMD.

[0038] **(a)** Representative images of HD CD4 T cells treated with plasma (10%) from VP (HDc: VPp), HIC (HDc: HICp) or ART patients (HDc: ARTp) are shown. MMD
5 were stained with cholera toxin (CtxB-AF488). For each group the top half of a representative CD4 T-cell from Z-stack images before (left) and after IL-7 stimulation (2nM, 15min) (right) is shown.

[0039] **(b)** MMD induced at the surface of CD4 T-cells (HDc) by plasmas (10%) from 5 different VP (VPp1 to VPp5). Results were obtained from the analysis of 50 cells
10 before (white) and after (blue) IL-7 stimulation. Mean values and quartiles are shown.

[0040] **(c)** Comparison of the effects of plasmas from HD (HDp), VP (VPp), HIC (HICp) and ART patients (ARTp) after (blue) and before (white) IL-7 stimulation.

[0041] **(d)** Dose (0.01% to 10%)-response obtained with the plasmas described in c. The number of MMD induced at the surface of HDc CD4 T-cells is shown. The effect of
15 VP plasma is shown as a plain red line.

[0042] **Figures 5a to 5d** show that plasma from VP inhibits IL-7-induced STAT5 phosphorylation and nuclear translocation of phospho-STAT5 in HD CD4 T lymphocytes.

[0043] **(a)** Before IL-7 stimulation, purified HD CD4 T cells were pre-incubated with plasma (10%). IL-7-induced phosphorylation and nuclear translocation of phospho-
20 STAT5 were followed by pulsed-STED microscopy (0.5µm slice). The following plasmas (10%) were studied: control (HDc: NS), VP (HDc: VPp), HIC (HDc: HICp) and ART patients (HDc: ARTp).

[0044] **(b)** Analysis of phospho-STAT5 recovered in the cytoplasm (blue) and nucleus (red) of IL-7-stimulated HD CD4 T-cells pre-treated with plasmas from 5 different
25 VP (10%).

[0045] (c) Comparison of the effects of plasma (10%) pre-incubation on IL-7-stimulated HD CD4 T cells. Plasma were from HD (HDp), VP (VPp), HIC (HICp) and ART patients (ARTp)

5 [0046] (d) Dose (0.01%-10%)-response obtained with the plasmas as measured by the inhibition of phospho-STAT5 nuclear translocation in IL-7-stimulated HD CD4 T-cells. The effect of VP plasma is shown as a plain red line.

[0047] **Figures 6a to 6d** show molecular characterization of the Refractory state Inducing Factor (RIF) recovered from VP plasma.

10 [0048] (a) Treatment of VP plasma by trypsin, DNase, RNase and PNGase. RIF activity was followed by measuring the number of MMD and effects on IL-7-induced nuclear phospho-STAT5 in HD CD4 T-cells.

[0049] (b) RIF MW was measured by gel filtration on a Sephadex G100 column. RIF activity on HD CD4 T-cells was followed by measuring the numbers of MMD induced by the different fractions of the column (thick red curve). Each fraction was also tested for
15 the presence of viral proteins by dot blot using polyclonal antibodies from VP plasma. Background obtained with HD plasma has been subtracted. Experiments were repeated three times.

[0050] (c) RIF MW was also measured after gel filtration on a Sephadex G100 column and its activity followed by inhibition of IL-7-induced phospho-STAT5 as
20 measured by FACS. Percentages of maximum IL-7-induced phospho-STAT5 were recorded. The amount of protein in each fraction is also reported. Experiments were repeated twice.

[0051] (d) Isoelectric point was measured as follows. RIF eluted from the Sephadex G100 column was loaded onto an anion (MonoQ) or cation (MonoS) exchange column.
25 RIF activity was eluted by pH-step buffers. The number of MMD on HD CD4 T-cells was plotted against pH.

[0052] **Figures 7a to 7c** show a 2D gel analysis of the IL-7 signalosome in purified CD4 T cells from HD, VP and IL-7-stimulated HD cells. **(a)** non-stimulated (NS) HD CD4 T-cells. **(b)** VP CD4 T-cells. **(c)** IL-7-stimulated HD CD4 T-cells.

[0053] **Figures 8a to 8g** show an analysis of the diffusion rate of IL-7Ralpha at the surface of purified CD4 T cells from HD, VP and PHA-stimulated HD cells. **(a, d)** at the surface of HD CD4 T-cells, **(b, e)** at the surface of VP CD4 T cells, **(c, f)** at the surface of HD CD4 T cells pre-activated with PHA (1µg/ml). **(g)** Scheme of the mechanism of IL-7Ralpha diffusion embedded in MMD before and after treatment by MMD inhibitors or cytoskeleton inhibitors.

[0054] **Figures 9a to 9d** show a schematic representation of the hypothetical mode of action of RIF on HD CD4 T cells and mechanism of IL-7 unresponsiveness. RIF induces abnormal MMD which are non functional. The IL-7 signalosome is therefore altered and the cells remain unresponsive to the cytokine, as in VP CD4 T cells. Aberrant activation patterns and signalling defects in RIF-induced HD CD4 T cells and in VP CD4 T cells are undistinguishable. The left part of the scheme illustrates the different steps in the mechanisms of IL-7 signal transduction in HD (10, 12).

[0055] **(a)** In resting CD4 T cells, before IL-7 recognition, the IL-7R chains are associated but their intracytoplasmic domains are far apart and the signaling molecules Jak1 and Jak3 are not interacting.

[0056] **(b)** In IL-7-activated CD4 T cells, the IL-7R is compartmentalized in normal MMD (90 nm in diameter) and the signalosome becomes functional. After cytoskeleton organization, STAT5A and STAT5B are phosphorylated in contact with the IL-7R/Jak1/Jak3 complexes then migrate to the nucleus by moving along the microtubules as previously discussed (12).

[0057] The right part of the scheme illustrates the hypothetical mechanism of action of RIF. The proposed mechanism of action is derived from preliminary data and

comparison of RIF-induced defects with the alterations characterized in purified CD4 T cells from VP (unpublished data).

[0058] (c) RIF induces many large abnormal MMDs. IL-7Rs are embedded in abnormal MMDs and their ability to induce a functional signalosome is altered.

- 5 [0059] (d) RIF-treated HD CD4 T cells are unresponsive to IL-7. Jak1 and Jak3 phosphorylate STAT5, although with reduced kinetics, but phospho-STAT5 do not migrate into the nucleus due to the lack of cytoskeleton and microtubules organization.

- [0060] Panels **a**, **b**, **c** and **d** show STED microscopy images of MMD labelled with CtxB: AF488 (half pile of Z-stack from CW-STED). Panels **b** and **d** show tubulin stained
 10 with rabbit anti-tubulin/goat anti-rabbit-Atto642, actin stained with mouse anti-actin/goat-anti-mouse-Chr494 and phospho-STAT5 stained with rabbit anti-phospho-STAT5/goat-anti-rabbit-Atto642. Pulsed-STED microscopy shows a 0.5µm slice of methanol-permeabilized CD4 T-cells. After IL-7 stimulation, actin in the MMD cytoplasmic area of RIF-treated HD CD4 T lymphocytes fails to concentrate as structured pads and does not
 15 form a cortex surrounding the nucleus, unlike in HD. Furthermore, the tubulin in these RIF-treated HD CD4 T cells, like in VP CD4 T cells, fails to form microtubules which have been hypothesized as being critical rods bridging the cytoplasm and nuclear membrane and thereby essential for STAT5 nuclear translocation.

- [0061] Summary of the defects: Circled numbers 1, 2, 3 and 4 indicate the different
 20 defective steps related to the aberrant activation pattern and IL-7 unresponsiveness in RIF-treated HD T cells: (1) abnormal protein pattern of signalling complexes as described by 2D-gels, (2) abnormal membrane structures such as large MMD as seen by STED microscopy, (3) abnormal cytoskeleton organization as measured by diffusion kinetics and STED microscopy, and (4) abnormal signalling intermediate and inhibition of phospho-
 25 STAT5 nuclear translocation as shown by STED microscopy.

Figure 10: PLA2sGIB inhibits IL-2 induced PStat5 nuclear translocation in CD4 T cells of healthy donors (HD): Resting CD4 T cells purified from 4 healthy donors were

treated for 30 minutes at 37°C with 3% or 1% of plasma from 5 VP (VP63, VP68, VP69, VP74 and VP75) and from 3 HD used as control. When indicated they were stimulated with 2nM IL-2 for 15 minutes at 37°C. The percentage of cells positive for nuclear PStat5, with mean and SD, in whole CD4 T cells (a) and in CD4+ CD25+ T cells (b), before (blue points) and after IL-2 stimulation (red points) are shown. Intracellular localisation of PStat5 was observed using Laser Scanning Confocal Microscopy (LSM 700, Zeiss) after indirect staining with rabbit anti human PStat5 (pY694) followed by donkey anti rabbit IgG-Die light 405. Total CD4 T cells were stained with goat anti human α -Tubulin followed by donkey anti goat IgG-AF555. CD25+ CD4 T cells were targeted with a mouse anti human CD25 followed by donkey anti mouse IgG-AF488.

Figure 11: PLA2sGIB inhibits IL-4 induced PStat6 nuclear translocation in CD4 T cells of healthy donors (HD): Resting CD4 T cells purified from 4 healthy donors were treated for 30 minutes at 37°C with 3% or 1% of plasma from 5 VP (VP63, VP68, VP69, VP74 and VP75) and from 3 HD used as control. When indicated they were stimulated with 2nM IL-4 for 15 minutes at 37°C. The percentage of cells positive for nuclear PStat6, with mean and SD, in whole CD4 T cells, before (blue points) and after IL-2 stimulation (red points) are shown. Intracellular localisation of PStat6 was observed using Laser Scanning Confocal Microscopy (LSM 700, Zeiss) after indirect staining with rabbit anti human PStat6 (pY694) followed by goat anti rabbit IgG-AF488. Total CD4 T cells were stained with mouse anti human α -Tubulin followed by goat anti mouse IgG-AF647.

Figure 12: Absence of activity of mutant pPLA2GIB H48Q.

Figure 13: Comparison of the activity of wild type cloned porcine PLA2 GIB and of its mutant H48Q. A: induction of abnormal Membrane Microdomains (aMMD); B: effect on the IL-7 induced Nuclear Translocation of phosphoSTAT5 (NT of pSTAT5).

Figure 14 shows the treatment of plasma from viremic patients with goat anti-PLA2 G1B antibodies coupled to sepharose beads. Green: VP68; pink: VP69; blue: VP LJT. After treatment (30 min at room temperature) the plasmas were tested:

- a. The percentage of CD4 T cells showing abnormal MMD/cell was measured after staining with Cholera toxin B (CtxB-AF488)
- b. The nuclear translocation of pSTAT5 was measured after IL-7 stimulation and the percentage of positive nucleus counted.

5 **Figure 15:** Effect of anti-PLA2 GIB antibodies on the induction of aMMD and inhibition of NT pSTAT5.

Figure 16 : Soluble PLA2G1B mouse receptor (sMR) inhibits the activity of human PLA2G1B (huPLA2G1B) on the response to IL-7 of CD4 T cells from healthy donors, expressed as the percent of cells positive for nuclear translocation of PStat5. The
10 restoration of the response is calculated as:

$$100 \times (\% \text{Pos cell}_{\text{huG1B+sMR}} - \% \text{Pos cell}_{\text{huG1B}}) / (\% \text{Pos cell}_{\text{culture medium}} - \% \text{Pos cell}_{\text{huG1B}})$$

Figure 17 shows the plasma from CD4 non-responder (CD4-NR) patients induce aberrant MMD in HD CD4 T cells – (a) Images of HD CD4 T cells treated with plasma
15 (1%) from CD4-NR patient obtained using Structured Illumination Microscopy (SIM). MMD were stained with cholera toxin B (CtxB-AF488). Projection of Z-stacks images of a representative CD4 T cell is shown. After IL-7 stimulation (2nM, 15min) there is no modification of the image (right). (b) Dose curve response (0.0001% to 1%) obtained with plasmas from 5 CD4-NR patients (blue curve, mean and SD) and from a representative
20 viremic patient (red curve). The number of abnormal MMD induced at the surface of HD CD4 T cells.

DETAILED DESCRIPTION OF THE INVENTION

 [0062] The present invention relates to compositions and methods for modulating
25 the immune system in a subject in need thereof. The invention more particularly discloses the identification of GIBsPLA2 as a key endogenous factor of the immune response and

provides novel therapeutic and diagnostic methods and compositions based on a modulation of this factor.

[0063] A hypothesis of the present invention was that chronic activation of the immune system in HIV-infected patients is abnormal and drives CD4 T cells into an aberrant state of activation/differentiation that is unresponsive to the gamma-c cytokines involved in controlling many aspects of immune defenses and homeostasis of the CD4 compartment, despite the fact that more than 99.5% of CD4 T cells from the peripheral compartment are uninfected. This hypothesis was evaluated by the inventors and the present invention elucidates the nature and significance of this aberrant state of activation.

[0064] More specifically, in a first aspect, the present invention demonstrates that the characteristics of this state may be summarized as follows: 1) before any stimulation, all the CD4 T cells in Viremic HIV-infected patients (VP) possess numerous large MMD on their surface, 2) these abnormal MMD sequester all the cell's IL-7Ralpha and gamma-c chains and 3) this sequestering of the chains in abnormal MMD alters their ability to induce the formation of a functional signalosome, 4) leading to a slowdown and a reduction of STAT5 phosphorylation and 5) a reduction of phospho-STAT5 nuclear import. This abnormal pattern of pre-existing MMD on the surface of VP CD4 T lymphocytes has multiple consequences and is a basic mechanism explaining the various manifestations of the immunodeficiency in HIV-infected patients. Loss of IL-7 responsiveness is an important factor that partly explains the CD4 lymphopenia observed. The persistent loss of these cells in VP - due to their sensitivity to apoptosis and their destruction by low-level but continuous virus proliferation - cannot be compensated despite increased levels of IL-7. In addition, since abnormal MMD sequester all the gamma-c chains in a non functional state, this blocks the function of the other cytokines in this family.

[0065] The present invention further discloses the identification of the key endogenous factor responsible for this abnormal state of the immune system in infected subjects and, more generally, responsible for a drastic modulation of the immune response in various pathophysiological conditions. Plasma samples from VP were indeed shown to

contain an activity - termed RIF – which is able to induce aberrant activation of Healthy Donors (HD) CD4 T lymphocytes. RIF was found in all the plasma samples of the VP examined. The pathophysiological significance of this activity was demonstrated by its absence in HIV Controller (HIC) patients where the IL-7/IL-7R system is normal and immune activation is beneficial. RIF is also absent in the plasma of ART patients who have diminished their immune activation, restored IL-7R function and recovered CD4 counts > 500 / mm³ (5).

[0066] RIF thus represents a major factor that controls the immune response, particularly through a modulation of CD4 T lymphocytes. It is remarkable that RIF induces an aberrant pattern of activation in HD CD4 T cells that is undistinguishable from that observed directly ex vivo in purified VP CD4 T cells. The invention further shows that RIF is the secreted phospholipase A2 from Group I B (“PLA2 GIB”). The results disclosed in this application show that (i) over expression of PLA2 GIB leads to a potent immunosuppression and that (ii) inhibition of PLA2 GIB leads to a remarkable increase or stimulation of immune function. GIBsPLA2 inhibitors were able to correct the inappropriate state of the immune cells in plasma from subjects and can thus be used to treat (e.g., prevent, correct) immunodeficiency or immune disorders in mammals. GIBsPLA2 inhibition can also induce, stimulate, or help maintaining CD4 T cell counts and function, and thereby help stimulate efficient immune responses in patients. In particular, in HIV-infected patients, ART might be spared, or could be suspended, were an equilibrium to be reached between patient immune defenses and the virus. Were ART, given very early after infection as suggested by recent studies, to be combined with RIF inhibitors, this would prevent any RIF-induced alteration of the immune system. In addition, in the context of some current failures of ART, patients with low CD4 counts after prolonged ART may benefit from these inhibitors. Accordingly, the invention provides methods for treating a subject by modulating GIBsPLA2 expression or activity in the subject. More particularly, the invention provides a method for modulating an immune response in a subject in need thereof, comprising modulating GIBsPLA2 activity or expression in said subject.

[0067] The data provided in the examples also demonstrate that the presence of RIF in the plasma of a subject indicates the HIV-induced pathogenesis state of CD4 T cells. Accordingly, this invention provides methods of monitoring and/or diagnosing HIV infection in a subject by detecting the level of RIF in the plasma of the subject, among
5 other things.

[0068] The data provided in the examples further demonstrate that the number and/or size of membrane microdomains (MMD) on the T-cells of a subject indicates the HIV-induced pathogenesis state of CD4 T cells. Accordingly, this disclosure also provides provides methods of monitoring and/or diagnosing HIV infection in a subject by measuring
10 the number and/or size of membrane microdomains (MMD) on the T-cells of the subject, among other things.

[0069] The data provided in the examples also indicate a role for RIF in creating and/or maintaining the CD4 T cell disease state in HIV infected subjects. Accordingly, this disclosure also provides methods for identifying a candidate HIV therapeutic agent that
15 include measuring RIF-induced CD4 T cell activation in the presence of an agent. In some embodiments the methods comprise comparing the level of RIF-induced CD4 T cell activation in the presence of the agent with the level of RIF-induced CD4 T cell activation in the absence of the agent.

20 Definitions

The term “sequence identity” as applied to nucleic acid or protein sequences, refers to the quantification (usually percentage) of nucleotide or amino acid residue matches between at least two sequences aligned using a standardized algorithm such as Smith-Waterman
25 alignment (Smith and Waterman (1981) J Mol Biol 147:195-197), CLUSTALW (Thompson et al. (1994) Nucleic Acids Res 22:4673-4680), or BLAST2 (Altschul et al. (1997) Nucleic Acids Res 25:3389-3402). BLAST2 may be used in a standardized and

reproducible way to insert gaps in one of the sequences in order to optimize alignment and to achieve a more meaningful comparison between them.

As used herein, "treatment" or "treat" refers to clinical intervention in an attempt to alter the natural course of the individual being treated, and can be performed either for preventive or curative purpose. Desirable effects of treatment include, but are not limited to, preventing occurrence or recurrence of disease, alleviation of symptoms, diminishment of any direct or indirect pathological consequences of the disease, preventing metastasis, decreasing the rate of disease progression, amelioration or palliation of the disease state, and remission or improved prognosis. In some embodiments, compositions and methods of the invention are used to delay development of a disease or disorder or to slow the progression of a disease or disorder.

The term "isolated", as used herein, refers to molecules (e.g., nucleic or amino acid) that are removed from a component of their natural environment, isolated or separated, and are at least 60% free, preferably 75% free, and most preferably 90% free from other components with which they are naturally associated. An "isolated" polypeptide (or protein) is for instance a polypeptide separated from a component of its natural environment and, preferably purified to greater than 90% or 95% purity as determined by, for example, electrophoretic (e.g., SDS-PAGE, isoelectric focusing (IEF), capillary electrophoresis) or chromatographic (e.g., ion exchange or reverse phase HPLC) migration. An "isolated" nucleic acid refers to a nucleic acid molecule separated from a component of its natural environment and/or assembled in a different construct (e.g., a vector, expression cassette, recombinant host, etc.).

"Nucleic acid encoding an anti-GIBsPLA2 antibody" refers to one or more nucleic acid molecules encoding antibody heavy and light chains (or fragments thereof), including such

nucleic acid molecule(s) in a single vector or separate vectors, and such nucleic acid molecule(s) present at one or more locations in a host cell.

A "subject" refers to a mammal. Examples of mammals include humans and non-human animals such as, without limitation, domesticated animals (e.g., cows, sheep, cats, dogs, and horses), non-human primates (such as monkeys), rabbits, and rodents (e.g., mice and rats).

The "*modulation of an immune response*" designates, within the context of the invention, any modification of the amount or activity or ratio of immune cells, preferably white blood cells (e.g., T lymphocytes, B lymphocytes, NK, NKT cells, macrophages, dendritic cells).

10 In a particular embodiment, modulating an immune response includes modulating the amount or activity of T lymphocytes, preferably of CD4-T lymphocytes.

Refractory State Inducing Factor (RIF) or Phospholipase A2 group IB

[0070] The term RIF is used interchangeably with Phospholipase A2 group IB, GIBsPLA2 (or PLA2 GIB). Phospholipase A2 group IB is a secreted protein having a MW of from about 15 kDa and an isoelectric point of from about 6.5 to about 8.0.

[0071] Within the context of the present invention, the term "GIBsPLA2" or "phospholipase A2 group IB" designates any native GIBsPLA2 protein from any vertebrate source, including mammals such as primates (e.g. humans) and rodents (e.g., mice and rats), unless otherwise indicated. The term encompasses "full-length," unprocessed GIBsPLA2, as well as any form of GIBsPLA2 that results from processing inside or outside a cell. The term also encompasses naturally-occurring variants of GIBsPLA2, e.g., splice variants or allelic variants.

[0072] The amino acid sequence of an exemplary human GIBsPLA2 is shown below (SEQ ID NO: 2).

MKLLVLAVLL TVAAADSGIS **PRAVWQFRKM** IKCVIPGSDP FLEYNNGCY
 CGLGGSGTPV DELDKCCQTH DNCYDQAKKL DSCKFLDNP YHTTYSYSCS
 GSAITCSSKN KECEAFICNC DRNAAICFSK APYNKAHKNL DTKKYCQS

[0073] Amino acids 1 to 15 of SEQ ID NO: 2 (underlined) are a signal sequence,
 5 and amino acids 16 to 22 of SEQ ID NO: 2 (in bold) are a propeptide sequence. The mature protein corresponds to amino acid residues 23-148 of SEQ ID NO: 2, which is an exemplary processed human GIBsPLA2 protein.

[0074] Naturally-occurring variants include any protein comprising the sequence of SEQ ID NO: 2, or the sequence of amino acid residues 23-148 of SEQ ID NO: 2, with one
 10 or more amino acid substitution, addition and/or deletion of one or several (typically 1, 2 or 3) amino acid residues, preferably not more than 10 distinct amino acid substitution(s), addition(s), and/or deletion(s) of one or several (typically 1, 2 or 3) amino acid residues. Typical naturally-occurring variants retain a biological activity of SEQ ID NO: 2.

[0075] In this regard, in some embodiments, GIBsPLA2 has at least one activity
 15 selected from induction of formation of membrane microdomains (MMD) in CD4 T cells from healthy subjects, or rendering CD4 T cells of healthy subjects refractory to interleukin signaling, such as refractory to IL-2 signaling or refractory to IL-7 signaling.

[0076] In some embodiments inducing formation of MMD comprises increasing the number of MMD on CD4 T cells of healthy subjects to at least about 80 per cell, at least
 20 about 90 per cell, at least about 100 per cell, at least about 110 per cell, or at least about 120 per cell. In a non-limiting preferred embodiment, inducing formation of MMD comprises increasing the number of MMD on CD4 T cells of healthy subjects to more than 100 MMD per cell.

[0077] In some embodiments inducing formation of MMD comprises stimulating
 25 formation of larger MMD than would otherwise be present on the CD4 T cells. In some embodiments inducing formation of larger MMD comprises stimulating formation MMD having a diameter of at least 100 nm, at least 110 nm, at least 120 nm, at least 130 nm, or at

least 140 nm. In a non-limiting preferred embodiment, inducing formation of larger MMD comprises stimulating formation of MMD having a diameter larger than 120 nm.

[0078] In some embodiments rendering CD4 T cells of healthy subjects refractory to interleukin-7 signaling comprises a reduction of STAT5A and/or B phosphorylation in said cells by at least about 10%, at least about 20%, at least about 30%, or at least about 40%. In some embodiments rendering CD4 T cells of healthy subjects refractory to interleukin-7 signaling comprises reducing the rate of nuclear translocation of phospho-STAT5A and/or phospho-STAT5B by at least about 20%, at least about 30%, at least about 40%, or at least about 50%.

[0079] GIBsPLA2 activity may be measured by any suitable method known in the art, as illustrated in the examples, or later developed. GIBsPLA2 activity may be measured in a plasma sample such as for example a fractionated plasma sample, using e.g., ligand recruitment assays, immunoassays and/or enzymatic assays.

In a particular embodiment, the term GIBsPLA2 designates a human protein, particularly a protein comprising or having SEQ ID NO: 2, or a naturally-occurring variant thereof.

[0080] GIBsPLA2 according to this disclosure may be isolated, purified, and/or recombinant. In certain embodiments, the invention may use, instead or in addition to a GIBsPLA2 protein, a nucleic acid encoding GIBsPLA2. The nucleic acid may be DNA or RNA, single- or double-stranded.

[0081] An exemplary nucleic acid sequence encoding a GIBsPLA2 is shown in SEQ ID NO: 1 below.

ATGAAACTCCTTGTGCTAGCTGTGCTGCTCACAGTGGCCGCCGCCGACAGCGGCATCAGC
CCTCGGGCCGTGTGGCAGTTCCGCAAAATGATCAAGTGCGTGATCCCGGGGAGTGACCCC
TTCTTGGAATACAACAACACTACGGCTGCTACTGTGGCTTGGGGGGCTCAGGCACCCCCGTG
GATGAACTGGACAAGTGCTGCCAGACACATGACAACTGCTACGACCAGGCCAAGAAGCTG
GACAGCTGTAAATTTCTGCTGGACAACCCGTACACCCACACCTATTTCATACTCGTGCTCT

GGCTCGGCAATCACCTGTAGCAGCAAAAAACAAAGAGTGTGAGGCCTTCATTTGCAACTGC
 GACCGCAACGCTGCCATCTGCTTTTCAAAAGCTCCATATAACAAGGCACACAAGAACCTG
 GACACCAAGAAGTATTGTCAGAGTTGA

- 5 [0082] Alternative nucleic acid molecules encoding a GIBsPLA2 include any variant of SEQ ID NO:1 resulting from the degeneracy of the genetic code, as well as any sequence which hybridizes to SEQ ID NO: 1 under stringent conditions, more preferably having at least 80%, 85%, 90% , 95% or more sequence identity to SEQ ID NO; 1, and encoding a GIBsPLA2 protein.

10

Method of production of GIBsPLA2

- [0083] GIBsPLA2 can be produced by any conventionally known protein expression method and purification method. For example: (i) a method for synthesizing peptides; (ii) a method for purifying and isolating them from the living body or cultured cells; or (iii) a method for producing them with the use of genetic recombination techniques; and combinations thereof and the like (for example, the standard techniques described for example in Molecular Cloning (Sambrook, J., Fritsch, E. F., Maniatis, T., Cold Spring Harbor Laboratory Press) (1989) and Current Protocols in Molecular Biology (Ausubel, F. M., John Wiley and Sons, Inc. (1989)).
- 15
- 20 [0084] In a particular embodiment, the invention relates to a method for producing GIBsPLA2 by expression of a coding nucleic acid in a host cell, and collection or purification of GIBsPLA2. In this regard, the invention also described recombinant host cells comprising a nucleic acid encoding a GIBsPLA2. Such cells may be prokaryotic (such as bacteria) or eukaryotic (such as yeast cells, insect cells, plant cells or mammalian cells).
- 25 The nucleic acid may be placed under the control of any suitable regulatory sequence, such as a promoter, terminator, and the like. Alternatively, the nucleic acid may be inserted in

the host cell in a location where expression is driven by an endogenous promoter. Techniques for inserting nucleic acids in cells are well known in the art.

GIBsPLA2 modulation

5 The invention provides novel methods which comprise a modulation of GIBsPLA2 in a subject in need thereof. The term “modulation” designates any modification of the level (e.g., expression) or activity of GIBsPLA2 in a subject. Also, modulation designates either an increase or a decrease GIBsPLA2 level or activity. A modulation more preferably designates a change by at least 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80% or more as
10 compared to non-modulated situation. As a result, inhibiting GIBsPLA2 designates reducing by at least 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80% or more GIBsPLA2 level or activity, as well as completely blocking or suppressing GIBsPLA2 level or activity. Conversely, stimulating GIBsPLA2 designates increasing by at least 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80% or more GIBsPLA2 level or activity. Depending on the situation, the
15 modulation may be transient, sustained or permanent. Also modulating the activity includes modulating the amount of GIBsPLA2 in the subject, particularly in body fluids, modulating the potency of the protein (for instance by modulating the level of co-factors or substrate in the subject), and modulating the level or activity of degradation products produced by GIBsPLA2.

20 GIBsPLA2 inhibition

In a particular embodiment, the invention provides compositions and methods for inhibiting GIBsPLA2 in a subject. GIBsPLA2 inhibition may be obtained by the use of GIBsPLA2 inhibitors, i.e., any compound that inhibit the expression or activity of GIBsPLA2. GIBsPLA2 inhibitors include expression inhibitors, antagonists, sequestrators,
25 or target masking compounds. Preferred types of GIBsPLA2 inhibitors include GIBsPLA2 ligands (covalent or non-covalent), anti-GIBsPLA2 antibodies (and fragments and derivatives thereof), nucleic acids encoding anti-GIBsPLA2 antibodies (or fragments and

derivatives thereof), inhibitory nucleic acids, peptides, or small drugs, or combination(s) thereof. Alternatively, or in addition, GIBsPLA2 inhibition can be obtained by vaccinating a subject against a GIBsPLA2 antigen, so that antibodies are produced by the subject in need of PLA2-GIB inhibition.

5 *Antibodies against GIBsPLA2*

[0085] Specific examples of GIBsPLA2 inhibitors are antibodies that specifically bind to GIBsPLA2.

10 [0086] Antibodies can be synthetic, monoclonal, or polyclonal and can be made by techniques well known in the art. Such antibodies specifically bind via the antigen-binding sites of the antibody (as opposed to non-specific binding). GIBsPLA2 polypeptides, fragments, variants, fusion proteins, etc., can be employed as immunogens in producing antibodies immunoreactive therewith. More specifically, the polypeptides, fragments, variants, fusion proteins, etc. contain antigenic determinants or epitopes that elicit the formation of antibodies.

15 [0087] These antigenic determinants or epitopes can be either linear or conformational (discontinuous). Linear epitopes are composed of a single section of amino acids of the polypeptide, while conformational or discontinuous epitopes are composed of amino acids sections from different regions of the polypeptide chain that are brought into close proximity upon protein folding (C. A. Janeway, Jr. and P. Travers, *Immuno Biology* 3:9 (Garland Publishing Inc., 2nd ed. 1996)). Because folded proteins have complex surfaces, the number of epitopes available is quite numerous; however, due to the conformation of the protein and steric hinderances, the number of antibodies that actually bind to the epitopes is less than the number of available epitopes (C. A. Janeway, Jr. and P. Travers, *Immuno Biology* 2:14 (Garland Publishing Inc., 2nd ed. 1996)). Epitopes can be
20 identified by any of the methods known in the art. Both polyclonal and monoclonal
25 antibodies can be prepared by conventional techniques.

[0088] Preferred antibodies of the invention are directed to a GIBsPLA2 epitope, and/or have been generated by immunization with a polypeptide comprising a GIBsPLA2 epitope selected from: the mature GIBsPLA2 protein, a fragment of GIBsPLA2 comprising at least 8 consecutive amino acid residues of SEQ ID NO: 2 (or the corresponding residues of a natural variant of SEQ ID NO: 2), said fragment comprising at least amino acid 70, amino acid 121, amino acid 50, amino acid 52, amino acid 54, amino acid 71, or a combination thereof. Preferred antibodies of the invention bind an epitope comprised between amino acid residues 50-71 of SEQ ID NO: 2 or the corresponding residues of a natural variant of SEQ ID NO: 2.

10 [0089] The term “antibodies” is meant to include polyclonal antibodies, monoclonal antibodies, fragments thereof, such as F(ab')₂ and Fab fragments, single-chain variable fragments (scFvs), single-domain antibody fragments (VHHs or Nanobodies), bivalent antibody fragments (diabodies), as well as any recombinantly and synthetically produced binding partners, human antibodies or humanized antibodies.

15 [0090] Antibodies are defined to be specifically binding preferably if they bind to GIBsPLA2 with a K_a of greater than or equal to about 10^7 M⁻¹. Affinities of antibodies can be readily determined using conventional techniques, for example those described by Scatchard et al., Ann. N.Y. Acad. Sci., 51:660 (1949).

[0091] Polyclonal antibodies can be readily generated from a variety of sources, for example, horses, cows, donkeys, goats, sheep, dogs, chickens, rabbits, mice, or rats, using procedures that are well known in the art. In general, purified GIBsPLA2 or a peptide based on the amino acid sequence of GIBsPLA2 that is appropriately conjugated is administered to the host animal typically through parenteral injection. The immunogenicity of GIBsPLA2 can be enhanced through the use of an adjuvant, for example, Freund's complete or incomplete adjuvant. Following booster immunizations, small samples of serum are collected and tested for reactivity to GIBsPLA2 polypeptide. Examples of various assays useful for such determination include those described in Antibodies: A Laboratory Manual, Harlow and Lane (eds.), Cold Spring Harbor Laboratory Press, 1988;

as well as procedures, such as countercurrent immuno-electrophoresis (CIEP), radioimmunoassay, radio-immunoprecipitation, enzyme-linked immunosorbent assays (ELISA), dot blot assays, and sandwich assays. See U.S. Pat. Nos. 4,376,110 and 4,486,530.

5 [0092] Monoclonal antibodies can be readily prepared using well known procedures. See, for example, the procedures described in U.S. Pat. Nos. RE 32,011, 4,902,614, 4,543,439, and 4,411,993; Monoclonal Antibodies, Hybridomas: A New Dimension in Biological Analyses, Plenum Press, Kennett, McKeam, and Bechtol (eds.), 1980.

10 [0093] For example, the host animals, such as mice, can be injected intraperitoneally at least once and preferably at least twice at about 3 week intervals with isolated and purified wild-type or mutant GIBsPLA2 protein or conjugated GIBsPLA2 peptide, optionally in the presence of adjuvant. Mouse sera are then assayed by
15 conventional dot blot technique or antibody capture (ABC) to determine which animal is best to fuse. Approximately two to three weeks later, the mice are given an intravenous boost of protein or peptide. Mice are later sacrificed and spleen cells fused with commercially available myeloma cells, such as Ag8.653 (ATCC), following established protocols. Briefly, the myeloma cells are washed several times in media and fused to mouse spleen cells at a ratio of about three spleen cells to one myeloma cell. The fusing agent can
20 be any suitable agent used in the art, for example, polyethylene glycol (PEG). Fusion is plated out into plates containing media that allows for the selective growth of the fused cells. The fused cells can then be allowed to grow for approximately eight days. Supernatants from resultant hybridomas are collected and added to a plate that is first coated with goat anti-mouse Ig. Following washes, a label, such as a labeled GIBsPLA2
25 polypeptide, is added to each well followed by incubation. Positive wells can be subsequently detected. Positive clones can be grown in bulk culture and supernatants are subsequently purified over a Protein A column (Pharmacia).

[0094] The monoclonal antibodies of the disclosure can be produced using alternative techniques, such as those described by Alting-Mees et al., "Monoclonal Antibody Expression Libraries: A Rapid Alternative to Hybridomas", *Strategies in Molecular Biology* 3:1-9 (1990), which is incorporated herein by reference. Similarly,
5 binding partners can be constructed using recombinant DNA techniques to incorporate the variable regions of a gene that encodes a specific binding antibody. Such a technique is described in Larrick et al., *Biotechnology*, 7:394 (1989).

[0095] Antigen-binding fragments of such antibodies, which can be produced by conventional techniques, are also encompassed by the present invention. Examples of such
10 fragments include, but are not limited to, Fab and F(ab')₂ fragments. Antibody fragments and derivatives produced by genetic engineering techniques are also provided.

[0096] The monoclonal antibodies of the present disclosure include chimeric antibodies, e.g., humanized versions of murine monoclonal antibodies. Such humanized antibodies can be prepared by known techniques, and offer the advantage of reduced
15 immunogenicity when the antibodies are administered to humans. In one embodiment, a humanized monoclonal antibody comprises the variable region of a murine antibody (or just the antigen binding site thereof) and a constant region derived from a human antibody. Alternatively, a humanized antibody fragment can comprise the antigen binding site of a murine monoclonal antibody and a variable region fragment (lacking the antigen-binding
20 site) derived from a human antibody. Procedures for the production of chimeric and further engineered monoclonal antibodies include those described in Riechmann et al. (*Nature* 332:323, 1988), Liu et al. (*PNAS* 84:3439, 1987), Larrick et al. (*Bio/Technology* 7:934, 1989), and Winter and Harris (*TIPS* 14:139, May, 1993). Procedures to generate antibodies transgenically can be found in GB 2,272,440, U.S. Pat. Nos. 5,569,825 and 5,545,806.

25 [0097] Antibodies produced by genetic engineering methods, such as chimeric and humanized monoclonal antibodies, comprising both human and non-human portions, which can be made using standard recombinant DNA techniques, can be used. Such chimeric and humanized monoclonal antibodies can be produced by genetic engineering using standard

DNA techniques known in the art, for example using methods described in Robinson et al. International Publication No. WO 87/02671; Akira, et al. European Patent Application 0184187; Taniguchi, M., European Patent Application 0171496; Morrison et al. European Patent Application 0173494; Neuberger et al. PCT International Publication No. WO 86/01533; Cabilly et al. U.S. Pat. No. 4,816,567; Cabilly et al. European Patent Application 0125023; Better et al., Science 240:1041 1043, 1988; Liu et al., PNAS 84:3439 3443, 1987; Liu et al., J. Immunol. 139:3521 3526, 1987; Sun et al. PNAS 84:214 218, 1987; Nishimura et al., Canc. Res. 47:999 1005, 1987; Wood et al., Nature 314:446 449, 1985; and Shaw et al., J. Natl. Cancer Inst. 80:1553 1559, 1988); Morrison, S. L., Science 229:1202 1207, 1985; Oi et al., BioTechniques 4:214, 1986; Winter U.S. Pat. No. 5,225,539; Jones et al., Nature 321:552 525, 1986; Verhoeyan et al., Science 239:1534, 1988; and Beidler et al., J. Immunol. 141:4053 4060, 1988.

[0098] In connection with synthetic and semi-synthetic antibodies, such terms are intended to cover but are not limited to antibody fragments, isotype switched antibodies, humanized antibodies (e.g., mouse-human, human-mouse), hybrids, antibodies having plural specificities, and fully synthetic antibody-like molecules.

[0099] For therapeutic applications, "human" monoclonal antibodies having human constant and variable regions are often preferred so as to minimize the immune response of a patient against the antibody. Such antibodies can be generated by immunizing transgenic animals which contain human immunoglobulin genes. See Jakobovits et al. Ann NY Acad Sci 764:525-535 (1995).

[00100] Human monoclonal antibodies against GIBsPLA2 polypeptides can also be prepared by constructing a combinatorial immunoglobulin library, such as a Fab phage display library or a scFv phage display library, using immunoglobulin light chain and heavy chain cDNAs prepared from mRNA derived from lymphocytes of a subject. See, e.g., McCafferty et al. PCT publication WO 92/01047; Marks et al. (1991) J. Mol. Biol. 222:581 597; and Griffiths et al. (1993) EMBO J 12:725 734. In addition, a combinatorial library of antibody variable regions can be generated by mutating a known human

antibody. For example, a variable region of a human antibody known to bind GIBsPLA2, can be mutated by, for example, using randomly altered mutagenized oligonucleotides, to generate a library of mutated variable regions which can then be screened to bind to GIBsPLA2. Methods of inducing random mutagenesis within the CDR regions of immunoglobulin heavy and/or light chains, methods of crossing randomized heavy and light chains to form pairings and screening methods can be found in, for example, Barbas et al. PCT publication WO 96/07754; Barbas et al. (1992) Proc. Nat'l Acad. Sci. USA 89:4457 4461.

[00101] An immunoglobulin library can be expressed by a population of display packages, preferably derived from filamentous phage, to form an antibody display library. Examples of methods and reagents particularly amenable for use in generating antibody display library can be found in, for example, Ladner et al. U.S. Pat. No. 5,223,409; Kang et al. PCT publication WO 92/18619; Dower et al. PCT publication WO 91/17271; Winter et al. PCT publication WO 92/20791; Markland et al. PCT publication WO 92/15679; Breitling et al. PCT publication WO 93/01288; McCafferty et al. PCT publication WO 92/01047; Garrard et al. PCT publication WO 92/09690; Ladner et al. PCT publication WO 90/02809; Fuchs et al. (1991) Bio/Technology 9:1370 1372; Hay et al. (1992) Hum Antibod Hybridomas 3:81 85; Huse et al. (1989) Science 246:1275 1281; Griffiths et al. (1993) supra; Hawkins et al. (1992) J Mol Biol 226:889 896; Clackson et al. (1991) Nature 352:624 628; Gram et al. (1992) PNAS 89:3576 3580; Garrad et al. (1991) Bio/Technology 9:1373 1377; Hoogenboom et al. (1991) Nuc Acid Res 19:4133 4137; and Barbas et al. (1991) PNAS 88:7978 7982. Once displayed on the surface of a display package (e.g., filamentous phage), the antibody library is screened to identify and isolate packages that express an antibody that binds a GIBsPLA2 polypeptide. In a preferred embodiment, the primary screening of the library involves panning with an immobilized GIBsPLA2 polypeptide and display packages expressing antibodies that bind immobilized GIBsPLA2 polypeptide are selected.

[00102] In a particular embodiment, the invention relates to a composition comprising an anti-GIBsPLA2 antibody (or a fragment or derivative thereof) and a pharmaceutically acceptable excipient.

[00103] Existing anti-Phospholipase A2-GIB monoclonal antibodies include Mab
5 CH-7 (Labome), MAB5018 (Labome), EPR5186 (Genetex); LS-C138332 (Lifespan) or
CABT-17153MH (creative biomart). Examples of polyclonal antibodies include for
instance N1C3 from GeneTex. As indicated above, preferred anti-GIBsPLA2 antibodies of
the invention bind mature GIBsPLA2, even more preferably an epitope comprised in a
domain of GIBsPLA2 comprising an amino acid selected from amino acid 70, amino acid
10 121, amino acid 50, amino acid 52, amino acid 54, amino acid 71, or a combination thereof.
Preferred antibodies of the invention bind an epitope comprised between amino acid
residues 50-71 of SEQ ID NO: 2 or the corresponding residues of a natural variant of SEQ
ID NO: 2.

[00104] In an alternative embodiment, the invention relates to and uses a
15 composition comprising a nucleic acid encoding an anti-GIBsPLA2 antibody (or a
fragment or derivative thereof) and a pharmaceutically acceptable excipient.

Inhibitory Nucleic acids

In an alternative embodiment, the GIBsPLA2 inhibitor is an inhibitory nucleic acid, i.e.,
20 any nucleic acid molecule which inhibits GIBsPLA2 gene or protein expression. Preferred
inhibitory nucleic acids include antisense nucleic acids, short interfering RNAs (siRNAs),
small hairpin RNAs (shRNA), microRNAs, aptamers, or ribozymes. In a particular
embodiment, the inhibitory nucleic acid is a small interfering RNA that prevents translation
of GIBsPLA2 mRNA. In another particular embodiment, the inhibitory nucleic acid is an
25 antisense oligonucleotide that prevents translation of GIBsPLA2 mRNA. In another
particular embodiment, the inhibitory nucleic acid is a small hairpin RNA that prevents
translation of GIBsPLA2 mRNA.

siRNA comprise a sense nucleic acid sequence and an anti-sense nucleic acid sequence of the polynucleotide of interest. siRNA are constructed such that a single transcript (double stranded RNA) have both the sense and complementary antisense sequences from the target gene. The nucleotide sequence of siRNAs may be designed using an siRNA design
5 computer program available from, for example, the Ambion website on the world wide web.

In some embodiments, the length of the antisense oligonucleotide or siRNAs is less than or equal to 10 nucleotides. In some embodiments, the length of the antisense oligonucleotides and siRNAs is as long as the naturally occurring transcript. In some embodiments, the
10 antisense oligonucleotides and siRNAs have 18-30 nucleotides. In some embodiments, the antisense oligonucleotides and siRNAs are less than 25 nucleotides in length.

Preferred inhibitory nucleic acid molecules comprise a domain having a nucleotide sequence that is perfectly complementary to a region of a GIBsPLA2 gene or RNA. Such a domain contains typically from 4 to 20 nucleotides, allowing specific hybridization and
15 optimal inhibition the the gene transcription or RNA translation. The sequence of the inhibitory nucleic acids may be derived directly from the sequence of a gene encoding GIBsPLA2, such as SEQ ID NO: 1. Alternatively, or in addition, inhibitory nucleic acids may hybridize to a regulatory element in a GIBsPLA2 gene or RNA, such as a promoter, a splicing site, etc., and prevent effective regulation thereof.

20 Specific examples of inhibitory nucleic acid molecules of the present invention include isolated single strand nucleic acid molecules consisting of from 10 to 50 consecutive nucleotides of SEQ ID NO: 1. Specific examples of inhibitory nucleic acid molecules of the invention are antisense nucleic acids consisting of the following nucleoitide sequence or the perfectly complementary strand thereof:

25 ATGAAACTCCTTGTGCTAG (SEQ ID NO: 3)

ACAGCGGCATCAGC (SEQ ID NO: 4)

TTCCGCAAAATGATCAA (SEQ ID NO: 5)

CCCGGGGAGTGACCCC (SEQ ID NO: 6)

TACGGCTGCTACTGTGGCTT (SEQ ID NO: 7)

GACACATGACAACTGCTACGACC (SEQ ID NO: 8)

ACCCACACCTATTCATACTCGT (SEQ ID NO: 9)

5 ATCACCTGTAGCAGCA (SEQ ID NO: 10)

AGCTCCATATAACAAGGCA (SEQ ID NO: 11)

CAAGAAGTATTGTCAGAG (SEQ ID NO: 12)

Peptide and Small Drugs

- 10 In an alternative embodiment, the GIBsPLA2 inhibitor is a peptide or small drug that inhibits the activity of GIBsPLA2. The peptide or small drug is typically a molecule that selectively binds GIBsPLA2, or a substrate of GIBsPLA2, or a co-factor of GIBsPLA2, or a degradation product or metabolite of GIBsPLA2 pathway.

- 15 [00105] Peptides preferably contain from 3 to 20 amino acid residues, and their sequence may be identical to a domain of GIBsPLA2 (bait peptide) or to a domain of a GIBsPLA2 substrate, co-factor, degradation product or metabolite. Preferred peptides of the invention contain from 4 to 30 consecutive amino acid residues of SEQ ID O: 2 (or of a corresponding sequence of a natural variant of SEQ ID NO: 2). Most preferred peptides of the invention comprise from 5 to 25 consecutive amino acid residues of SEQ ID O: 2 (or of a corresponding sequence of a natural variant of SEQ ID NO: 2) and further comprise at least one of the following amino acid residues of SEQ ID O: 2 (or of a corresponding sequence of a natural variant of SEQ ID NO: 2): amino acid 70, amino acid 121, amino acid 50, amino acid 52, amino acid 54, amino acid 71, or a combination thereof. Specific examples of peptides of the invention are peptides of less than 25 amino acids comprising
- 25 anyone of the following sequences:

NNYGCY (SEQ ID NO: 13)

CYCGLG (SEQ ID NO: 14)

YNNYGCYCGLGGSG (SEQ ID NO: 15)

FLEYNNYGCYCGLGGSGTPV (SEQ ID NO: 16)

5 QTHDN (SEQ ID NO: 17)

CQTHDNC (SEQ ID NO: 18)

ECEAFICNC (SEQ ID NO: 19)

DRNAAI (SEQ ID NO: 20)

DRNAAICFSKAPYNKAHKNL (SEQ ID NO: 21)

10

The peptides of the invention can comprise peptide, non-peptide and/or modified peptide bonds. In a particular embodiment, the peptides comprise at least one peptidomimetic bond selected from intercalation of a methylene (-CH₂-) or phosphate (-PO₂-) group, secondary amine (-NH-) or oxygen (-O-), alpha-azapeptides, alpha-alkylpeptides, N-alkylpeptides, phosphonamidates, depsipeptides, hydroxymethylenes, hydroxyethylenes, dihydroxyethylenes, hydroxyethylamines, retro-inverso peptides, methyleneoxy, cetomethylene, esters, phosphinates, phosphinics, or phosphonamides. Also, the peptides may comprise a protected N-ter and/or C-ter function, for example, by acylation, and/or amidation and/or esterification.

20

The peptides of the invention may be produced by techniques known per se in the art such as chemical, biological, and/or genetic synthesis.

Each of these peptides, in isolated form, represents a particular object of the present invention.

25 Preferred small drugs are hydrocarbon compounds that selectively bind GIBsPLA2.

Small drugs and peptides are preferably obtainable by a method comprising: (i) contacting a test compound with GIBsPLA2 or a fragment thereof, (ii) selecting a test compound which binds GIBsPLA2 or said fragment thereof, and (iii) selecting a compound of (ii) which inhibits an activity of GIBsPLA2. Such a method represents a particular object
5 of the invention.

Small drugs and peptides are also obtainable by a method comprising: (i) contacting a test compound with a GIBsPLA2 substrate, co-factor, or degradation product, or a fragment thereof, (ii) selecting a test compound which binds to said GIBsPLA2 substrate, co-factor, or degradation product, or a fragment thereof, and (iii) selecting a compound of (ii) which
10 inhibits an activity of GIBsPLA2. Such a method represents a particular object of the invention.

GIBsPLA2 soluble receptors

In an alternative embodiment, the GIBsPLA2 inhibitor is a soluble form of a GIBsPLA2 receptor. Such soluble receptor compounds are able to bind GIBsPLA2, thereby inhibiting
15 its activity by acting as a bait or masking agent.

A specific embodiment of such inhibitors is a soluble form of a human or murine GIBsPLA2 receptor, or a GIBsPLA2-binding fragment thereof.

The amino acid sequences of murine and human soluble receptors are depicted in SEQ ID NOs: 22 and 23, respectively. The term soluble receptor thus encompasses any GIBsPLA2-
20 binding polypeptide comprising all or a fragment of the sequence of SEQ ID NO: 22 or 23.

A GIBsPLA2-binding fragment designates any fragment of such a polypeptide comprising preferably at least 5 consecutive amino acid residues thereof, more preferably at least 8, 10, or 12, which binds PLA2GIB specifically. Specific binding of the receptor molecule indicates that the receptor molecule binds to PLA2GIB with higher affinity (e.g., by at least
25 5 fold) than to PLA2-IIA or IID. A fragment as defined above most preferably comprises less than 50 amino acid residues.

Examples of GIBsPLA2-binding polypeptides are, without limitation, polypeptides comprising at least one of the following amino acid sequences:

LSLYECDSTLVSLRWRCNRKMITGPLQYSVQVAHDNTVVASRKYIHKW (SEQ ID NO: 24)

WEKDLNSHICYQFNLLS (SEQ ID NO: 25)

5 DCESTLPYICKKYLNHIDHEIVEK (SEQ ID NO: 26)

QYKVQVKSDNTVVARQIHRWIAYTSSGGDICE (SEQ ID NO: 27)

LSYLNWSQEITPGPFVEHHCGTLEVVSA (SEQ ID NO: 28)

SRFEQAFITSLISSVAEKDSYFW (SEQ ID NO: 29)

WICRIPRDVRPKFPDWYQYDAPWLFYQNA (SEQ ID NO: 30)

10 AFHQAFLLTVLLSRLGHTHWIGLSTTDNGQT (SEQ ID NO: 31)

SEQ ID NOs: 24-26 derive from the sequence of human soluble PLA2GIB receptor, while SEQ ID NOs: 27-31 derive from the sequence of murine soluble PLA2GIB receptor.

Vaccination

15 In an alternative (or cumulative) embodiment, inhibition of GIBsPLA2 in a subject is obtained by vaccinating (or immunizing) the subject with a GIBsPLA2 antigen. As a result of such a vaccination or immunization, the subject produces antibodies (or cells) which inhibit GIBsPLA2. In particular, injection(s) of a GIBsPLA2 antigen (e.g., an immunogenic GIBsPLA2 essentially devoid of biological activity) can generate antibodies in the treated

20 subject. These antibodies will protect against an excess of GIBsPLA2 expression and can be used along as immunotherapy or a vaccine prophylaxis.

An object of the invention thus resides in a method of vaccinating a subject comprising administering to the subject a GIBsPLA2 antigen.

A further object of the invention relates to a GIBsPLA2 antigen for use to vaccinate a subject in need thereof.

In a particular embodiment, the GIBsPLA2 antigen used for vaccination is an inactivated immunogenic molecule that induces an immune response against GIBsPLA2 in a subject. Inactivation may be obtained e.g., by chemically or physically altering GIBsPLA2 or by mutating or truncating the protein, or both; and immunogenicity may be obtained as a result of the inactivation and/or by further conjugating the protein to a suitable carrier or hapten, such as KLH, HSA, polylysine, a viral anatoxin, or the like, and/or by polymerization, or the like. The antigen may thus be chemically or physically modified, e.g., to improve its immunogenicity.

In a preferred embodiment, the GIBsPLA2 antigen of the invention comprises GIBsPLA2 or an epitope-containing fragment or mimotope thereof.

In a particular embodiment, the GIBsPLA2 antigen comprises a full length GIBsPLA2 protein. In a further particular embodiment, the GIBsPLA2 antigen comprises a protein comprising SEQ ID NO: 2, or a sequence having at least 90% identity to SEQ ID NO: 2.

In an alternative embodiment, the GIBsPLA2 antigen comprises a fragment of a GIBsPLA2 protein comprising at least 6 consecutive amino acid residues and containing an immunogenic epitope, or a mimotope thereof. In a preferred embodiment, the GIBsPLA2 antigen comprises at least from 6 to 20 amino acid residues. Preferred peptides of the invention contain from 4 to 30 consecutive amino acid residues of SEQ ID NO: 2 (or of a corresponding sequence of a natural variant of SEQ ID NO: 2). Most preferred peptides of the invention comprise from 5 to 25 consecutive amino acid residues of SEQ ID NO: 2 (or of a corresponding sequence of a natural variant of SEQ ID NO: 2) and further comprise at least one of the following amino acid residues of SEQ ID NO: 2 (or of a corresponding sequence of a natural variant of SEQ ID NO: 2): amino acid 70, amino acid 121, amino acid 50, amino acid 52, amino acid 54, amino acid 71, or a combination thereof. Specific

examples of peptides of the invention are peptides of less than 50 amino acids comprising anyone of the following sequences:

- NNYGCY (SEQ ID NO: 13)
- CYCGLG (SEQ ID NO: 14)
- 5 YNNYGCYCGLGGSG (SEQ ID NO: 15)
- FLEYNNYGCYCGLGGSGTPV (SEQ ID NO: 16)
- QTHDN (SEQ ID NO: 17)
- CQTHDNC (SEQ ID NO: 18)
- ECEAFICNC (SEQ ID NO: 19)
- 10 DRNAAI (SEQ ID NO: 20)
- DRNAAICFSKAPYNKAHKNL (SEQ ID NO: 21)

- The GIBsPLA2 antigen may be in various forms such as in free form, polymerized, chemically or physically modified, and/or coupled (i.e., linked) to a carrier molecule. Coupling to a carrier may increase the immunogenicity and (further) suppress the
- 15 biological activity of the GIBsPLA2 polypeptide. In this regard, the carrier molecule may be any carrier molecule or protein conventionally used in immunology such as for instance KLH (Keyhole limpet hemocyanin), ovalbumin, bovine serum albumin (BSA), a viral or bacterial anatoxin such as toxoid tetanos, toxoid diphteric B cholera toxin, mutants thereof such as diphtheria toxin CRM 197, an outer membrane vesicle protein, a polylysine
- 20 molecule, or a virus like particle (VLP). In a preferred embodiment, the carrier is KLH or CRM197 or a VLP.

- Coupling of GIBsPLA2 to a carrier may be performed by covalent chemistry using linking chemical groups or reactions, such as for instance glutaraldehyde, biotin, etc. Preferably, the conjugate or the GIBsPLA2 protein or fragment or mimotope is submitted
- 25 to treatment with formaldehyde in order to complete inactivation of GIBsPLA2.

In a particular embodiment, the GIBsPLA2 antigen comprises a full length GIBsPLA2 protein, optionally coupled to a carrier protein. In a preferred embodiment, the GIBsPLA2 antigen comprises a protein comprising SEQ ID NO: 2, or a sequence having at least 90% identity to SEQ ID NO: 2, coupled to a carrier protein.

In another particular embodiment, the GIBsPLA2 antigen comprises an immunogenic peptide or mimotope of GIBsPLA2, optionally coupled to a carrier protein. In a more preferred embodiment, the GIBsPLA2 antigen comprises a polypeptide of at least 10 amino acids long comprising at least one of the following amino acid residues of SEQ ID O: 2 (or
5 of a corresponding sequence of a natural variant of SEQ ID NO: 2): amino acid 70, amino acid 121, amino acid 50, amino acid 52, amino acid 54, amino acid 71, or a combination thereof, optionally coupled to a carrier molecule.

The immunogenicity of the GIBsPLA2 antigen may be tested by various methods, such as by immunization of a non-human animal grafted with human immune cells, followed by
10 verification of the presence of antibodies, or by sandwich ELISA using human or humanized antibodies. The lack of biological activity may be verified by any of the activity tests described in the application. In a preferred embodiment, the GIBsPLA2 antigen has less than 20%, more preferably less than 15%, 10%, 5% or even 1% of the activity of a wild-type GIBsPLA2 protein in an in vitro method of (i) induction of formation of
15 membrane microdomains (MMD) in CD4 T cells or (ii) in rendering CD4 T cells refractory to IL-2 signaling or refractory to IL-7 signaling.

In a particular embodiment, the invention relates to an inactivated and immunogenic GIBsPLA2.

In a further particular embodiment, the invention relates to a GIBsPLA2 protein or a
20 fragment or mimotope thereof conjugated to a carrier molecule, preferably to KLH.

In a further aspect, the invention relates to a vaccine comprising a GIBsPLA2 antigen, a suitable excipient and, optionally, a suitable adjuvant.

Such molecules and conjugates and vaccines represent potent agents for use to immunize subjects, thereby causing a sustained GIBsPLA2 inhibition. Upon repetition,
25 such methods can be used to cause a permanent GIBsPLA2 inhibition.

A further object of the invention relates to of a method for inducing the production of antibodies that neutralize the activity of endogenous GIBsPLA2 in a subject in need thereof, the method comprising administering to said subject a therapeutically effective amount of a GIBsPLA2 antigen or vaccine.

- 5 Administration of an antigen or vaccine of the invention may be by any suitable route, such as by injection, preferably intramuscular, subcutaneous, transdermal, intraveinuous or intraarterial; by nasal, oral, mucosal or rectal administration.

- 10 The GIBsPLA2 antigen or vaccine may be used for treating any disease linked to an over-production of GIBsPLA2. More specifically, this invention relates to a method for treating a disease linked to an over-production of GIBsPLA2 in a subject in need thereof, comprising administering to the subject a therapeutically effective amount of a GIBsPLA2 antigen or of a vaccine composition comprising a GIBsPLA2 antigen.

GIBsPLA2 agonists or activators

- 15 The term GIBsPLA2 “agonist”, within the context of the present invention, encompasses any substance having, or mediating or up-regulating GIBsPLA2 activity such as, without limitation, a peptide, a polypeptide, a recombinant protein, a conjugate, a natural or artificial ligand, a degradation product, a homolog, a nucleic acid, DNA, RNA, an aptamer, etc., or a combination thereof. The term “agonist” encompasses both full and
20 partial agonists. A particular example of a GIBsPLA2 agonist is a GIBsPLA2 protein or a nucleic acid encoding a GIBsPLA2 protein.

In a particular embodiment, the invention relates to methods for inhibiting an immune response in a subject, comprising administering to the subject a GIBsPLA2 protein or a nucleic acid encoding a GIBsPLA2 protein.

Compositions

The invention also relates to compositions comprising a GIBsPLA2 modulator or antigen as herein described as an active ingredient, and preferably a pharmaceutically acceptable carrier.

5 A “pharmaceutical composition” refers to a formulation of a compound of the invention (active ingredient) and a medium generally accepted in the art for the delivery of biologically active compounds to the subject in need thereof. Such a carrier includes all pharmaceutically acceptable carriers, diluents, medium or supports therefore. Conventional pharmaceutical practice may be employed to provide suitable formulations or compositions
10 to subjects, for example in unit dosage form.

The compounds or compositions according to the invention may be formulated in the form of ointment, gel, paste, liquid solutions, suspensions, tablets, gelatin capsules, capsules, suppository, powders, nasal drops, or aerosol, preferably in the form of an injectible solution or suspension. For injections, the compounds are generally packaged in
15 the form of liquid suspensions, which may be injected via syringes or perfusions, for example. In this respect, the compounds are generally dissolved in saline, physiological, isotonic or buffered solutions, compatible with pharmaceutical use and known to the person skilled in the art. Thus, the compositions may contain one or more agents or excipients selected from dispersants, solubilizers, stabilizers, preservatives, etc. Agents or excipients
20 that can be used in liquid and/or injectable formulations are notably methylcellulose, hydroxymethylcellulose, carboxymethylcellulose, polysorbate 80, mannitol, gelatin, lactose, vegetable oils, acacia, etc. The carrier can also be selected for example from methyl-beta-cyclodextrin, a polymer of acrylic acid (such as carbopol), a mixture of polyethylene glycol and polypropylene glycol, monoethanol amine and hydroxymethyl
25 cellulose.

The compositions generally comprise an effective amount of a compound of the invention, e.g., an amount that is effective to modulate GIBsPLA2. Generally, the compositions according to the invention comprise from about 1 µg to 1000 mg of a

GIBsPLA2 modulator, such as from 0.001-0.01, 0.01-0.1, 0.05-100, 0.05-10, 0.05-5, 0.05-1, 0.1-100, 0.1-1.0, 0.1-5, 1.0-10, 5-10, 10-20, 20-50, and 50-100 mg, for example between 0.05 and 100 mg, preferably between 0.05 and 5 mg, for example 0.05, 0.1, 0.2, 0.3, 0.4, 0.5, 1, 2, 3, 4 or 5 mg. The dosage may be adjusted by the skilled person depending on the
5 modulator and the disease.

The compositions of the invention can further comprise one or more additional active compounds, for simultaneous or sequential use.

The invention also relates to a method for preparing a pharmaceutical composition, comprising mixing a GIBsPLA2 modulator as previously described and a pharmaceutically
10 acceptable excipient, and formulating the composition in any suitable form or container (syringe, apoule, flask, bottle, pouch, etc).

The invention also relates to a kit comprising (i) a composition comprising a GIBsPLA2 modulator as previously described, (ii) at least one container, and optionally (iii) written instructions for using the kit.

15 Diseases

The compounds and compositions of the invention may be used to treat any disease related to an inappropriate (e.g., defective or improper) immune response, particularly to an inappropriate CD4 T cell activity, as well as any disease where an increased immunity may ameliorate the subject condition. These diseases are sometime referred to as “immune
20 disorders” in the present application. This includes immunodefactive situations (e.g., caused by viral infection, pathogenic infection, cancer, etc.), autoimmune diseases, grafts, diabetes, inflammatory diseases, cancers, allergies, asthma, psoriasis, urticaria, eczema and the like.

Immunodeficiencies and associated disorders

In a first aspect, the invention is based on an inhibition of GIBsPLA2 in a subject, thereby increasing or restoring an immune activity, particularly a CD4-T cell-mediated activity.

- 5 In a particular embodiment, the invention is therefore directed to methods for stimulating an immune response in a subject in need thereof, comprising inhibiting GIBsPLA2 in said subject.

In a particular embodiment, the invention is directed to methods for modulating white blood cells in a subject in need thereof, comprising inhibiting GIBsPLA2 in said subject.

10

Examples of diseases that can benefit from GIBsPLA2 inhibitors are all diseases with an immunodeficiency such as HIV-mediated immunodeficiency. In this regard, in a particular embodiment, the invention is directed to methods for treating an immunodeficiency or an associated disorder in a subject in need thereof, comprising
15 inhibiting GIBsPLA2 in said subject.

In another particular embodiment, the invention is directed to a GIBsPLA2 inhibitor for use for treating an immunodeficiency or an associated disorder in a subject in need thereof.

Immunodeficiencies and associated disorders designate any condition or pathology characterized by and/or caused by a reduced immune function or response in a subject.

- 20 Immunodeficiencies may be caused by e.g., viral infection (e.g., HIV, hepatitis B, etc.), bacterial infection, cancer, or other pathological conditions. The term “immunodeficiency-associated disorder” therefore designates any disease caused by or associated with an immunodeficiency. The invention is particularly suitable for treating immunodeficiencies related to CD4-T cells, and associated diseases. The present application indeed
25 demonstrates that the biological effects of GIBsPLA2 are involved in CD4 T cell disease state. Accordingly, blocking the activity of GIBsPLA2 has a therapeutic benefit in subjects

with altered response to cytokine causing immunodeficiency as often observed in patients infected with HIV.

[00106] Accordingly, in a particular embodiment, the invention relates to methods of treating HIV infection in a subject by inhibiting GIBsPLA2 in the subject, preferably by
5 administering a GIBsPLA2 inhibitor or vaccine to the subject. In some embodiments the subject is an early HIV patient and the methods results in increasing the probability that the patient is a HIV controller. In some embodiments the subject is a patient with low immunoreconstitution after antiretroviral treatment and/or with severe idiopathic CD4 T lymphopenia (ICL). The invention also relates to a method for increasing CD4-T cell
10 activity in a HIV-infected subject by inhibiting GIBsPLA2 in the subject, preferably by administering a GIBsPLA2 inhibitor or vaccine to the subject.

[00107] In another embodiment, the invention relates to methods of treating acute and/or chronic inflammation and processus derived from inflammatory reactions in a subject by injecting GIBsPLA2 in the subject, either directly or associated with anti-
15 inflammatory drugs.

[00108] The invention also provides methods for treating cancer by increasing an immune response in the subject, comprising inhibiting GIBsPLA2 in the subject, preferably by administering a GIBsPLA2 inhibitor or vaccine to the subject. The invention also provides methods of treating CD4 T cell-linked immunodeficiency associated with cancer
20 in a subject by inhibiting GIBsPLA2 in the subject, preferably by administering a GIBsPLA2 inhibitor or vaccine to the subject.

Pathologic immune responses and associated diseases

The invention may be used to treat any disease related to an inappropriate (e.g.,
25 pathologic or improper) immune response or to an undesirable (hyper)activity or (hyper)activation of the immune system, particularly to an inappropriate CD4 T cell

activity. These diseases include, for instance, autoimmune diseases, grafts, diabetes, allergies, asthma, psoriasis, urticaria, eczema and the like.

In a further aspect, the invention is thus based on an activation or induction of GIBsPLA2 in a subject, thereby inhibiting an immune activity, particularly a CD4-T cell-mediated activity.

In a particular embodiment, the invention is therefore directed to methods for inhibiting an immune response in a subject in need thereof, comprising inducing or activating GIBsPLA2 in said subject.

In a particular embodiment, the invention is directed to methods for inhibiting white blood cells in a subject in need thereof, comprising inhibiting GIBsPLA2 in said subject.

In another particular embodiment, the invention is directed to methods for treating disorder caused by an undesirable immune response in a subject in need thereof, comprising inducing or activating GIBsPLA2 in said subject.

Inducing or activating GIBsPLA2 in a subject preferably comprises administering to the subject a GIBsPLA2 agonist, for example a GIBsPLA2 protein or a functional fragment thereof.

In another particular embodiment, the invention is directed to a GIBsPLA2 agonist or activator for use for treating a disorder caused by an undesirable immune response in a subject in need thereof.

Examples of diseases that can benefit from GIBsPLA2 agonists are autoimmune disorders, cancers, viral diseases, bacterial infections, etc.

In a particular embodiment, the invention is directed to methods for treating an autoimmune disorder in a subject in need thereof, comprising stimulating or inducing GIBsPLA2 in said subject.

In another particular embodiment, the invention is directed to a compound or a composition of the invention for use in treating an auto-immune disorder in a subject in need thereof.

5 In a particular embodiment, the invention is directed to methods for treating a cancer in a subject in need thereof, comprising stimulating or inducing GIBsPLA2 in said subject.

In another particular embodiment, the invention is directed to a compound or a composition of the invention for use in treating cancer in a subject in need thereof.

10 Another particular embodiment of the invention relates to a method for treating (e.g., reducing or preventing or inhibiting) graft rejection, or for treating graft vs host disease in a transplanted subject, comprising stimulating or inducing GIBsPLA2 in said subject. A further object of the invention is a method for improving allogeneic graft tolerance in a subject comprising stimulating or inducing GIBsPLA2 in said subject.

Anti-microbial activity

15 The present application also provides, in a further aspect, a method for killing microbes using GIBsPLA2. By acting directly on the membranes, GIBsPLA2 can destroy or kill bacteria, enveloped viruses, parasites and the like.

20 In acute infections or in infections, GIBsPLA2 may be used either alone or associated with antibiotics, anti-viral, anti-retroviral and anti-parasite drugs. In the case of microbes resistant to known anti-microbial drugs, GIBsPLA2 may represent an alternative therapy. It can be used in very short term treatment, e.g., in very dangerous and acute clinical situations.

25 Specific examples of diseases that can benefit from treatment by GIBsPLA2 according to the invention are all the clinical situations with an hyper activity of the immune system

or a chronic inflammation such as Multiple sclerosis, Myasthenia gravis, Autoimmune neuropathies such as Guillain-Barré, Autoimmune uveitis, Uveitis, Autoimmune hemolytic anemia, Pernicious anemia, Autoimmune thrombocytopenia, Temporal arteritis, Anti-phospholipid syndrome, Vasculitides such as Wegener's granulomatosis, Behcet's disease, 5 Atherosclerosis, Psoriasis, Dermatitis herpetiformis, Pemphigus vulgaris, Vitiligo, Pemphigus Vulgaris, Mycosis Fungoides, Allergic Contact Dermatitis, Atopic Dermatitis, Lichen Planus, PLEVA, eczema, Crohn's Disease, Ulcerative colitis, Primary biliary cirrhosis, Autoimmune hepatitis, Type 1 diabetes mellitus, Addison's Disease, Grave's Disease, Hashimoto's thyroiditis, Autoimmune oophoritis and orchitis, Autoimmune 10 Thyroiditis, Rheumatoid arthritis, Systemic lupus erythematosus, Scleroderma, Polymyositis, Dermatomyositis, Spondyloarthropathies such as ankylosing spondylitis, or Sjogren's Syndrome.

[00109] The duration, dosages and frequency of administering compounds or 15 compositions of the invention may be adapted according to the subject and disease. The treatment may be used alone or in combination with other active ingredients, either simultaneously or separately or sequentially.

[00110] The compounds or compositions according to the invention may be administered in various ways or routes such as, without limitation, by systemic injection, 20 intramuscular, intravenous, intraperitoneal, cutaneous, subcutaneous, dermic, transdermic, intrathecal, ocular (for example corneal) or rectal way, or by a topic administration on an inflammation site, and preferably by intramuscular or intravenous injection.

[00111] A typical regimen comprises a single or repeated administration of an effective amount of a GIBsPLA2 modulator over a period of one or several days, up to one 25 year, and including between one week and about six months. It is understood that the dosage of a pharmaceutical compound or composition of the invention administered *in vivo* will be dependent upon the age, health, sex, and weight of the recipient (subject), kind of concurrent treatment, if any, frequency of treatment, and the nature of the pharmaceutical

effect desired. The ranges of effective doses provided herein are not intended to be limiting and represent preferred dose ranges. However, the most preferred dosage will be tailored to the individual subject, as is understood and determinable by one skilled in the relevant arts (see, e.g., Berkow et al., eds., The Merck Manual, 16th edition, Merck and Co., Rahway, N.J., 1992; Goodman et al., eds., Goodman and Gilman's The pharmacological Basis of Therapeutics, 10th edition, Pergamon Press, Inc., Elmsford, N.Y., (2001)).

Diagnosis

10 The invention also provides methods for detecting an immune defect in a subject based on a detection of the presence or amount or absence of GIBsPLA2 in a sample from a subject. The method of the invention may be carried out using a variety of detection technologies or platforms known per se in the art such as, without limitation Capture assay, Sandwich assay, Competition assay, Radio-immuno assays, Enzyme labels with substrates
15 that generate colored, fluorescent, chemiluminescent, or electrochemically-active products, Fluorescence, fluorescent polarization, Chemiluminescence, Optical and colorimetric, Electrochemiluminescence, Time-resolved fluorescence, Surface plasmon resonance, Evanescent wave, Multiwell plate (ELISA), Individual assay, Multiplex assay, Latex bead – multiplex assay, Microarray (Laminar surface) – multiplex assay, Glass, Plate based
20 assays or Strip based assays.

In a particular embodiment, the method comprises determining the presence, or amount, or absence of a polymorphism in the GIBsPLA2 gene, RNA or protein. Our results show that GIBsPLA2 is subject to high polymorphism and that this correlates to the physiological status of subjects. The invention thus comprises (i) determining the presence, or amount, or
25 absence of a particular polymorphic isoform of GIBsPLA2, and/or (ii) determining the global rate of polymorphism of GIBsPLA2 in a subject, said data being correlated to the physiological status of the subject. In particular, specific isoforms may be characteristic of

the predisposition, presence or onset in a subject of a disorder as described above. Such determination may also be used in personalized medicine, to adjust treatment.

5 Methods of Monitoring and/or Diagnosing Immunodeficiency Associated With CD4 T Cell Defects Comprising Detecting GIBsPLA2

[00112] Methods of monitoring and/or diagnosing immunodeficiency associated to CD4 T cell defects in particular in human immunodeficiency virus (HIV) infection in a subject, are provided by this disclosure. In some embodiments the methods comprise (a) providing a sample containing a body fluid, preferably plasma from a subject, and (b)
10 detecting a level of GIBsPLA2 in the sample above a threshold. The presence of GIBsPLA2 in the sample may be detected by any method known in the art, such as for example by a method comprising an enzymatic assay, a ligand-capture assay and/or an immunoassay.

[00113] In some embodiments the method comprises obtaining a sample comprising
15 plasma from a subject and determining whether the plasma has at least one activity selected from inducing formation of abnormal membrane microdomains (MMD) in CD4 T cells from healthy subjects and rendering CD4 T cells of healthy subject refractory to interleukin-7 (IL-7) signaling. If the plasma from the subject comprises such an activity then the subject is in some embodiments determined to have a CD4 T cell-linked
20 immunodeficiency as often observed in HIV-infected patients but not only. If the plasma fraction does not comprise such an activity then the subject is in some embodiments determined to have low exposure to immunodeficiency associated to the alteration of T CD4 cells to cytokine-regulated homeostasis.

[00114] In some embodiments the subject is determined to have an HIV infection.
25 In contrast, if the protein fraction does not comprise such an activity then the subject is in some embodiments determined to not have an immunodeficiency associated to CD4 T cell defects as disclosed herein. In some embodiments the subject is determined to not have an HIV infection.

[00115] In some embodiments the methods comprise contacting the sample comprising a body fluid, preferably plasma, from the subject with an antibody specific for GIBsPLA2 and determining the presence or absence of an immunological reaction. In some embodiments the presence or absence of an immunological reaction is determined by
5 a method comprising an enzyme-linked immunosorbent assay (ELISA). The presence of an immunological reaction between the antibody specific for GIBsPLA2 and the sample indicates the presence of GIBsPLA2 in the sample, which in turn indicates that the subject has an immunodeficiency associated to CD4 T cell defects. In some embodiments the subject is determined to have an HIV infection. In contrast, the absence of an
10 immunological reaction between the antibody specific for GIBsPLA2 and the sample indicates that the subject does not have an immunodeficiency associated to CD4 T cell defects as disclosed herein. In some embodiments the subject is determined to not have an HIV infection.

[00116] In some embodiments the assay for the presence of GIBsPLA2 in the sample
15 is qualitative. In some embodiments the assay for the presence of GIBsPLA2 in the sample is quantitative.

[00117] In some embodiments the methods comprise comparing the results of the assay to the results of a similar assay of a control sample comprising plasma of a subject who does not have an immunodeficiency associated to CD4 T cell defects. In some
20 embodiments the methods comprise comparing the results of the assay to the results of a similar assay of a sample comprising plasma of the same subject harvested earlier.

Methods of Monitoring and/or Diagnosing Immunodeficiency Associated With CD4 T Cell Alteration Comprising Characterizing Membrane Microdomains on CD4 T Cells

25 [00118] The data in the examples demonstrate that HIV-infected patients present formation of distinctive membrane microdomains (MMD) on the surface of CD4 T cells although very few cells are really infected by HIV. Accordingly, this disclosure also provides methods for diagnosing immunodeficiency associated with CD4 T cell alteration, such as for example immunodeficiency caused by human immunodeficiency virus (HIV)

infection in a subject. In some embodiments the methods comprise: (a) isolating CD4 T lymphocytes from a subject, and (b) measuring the number and/or size of membrane microdomains (MMD) on the T-cells. In some embodiments the methods further comprise at least one of (c) measuring the amount of phospho-STAT5 in the T-cells and (d) assaying
5 the nuclear import fraction of phospho-STAT5 in the T-cells. In some embodiments the number and/or size of MMD on the T-cells is measured in the absence of interleukin. In some embodiments the number and/or size of MMD on the T-cells is measured in the absence of IL-2. In some embodiments the number and/or size of MMD on the T-cells is measured in the absence of IL-7. In some embodiments the number and/or size of MMD
10 on the T-cells is measured in the presence of a subthreshold level of interleukin.

[00119] In some embodiments if the number of MMD on the T cells isolated from the subject is at least a threshold that indicates that the subject has immunodeficiency associated with CD4 T cell alteration. In some embodiments it indicates that the subject has an HIV infection. In some embodiments if the number of MMD on the T cells isolated
15 from the subject is not at least a threshold that indicates that the subject does not have immunodeficiency associated with CD4 T cell alteration as disclosed herein. In some embodiments it means that the subject does not have an impaired CD-4 T cell response to cytokine signaling. In some embodiments it means that the subject does not have an impaired CD-4 T cell response to interleukin-7. In some embodiments it indicates that the subject does not have an HIV infection. In some embodiments the threshold is at least
20 about 80 per cell, at least about 90 per cell, at least about 100 per cell, at least about 110 per cell, or at least about 120 per cell. In a non-limiting preferred embodiment, the threshold is at about 100 per cell. In some embodiments if the MMD on the T cells isolated from the subject have a diameter of at least a threshold that indicates that the subject has an HIV
25 infection. In some embodiments if the MMD on the T cells isolated from the subject do not have diameter of at least a threshold that indicates that the subject does not have an impaired response to interleukin-7 and more generally to cytokines. In some embodiments it indicates that the subject does not have an HIV infection. In some embodiments the threshold is a diameter of at least 100 nm, at least 110 nm, at least 120 nm, at least 130 nm,

or at least 140 nm. In a non-limiting preferred embodiment, the threshold is a diameter of at least about 120 nm.

[00120] Because RIF may alter the responsiveness of CD4 T cells to IL-7 by aggregating membrane receptors in abnormally large MMD, responses to other gamma-c
5 and cytokines may be affected as well and RIF might be also associated to other pathologies involving altered CD4 T cell response.

Methods of Identifying Candidate Therapeutic Agents

[00121] This invention also provides methods for identifying a candidate therapeutic agent, comprising: (a) contacting CD4 T lymphocytes with GIBsPLA2 in the presence of
10 an agent, and (b) measuring GIBsPLA2-induced CD4 T cell activation. In some embodiments the methods comprise (c) comparing the level of GIBsPLA2-induced CD4 T cell activation in the presence of the agent with the level of GIBsPLA2-induced CD4 T cell activation in the absence of the agent. In some embodiments, if the level of GIBsPLA2-induced CD4 T cell activation in the presence of the agent is lower than the level of
15 GIBsPLA2-induced CD4 T cell activation in the absence of the agent, then the agent is identified as a candidate immunodeficiency therapeutic agent. In some embodiments the agent is identified as a candidate HIV therapeutic agent. In some embodiments, if the level of GIBsPLA2-induced CD4 T cell activation in the presence of the agent is higher than the level of GIBsPLA2-induced CD4 T cell activation in the absence of the agent then the
20 agent is identified as a candidate immunosuppressive therapeutic agent.

[00122] In some embodiments, measuring GIBsPLA2-induced CD4 T cell activation comprises determining the number of MMD per CD4 T cell.

[00123] In some embodiments, measuring GIBsPLA2-induced CD4 T cell activation comprises determining the mean diameter of MMD on CD4 T cells.

25 [00124] In some embodiments, measuring GIBsPLA2-induced CD4 T cell activation comprises determining the IL-7 responsiveness of CD4 T cells assayed by STAT5 phosphorylation and/or nuclear import.

[00125] As used herein an “agent” may be any chemical entity under evaluation as a potential therapeutic. In some embodiments the agent is an organic molecule. In some embodiments the agent comprises from 2 to 100 carbon atoms, such as from 2 to 50 carbon atoms, 5 to 50 carbon atoms, or 10 to 50 carbon atoms. In some embodiments the agent is
5 a peptide, a protein, a glyco-protein, or a lipoprotein. In some embodiments the agent is an antibody.

[00126] In some embodiments the agent has not been previously determined to have a biological activity implying an utility as a therapeutic agent for treatment of immunodeficiency, such as that often associated with HIV infection. In some embodiments
10 the agent has been previously determined to have a biological activity implying an utility as a therapeutic agent for treatment of immunodeficiency such as that often associated with HIV infection.

[00127] As used herein, a “candidate immunodeficiency therapeutic agent” or a “candidate HIV therapeutic agent” is an agent that inhibits the ability of RIF to activate
15 CD4 T cells in at least one assay. Consistent with the data reported herein, the ability of an agent to inhibit the ability of GIBsPLA2 to activate CD4 T cells in at least one assay is a useful way to identify agents that are likely to be therapeutically useful for treating immunodeficiencies including immunodeficiencies associated with HIV infections. Accordingly, it is also a useful way to identify agents that are likely to be therapeutically
20 useful for treating HIV infection. Of course, as with all therapeutic molecules further characterization will be required. However, this does not detract from the utility of candidate HIV therapeutic agents of this disclosure.

Further aspects and advantages of the invention are disclosed in the following
25 experimental section, which shall be considered as illustrative.

EXAMPLES

1. Materials and Methods

1.1. Patients

5 [00128] VP included in the study had been HIV-positive for more than one year. They had never received any antiretroviral drugs and had a viral load > 10,000 RNA copies/ml with a CD4 count > 200/ μ l at the time of blood collection (ANRS EP 33 and EP20 studies). All blood samples from VP were drawn at the Centre Hospitalier de Gonesse. Blood from HD was provided by the Etablissement Français du Sang (Centre
10 Necker-Cabanel, Paris). Plasma samples from ART patients were drawn from individuals who had been receiving treatment for at least one year. Their viral load had been undetectable for at least 6 months and their CD4 counts > 500/ μ l at the time of blood collection. Plasma samples from HIC patients were drawn from individuals with an undetectable viral load 10 years after infection. Plasma samples were collected at Centre
15 d'Infectiologie Necker-Pasteur.

1.2. Analysis of membrane microdomains (MMD), receptor diffusion rates and phospho-STAT5 cellular compartmentalization in purified CD4 T lymphocytes

[00129] CD4 T-cells were purified by negative selection as already described (10)
20 then activated with 2 nM recombinant glycosylated human IL-7 (Cytheris) or 40 μ g PHA (Sigma). The confocal and STED microscopy used to study cell surface microdomains (MMD) and phospho-STAT5 cellular compartment distribution has already been described (10, 12). FCS analysis of protein diffusion at the surface of living cells has also been described (10, 12)

1.3. Preparation and analysis of detergent-resistant microdomains (DRM)

25 [00130] The preparation of Triton-X100 lysates of CD4 T lymphocytes from HD or VP, followed by centrifugation through sucrose gradients and Western blot analysis of the

fractions collected, has been previously described (12). mAb specific for flotillin, IL-7Ralpha and gamma c were used to detect the corresponding bands by Western blots (12).

1.4. Characterization of RIF from VP plasma

1.4.1. Bioassays

5 [00131] The MMD induction assay was as follows: VP plasma (5 or 10%) was first incubated (20 min) in medium with purified HD CD4 T cells. The cells were then plated on polylysine-coated glass slides for 10 min then activated by 15 min IL-7 (2nM) or not for control (NS), then fixed by PFA (PFA, 1.5 %, 15 min at 37°C followed by 15 min at room temperature) equilibrated one hour in PBS/SVF 5% before being stained by cholera toxin B
10 (CtxB-AF488). MMD were counted by STED microscopy.

[00132] The assay for inhibition of STAT phosphorylation and nuclear translocation was as follows: VP plasma (5 or 10%) was first incubated with purified HD CD4 T cells (20 min) before stimulation by IL-7 (2 nM, 15 min.). Cells were then plated on polylysine-coated glass slides for 10 min then activated by 15 min IL-7 (2nM) or not for control (NS),
15 then fixed by PFA (PFA, 1.5 %, 15 min at 37°C followed by 15 min at room temperature) and permeabilization by methanol (90% at -20°C). Cells were equilibrated one hour in PBS/SVF 5% then phospho-STAT5 was then stained by rabbit anti-STAT5 labelled with goat anti-rabbit-Atto642 and analyzed by FACS or STED microscopy.

1.4.2. Enzyme Treatments

20 [00133] The effects of enzyme digestion on RIF activity were evaluated by treating VP plasma filtered on a 30 kDa membrane. Plasma compounds with MW < 10 kDa were used as negative controls. Effects of porcine trypsin (1 U/ml for 30min at 37°C, followed by PMSF inhibition and buffer exchange with Millipore 5kDa-membrane centrifugal filters), or DNase I (1 U/ml for 30min at 37°C), or RNase (1 U/ml for 30min at 37°C) or
25 Peptide N-glycanase (1 U/ml for 30min at 37°C) were tested. All preparations were analyzed at 10% final concentration.

1.4.3. MW Determination or RIF purification

[00134] Size exclusion chromatography was performed by loading 1.6ml of plasma onto a 85-ml Sephadex G100 column pre-equilibrated with ammonium carbonate (0.1M) or PBS, then collecting 0.8 ml fractions of the eluate. The column was calibrated using a protein set (GE-Healthcare). Protein concentration was measured by the Bradford method.

- 5 VP plasma previously filtered on a 100 kDa membrane and total VP plasma were tested and gave identical results. Fractions between 13-17kDa were collected, which contain semi-purified RIF.

1.4.4 Isoelectric Point Determination

- 10 [00135] Anion or cation exchange chromatography was performed on MonoQ or MonoS 1ml columns (GE-Healthcare) with elution by successive pH steps (ammonium carbonate/ammonium acetate buffers). The pH of each eluted fraction was measured and these were then adjusted to pH 7.4 before testing of their biological effects. RIF activity was measured in the corresponding fractions immediately after elution.

1.4.5 MS analysis

- 15 [00136] Samples from gel filtration (G100) were lyophilized then resuspended, pooled and proteolysed with porcine trypsin, according to methods known per se in the art. Proteolytic peptides were then separated in 12 fractions by chromatography through C18 column eluted in ammonium acetate. The 12 fractions were separated through C18 eluted in reverse phase (acetonitrile) and directly injected by electrospray in an orbitrap Velos
20 (Thermo Scientific) for MS analysis with secondary Ar-fragmentation then MS/MS for the 10 higher-intensity peaks per MS scan.

[00137] Standard Mascot and X-Tandem programs were used. For each protein of database subsets, 3 criteria were computed:

- 25 - i-score: Computation of theoretical specificity of every peptides from trypsin digestion of a single protein in the NextProt database enriched with mature proteins with signal peptide cleavage (number of unique peptides/protein): number of specific peptides overall human sequences (all), sequences with a N-term signal peptide (sec) per protein

- Computation of the theoretical occurrence of peptides compatible with peaks from all MS scan series (theoretical peptide matching peaks/protein)
- Computation of the theoretical coverage of protein sequence with peak-matching peptides

5 [00138] For each protein a *p score* was determined as a computation of all three scores.

Example 1: Aberrant activation of CD4 T lymphocytes from VP as measured by the presence of abnormal membrane microdomains (MMD).

10 This example describes the investigation of new molecular and cellular parameters that explain some of the abnormal responses seen in the CD4 T lymphocytes of chronically HIV-infected patients. Chronic activation of the immune system is usually measured by assessing the over expression of cell surface molecules such as CD38, HLA-DR and CD25 that are considered as the main markers of CD4 dysfunction (15). However, despite many
15 efforts, these data have remained blurred, and the phenotype of the CD4 T cells cannot directly explain their immune defects.

[00139] STED microscopy and labeling with cholera toxin B (CtxB-AF488) were used to detect the presence of MMD (12). Before any stimulation, the surface of CD4 T lymphocytes purified from VP was found to bear far more MMD than quiescent CD4 T
20 lymphocytes purified from HD (Fig. 1a). And most importantly, all the CD4 T cells from VP showed increased numbers of MMD. This abnormal pattern was not the consequence of stimulation by IL-7 in VP plasma since average IL-7 concentrations in this plasma (0.4 pM) were only 100th the Kd of the IL-7R (13, 14). When purified CD4 T cells from HD were stimulated by IL-7, large numbers of MMD were observed. By contrast, the MMD pattern
25 of CD4 T cells from VP was unaffected by IL-7 (Fig. 1a). This abnormal activation coupled with the absence of any response to IL-7 can be mimicked by a non physiological stimulus such as with phytohemagglutinin (PHA) (Fig. 1a).

[00140] These various abnormal MMD were then counted. Around 150-200 MMD were observed per CD4 T cell from VP, as with PHA-stimulated HD CD4 T cells (Fig. 1c). Here again, the results obtained showed that all CD4 T cells from VP expressed MMD, including all the major CD4 subpopulations (Fig. 1c). IL-7 failed to increase MMD numbers in VP. By contrast, MMD numbers in HD CD4 T cells increased from a background level of around 10 MMD/cell to 300 after IL-7 stimulation. A study of MMD size was also conducted (Fig. 1d and e). This showed that the MMD on CD4 T cells from VP and on PHA-stimulated HD CD4 T cells were far larger (250 nm) than those from HD CD4 T cells stimulated by IL-7 (90 nm).

Example 2: All IL-7R alpha and gamma-c chains are sequestered in abnormal detergent-resistant membrane microdomains (DRM) isolated from VP CD4 T cells

[00141] Resting HD CD4 T cells were analyzed to verify that IL-7R alpha and gamma-c chains are located in high-density fractions outside MMD. When these HD CD4 T cells are stimulated by IL-7, these two chains are located in low-density fractions corresponding to detergent-resistant MMD or DRM containing all the proteins sequestered in MMD (Fig. 2).

[00142] When the study was repeated on CD4 T cells purified from VP, the pattern was different (Fig. 2). Before any stimulation, all the IL-7R alpha and gamma-c chains were already sequestered in DRM; none were located in the high-density fractions corresponding to free receptors outside the MMD. Furthermore, pre-stimulation of the CD4 T cells by IL-7, before DRM preparation, did not affect this pattern (data not shown). Here again, pre-stimulation of HD CD4 T cells by non physiological PHA reproduced this pathological situation. This confirms the data in Fig. 1 and demonstrates that the CD4 T cells in VP are subject to aberrant activation prior to any stimulation. In addition, these abnormal MMD contain all the IL-7R chains (Fig. 2).

Example 3: 2D gel analysis of the IL-7 signalosome in purified CD4 T cells from HD, VP and IL-7-stimulated HD cells. Characterization of the aberrant state of activation by the protein pattern recovered after immunoprecipitation

[00143] 2D-electrophoresis was used to demonstrate that the composition of the IL-7 signalosome in VP was abnormal and different from that in quiescent and IL-7-activated HD CD4 T cells (Figures 7a, 7b and 7c).

[00144] Proteins were immunoprecipitated with anti-IL-7Ralpha (mouse mAb 40131, R&D System) immobilized on proteinG-Sepharose 4G from purified CD4 T-cell lysate and separated on 2D-PAGE (IEF on pH 3-10 gel stripes followed by SDS-gel with 12% acrylamide-bis). pH and MW (kDa) scales are displayed. Gels were stained with Sypro-Ruby. The gels shown are representative of 8 NS/IL-7 pairs obtained from HD and 3 gels from VP.

[00145] (Fig. 7a) non-stimulated (NS) HD CD4 T-cells.

[00146] (Fig. 7b) VP CD4 T-cells. More spots were observed in Sypro Ruby-stained 2D-gels prepared from VP than from HD. In addition we observed that common spots were more intense when 2D-gels were prepared with VP extracts.

[00147] (Fig. 7c) IL-7-stimulated HD CD4 T-cells. The pattern in HD CD4 T cells stimulated by IL-7 differs from that in VP CD4 T cells. This further supports the proposal that the aberrant activation found in VP is not the consequence of IL-7 stimulation that could take place in organs with high levels of IL-7, for example in IL-7-producing organs.

[00148] It may be concluded from this analysis that IL-7R chains in VP CD4 T cells are not only part of abnormal MMD but also that they interact with protein complexes different from those found in the normal IL-7 signalosome.

Example 4: Diffusion rate of IL-7Ralpha at the surface of purified CD4 T cells from HD, VP and PHA-stimulated HD cells. IL-7Ralpha in VP CD4 T cells is embedded in lipid-rich abnormal MMD, thus limiting its diffusion rates and precluding any interactions with the cytoskeleton and therefore any ability to transmit signals

[00149] The two-dimensional diffusion of IL-7Ralpha stained with AF488-anti-IL-7Ralpha mAb was measured by FCS at the surface of living CD4 T-cells. The results are

shown in Figure 8. Diffusion times τ_D (in 10^{-3} sec) were measured in the absence of IL-7 (○, autocorrelation) or in the presence of IL-7-biotin·SAF633 (●, crosscorrelation) as described (10, 12). These times were then plotted versus cell surface area $\omega\sigma^2$ (in 10^3 nm²) intercepted by the confocal volume. The diffusion plots are shown with and without pre-
 5 treatment with MMD inhibitors (COase 1 µg/ml plus SMase 0.1 µg/ml for 30 min) or cytoskeleton inhibitors (CytD 20 µM plus Col 10µM for 30min).

[00150] Bars indicate SEM from 5 independent experiments. Slopes of the linear regression give effective diffusion rates D_{eff} and y-intercepts extrapolate confinement time τ_0 as we described previously (12). D_{eff} are shown in the bar graph Fig.3a.

10 [00151] (Figs. 8a, 8d) at the surface of HD CD4 T-cells,

[00152] (Figs. 8b, 8e) at the surface of VP CD4 T cells,

[00153] (Figs. 8c, 8f) at the surface of HD CD4 T cells pre-activated with PHA (1µg/ml).

[00154] (Fig. 8g) Scheme of the mechanism of IL-7Ralpha diffusion embedded in
 15 MMD before and after treatment by MMD inhibitors or cytoskeleton inhibitors. MMD are indicated by disks, receptors by rods, cytoskeleton is shown as a net. Diffusion rates (fast, slow, very slow) are indicated to facilitate data interpretation. This scheme illustrates the results also reported in Fig. 3a.

20 **Example 5: IL-7R chains sequestered in the abnormal MMD of VP CD4 T cells are non functional**

[00155] IL-7R alpha diffusion rates were measured at the surface of CD4 T cells as previously described (10, 12) and as detailed in Example 4. Before any stimulation, these diffusion rates were seen to be three times slower on VP than HD CD4 T cells (Fig. 3a). This further demonstrates that IL-7R alpha chains are embedded in abnormal MMD at the
 25 surface of these CD4 T cells (Fig. 3a). COase plus SMase treatment released the receptor from its MMD constraints and therefore increased its diffusion rate (Fig. 3a). By contrast,

treatment with cytochalasin D (Cyt D) plus colchicin (Col) - which disorganizes the cytoskeleton - had no effect on the diffusion rate of the IL-7R alpha chain in VP CD4 T cells (Fig. 3a). Since cytoskeleton organization is an absolute necessity for signal transduction, this absence of any functional or structural link between IL-7R alpha and the cytoskeleton meshwork suggests that signaling cannot proceed when IL-7R complexes are sequestered in abnormal MMD, as is the case in VP CD4 T cells.

[00156] Pulsed-STED microscopy was then used to study STAT5 phosphorylation (phospho-STAT5) and phospho-STAT5 partition in the cytoplasm and nucleus of both HD and VP CD4 T cells. Fig. 3b shows STED images of phospho-STAT5 distribution before and after 15 min of IL-7 stimulation. We noted that phospho-STAT5 accumulated in the nucleus of HD CD4 T cells, and this phenomenon was inhibited by cytoskeleton disorganization. By contrast, no phospho-STAT5 translocation to the nucleus occurred in VP CD4 T cells or in PHA pre-stimulated HD CD4 T cells (Fig. 3b).

[00157] The kinetics of phospho-STAT5 appearance in the cytoplasm and nucleus was then followed for one hour (Figs. 3c, d, e). This showed that phospho-STAT5 in VP CD4 T cells mostly accumulated in the cytoplasm and did not migrate to the nucleus (Fig. 3d), as in PHA-stimulated HD CD4 T cells (Fig. 3e). This was particularly clear when the results were compared with those obtained in the five minutes following IL-7 stimulation of HD CD4 T cells where 50% of phospho-STAT5 was found in the nucleus (Fig. 3c).

Example 6: Plasma from VP induces abnormal MMD at the surface of purified HD CD4 T cells

[00158] The origin of the aberrant activation of VP CD4 T cells was then investigated. The fact that all the CD4 T cells were involved and that a non physiological signal such as PHA mimics the results led to an investigation of the plasma of VP. Purified HD CD4 T cells were incubated with 10% VP plasma for 30 min and MMD counted at the surface of the CD4 T cells as detected by labeled cholera toxin B (CtxB-AF488). Fig. 4a shows the images obtained. VP plasma alone induced large numbers of MMD on HD CD4 T cells. Adding IL-7 did not affect the size or number of these MMD (Fig. 4a). These

results are shown for plasma from five different VP (Fig. 4b) and were verified using many more plasma samples from these VP (> 15). The experiments were also repeated using CD4 T cells from different HD (> 5). Controls consisted of testing plasma samples from HIV-controllors (HIC) and antiretroviral-treated (ART) patients on purified HD CD4 T cells.

5 None of these induced MMD or inhibited the IL-7 induction of MMD (Fig. 4c).

[00159] This was further verified by testing a large number of dilutions of the various plasmas (Fig. 4d). VP plasma down to a 0.1% dilution resulted in the formation of MMD scattered across the cell surface. VP plasma diluted 50 to 100 fold gave 50% maximun activity. None of the plasma samples from HIC or ART patients induced MMD at
10 any dilution.

Example 7: Plasma from VP inhibits IL-7-induced phospho-STAT5 nuclear translocation

[00160] The function of the IL-7R in HD CD4 T cells treated with VP plasma was tested by following STAT5 phosphorylation and nuclear translocation. As seen in Fig.5a,
15 pre-incubation of HD CD4 T cells with VP plasma (10% concentration) inhibited IL-7-induced STAT5 phosphorylation and its nuclear translocation. Fig 5b shows the results obtained with five VP plasma samples. All at a 10% dilution inhibited the nuclear translocation of phospho-STAT5. These results were confirmed with plasmas from different VP (> 15) and various sources of HD CD4 T cells (>5).

20 [00161] The effect of plasma derived from HIC and ART patients was also tested by pre-incubating these with purified HD CD4 T cells (Fig. 5a and 5c). Here again, only VP plasma was able to inhibit the IL-7-induced nuclear translocation of phospho-STAT5. It was also determined (Fig. 5d) that VP plasma was active down to a 0.1% dilution, and half maximun activity was obtained at a 50 to 100 fold dilution, thus correlating with the ability
25 to induce abnormal MMD (Fig. 4d).

[00162] The effect of plasma derived from ART-treated patients but non-responsive (CD4-NR) to their treatment (low count of viral RNA and low count of CD4 T-cells) was also tested by pre-incubating these with purified HD CD4 T cells. Here again, only CD4-

NR plasma was able to inhibit the IL-7-induced nuclear translocation of phospho-STAT5. It was also determined that CD4-NR plasma was active down to a 0.1% dilution, and half maximum activity was obtained at a 50 to 100 fold dilution, thus correlating with the ability to induce abnormal MMD as observed with VP.

5

Example 8: Molecular characterization of the Refractory state Inducing Factor

[00163] The chemical nature of RIF was investigated. The studies performed (Fig. 6a) showed that RIF is a protein since its activity was destroyed by trypsin. Treatment with peptide N-glycanase (PNGase) had no effect, indicating that N-glycosylation is not required for RIF activity.

10

[00164] The molecular weight of RIF was then measured by size-exclusion chromatography on Sephadex G-100. Induction of MMD (Fig. 6b) and inhibition of IL-7-induced phospho-STAT5 nuclear translocation (Fig. 6c) was measured for all fractions eluted from the column. Two representative column profiles are given in Fig. 6. Both show that RIF is a single factor with a MW between 10 and 15 kDa.

15

[00165] Fig. 6b shows the densities of the viral peptides or proteins measured by dot blot in each of the 100 fractions collected from the Sephadex G100 column. Measurements were repeated three times with different polyclonal antibodies from VP plasma samples characterized by their high activity against viral proteins. For each experiment the signals obtained with HD plasmas were then subtracted from the values. The pattern shown in Fig. 6b demonstrates that no viral proteins or fragments were detected in the fraction containing RIF activity while the dot blot assay was able to detect viral proteins at higher MW (from 190 to 32 kDa).

20

[00166] Ten to 15 kDa active, enriched fractions from the Sephadex G100 columns were then used to frame the isoelectric point of RIF by retention on anion (MonoQ) or cation (MonoS) exchange columns followed by pH elution (pH increase with MonoS or pH decrease with MonoQ) (Fig. 6d). The MMD-inducing activity of the various pH fractions

25

was then measured after adjusting their pH to 7.4. In all, 25 to 30% of the initial activity was recovered in two fractions, a result consistent with an isoelectric point of 6.5 to 8.0.

[00167] RIF is therefore a secreted protein, with a MW of about 15kDa, a pI around 7.5-8.0, which contains disulfide bridge. Following the above structural and functional features, RIF identity was directly obtained. In particular, amongst all of the 36853 known human proteins, 62 only had the above four characteristics of RIF. Semi-purified material prepared from three viremic patients and three HD were analyzed using mass spectrometry and standard Mascot program. Proteins recovered were ranked according to the *p score* described in Materials and Methods. The results shown in Table 1 below clearly and directly indicate that RIF is GIBsPLA2.

[00168] Table 1

Mnemonic	ID	PI	MW	i s p_score	description
PA21B_HUMAN	P04054	7.95	14138.99	9 0.64	phospholipase A2 group 1
TMEM9_HUMAN	Q9P0T7	6.23	18568.37	5 0.29	Transmembrane protein 9 (TM)
ESM1_HUMAN	Q9NQ30	6.83	18122.42	5 0.10	Endothelial cell-spe molecule 1
CYTD_HUMAN	P28325	6.76	13858.6	3 0.08	Cystatin-D
SSRB_HUMAN	P43308	7.03	18273.74	7 0.05	Signal seq R sub beta (TM)
GPIX_HUMAN	P14770	6.14	17316.06	6 0.04	Platelet glycoprotein IX
B2MG_HUMAN	P61769	7.67	18510.47	4 0.03	Beta-2-microglobulin
EPGN_HUMAN	Q6UW09	7.72	14724.99	1 0.02	Epigen
IL19_HUMAN	Q9UHD0	7.8	17812.56	5 0.02	Interleukin-19
IL3_HUMAN	P08700	7.05	15091.38	3 0.02	Interleukin-3
GML_HUMAN	Q99445	6.67	15918.41	7 0.02	Glycosyl-PPI-anc like protein
CYTM_HUMAN	P05113	7.02	13149.22	4 0.017	Cystatin-M

[00169] The protein found in the plasma of viremic patients is thus the secreted form of GIBsPLA2. The mature protein has 125 aa (MW14138), PI 7.95 and 7 disulfide bridges. Using commercial purified porcine GIBsPLA2, we were able to verify *in vitro* that this protein induces abnormal MDM, which block IL-7 pSTAT5 nuclear translocation in the plasma of viremic patients, further confirming that RIF is GIBsPLA2, more specifically the secreted form thereof. The amino acid sequence of a human GIBsPLA2 is provided as SEQ ID NO: 2.

Example 9: PLA2sGIB induces unresponsiveness (anergy) of CD4 lymphocytes

[00170] Example 7 shows that PLA2sGIB, through induction of aMMD, induces a blockade of IL-7-induced nuclear translocation of phospho STAT5 (NT pSTAT5). Consequently, CD4 T lymphocytes do not respond to IL-7 and despite of the high level of this cytokine in the plasma of HIV patients, their number decreases then leading to CD4 lymphopenia the hallmark of HIV-infected patients.

[00171] Here we investigated the possibility that PLA2sGIB also participates to the induction of anergy, another characteristic of the CD4 lymphocytes from chronically HIV-infected patients.

Bioassay

[00172] MMD induction:

VP plasma containing PLA2sGIB was first incubated (20 min) in medium with purified HD CD4 T cells. The cells were then plated on polylysine-coated glass slides for an additional 10 min. They were then fixed with paraformaldehyde (PFA, 1.5%, 15 min at 37°C followed by 15 min at room temperature) before being stained by cholera toxin B (CtxB-AF488), MMD were counted by CW-STED microscopy.

[00173] Inhibition of STAT phosphorylation and nuclear translocation:

VP plasma containing PLA2sGIB was first incubated with purified HD CD4 T cells (20 min) before stimulation by IL-7 (2 nM, 15 min.). Cells were then plated on polylysine coated glass slides before fixation by PFA (1.5%) and permeabilization by methanol (90% at - 20°C). pSTAT5 was then stained by rabbit anti-STAT5 labelled with goat anti-rabbit-
5 Atto642 and analyzed by FACS or pulsed STED microscopy.

Results

[00174] Figure 10a shows that after exposition to PLA2 GIB (plasma of viremic patient), CD4 lymphocytes from healthy donors (HD) become unable to respond to IL-2, as measured by the inhibition of the IL-2-induced NT pSTAT5. This inhibition is total with
10 3% plasma, and highly significant with 1% plasma ($p < 0.0001$).

[00175] We further studied the response of $CD4^+ CD25^+$ T reg lymphocytes to PLA2 GIB. The results are presented in Figure 10b. As illustrated, while 100% of healthy cells respond to IL-2 by NT pSTAT5, PLA2 GIB (1% plasma of viremic patients) completely inhibited this signal transduction mechanism. Since $CD4^+ CD25^+$ cells represent less than
15 5% of total CD4 T cells, they cannot significantly influence the data presented in Figure 10a.

[00176] IL-7 and IL-2 are members of the gamma c cytokine family. To confirm that unresponsiveness to this cytokine may be linked to gamma c, we tested the response to IL-4. IL-4 response was measured by following the IL-4 induced NT of pSTAT6 (Figure 11).
20 Our results clearly show that IL-4 response is inhibited by PLA2 GIB (completely with 3% plasma and greatly with 1% plasma).

[00177] These results therefore show that the signaling mechanisms induced by cytokines of the gamma c family are altered by PLA2 GIB. This is in complete agreement with our finding that gamma c receptor chain is found completely sequestered in aMMD
25 spontaneously found at the surface of CD4 lymphocytes from HIV-patients (data not shown).

Example 10: Activity of recombinant forms of PLA2 GIB

In this example, the activity of various purified forms of PLA2 GIB proteins was tested, to further confirm the effect of this protein in purified form on the immune system, and to further confirm its specificity.

5 Enzymatic assay

The assay was performed with the Enz Check PLA2 assay kit from Life Technologies (ref.: E102147). This assay provides a continuous rapid real-time monitoring of PLA2 enzyme activities. The PLA2 activity is followed by the intensity increase of a single wavelength at 515 nm. PLA2 is detected by changes in the emission intensity ratio at

- 10** 515/575nm with excitation at 460nm. Specific activities are expressed in amount of fluorescent substrate (U) obtained per second and per µg of enzyme in solution.

Results

The results are provided in Table 2 below.

Table 2: Activity of recombinant PLA2 GIB proteins

PLA2	Nature	Initial concentration (mg/ml)	Final concentration (ug/ml)	Quantity (ug)	Specific activity (U/ug/s)
ppPLA2 IB	Purified porcine pancreas	2.90	0.58	0.06	7694.31
pPLA2 IB	recombinant porcine (in E. coli)	1.40	2.80	0.14	10353.57
hPLA2 IB	recombinant human (in E.coli)	0.70	1.40	0.07	10694.57

hPLA2 IIA	recombinant human (in E. coli)	1.45	2.90	0.15	214.93
hPLA2 IID	recombinant human (E. coli)	0.70	1.40	0.07	445.21
hPLA2 X	recombinant human (in E. coli)	0.68	1.36	0.07	3318.97

The results show that recombinant human PLA2 GIB produced in E. Coli exhibit a potent enzymatic activity. Furthermore, the results also show that recombinant porcine PLA2GIB produced in E. Coli has a specific activity similar to that of recombinant human PLA2GIB.

- 5 By contrast, recombinant PLA2GIIA and PLA2GIID are not active and PLA2GX has a very limited activity.

Recombinant PLA2 GIB thus represents a potent active agent for use in the present invention.

10 **Example 11: The effects of PLA2sGIB on CD4 lymphocytes involve its enzymatic activity**

In this example, we investigated whether the activity of PLA2sGIB on CD4 lymphocytes involved (e.g., was a consequence of) an enzymatic (e.g., catalytic) activity of PLA2sGIB. Such enzymatic activity would modify the membrane structure leading to the formation of multiple aMMD at the surface of CD4 lymphocytes.

- 15 In these experiments, we tested a mutant of PLA2sGIB where a critical histidine at position 48 was replaced by glutamine (mutant H48Q). Using the enzymatic test described in example 10, we compared the enzymatic activity of recombinant porcine PLA2 GIB produced in E. Coli with the activity of mutant H48Q also produced in E. Coli. Each

protein was used at 200microM. As shown Figure 12, the mutant has lost all of its enzymatic activity, illustrating the critical role of histidine at position 48 in PLA2 GIB.

We then compared the activity of wild type porcine PLA2 GIB with its mutant H48Q in a bioassay. The results presented in Figure 13 show that the mutant has lost the ability of wtPLA2 GIB to induce aMMD or to reduce or abrogate IL-7 induced Nuclear Translocation of pSTAT5 (NT pSTAT5).

These results thus demonstrate that the enzymatic activity is involved in the pathogenic effects of PL2 GIB on CD4 lymphocytes.

Example 12: Anti-GIBsPLA2 antibodies restore CD4-T cell activity in the plasma of HIV viremic patients.

This example illustrates that, in the plasma of viremic patients, GIBsPLA2 transforms CD4 lymphocytes from HD into “sick” lymphocytes comparable to those characterized in the blood of HIV-infected patients. This example further shows that anti-GIBsPLA2 antibodies do effectively suppress the pathogenic activity.

In a first series of experiments, the plasma were treated by sepharose beads coated either by goat antibodies directed against human GIBsPLA2 or by two control goat antibodies directed against non relevant antigens. Fig. 14(a) clearly shows that anti-GIBsPLA2 antibodies completely abolished or removed the activity of the plasma, which became unable to induce abnormal MMD in CD4 lymphocytes from HD. Control I and control II antibodies had no effect. These experiments were repeated three times for each plasma and three different plasma from viremic patients were studied.

Fig. 14(b) shows identical results. Here the plasma were treated as above but were analyzed using the second bioassay. The plasma treated by sepharose beads coated with anti-GIBsPLA2 antibodies do not inhibit anymore IL-7-induced pSTAT5 nuclear translocation. Control I and control II goats antibodies did not affect the ability of the plasma from viremic patients to inhibit IL-7 induced pSTAT5 nuclear translocation.

In a second series of experiments, we tested the effects of neutralizing rabbit antibodies specifically directed against human GIBsPLA2, -GIIA and -GIID. These antibodies were incubated with the plasma and the cells during the bio assays. The results obtained show that anti-GIBsPLA2 antibodies neutralize the effects of the viremic plasma as measured by the induction of abnormal MMD and by inhibition of IL-7-induced pSTAT5 nuclear translocation. It is noteworthy that antibodies directed against secreted PLA2-GIIA or secreted PLA2-GIID, two phospholipases which are closely related to GIBsPLA2, had no effect in this test.

These results show that anti-GIBsPLA2 antibodies can revert and prevent the immunosuppressive effect of viremic plasma. These results show that anti-GIBsPLA2 antibodies can prevent immunodeficiency and restimulate the immune response in immuno-defective subjects.

These results further demonstrate that the response is specific. GIBsPLA2 is the only effector involved in the pathogenic effect examined and characterizing the plasma of viremic patients.

Example 13: Anti-PLA2GIB antibodies inhibit PLA2 GIB effects on CD4 cells.

Cloned and purified human PLA2G1B was used to immunize rabbits. Immunoglobulin fractions of the corresponding sera were prepared. Their capacity to inhibit the enzymatic activity of PLA2G1B was measured on radiolabelled E. Coli membranes. Active immunoglobulin fractions were added to the bioassay including CD4 Lymphocytes purified from the blood of healthy donors. Cloned and purified secreted PLA2 (GIB, GIIA, GIID and GX) were subsequently added to the cultures. As controls immunoglobulin fractions prepared from rabbits immunized with various secreted PLA2 were used

Figure 15 show that different concentrations of polyclonal antibody inhibit the induction of aMMD (Figure 15a) and block the IL-7-induced NT pSTAT5 (Figure 15b). This activity can be obtained from 1 µg/ml to 100 µg/ml of Ig containing anti-PLA2 GIB antibodies.

This activity is totally specific since antibodies directed against PLA2 GIIA, PLA2GIID or PLA2GX showed no effect in the bioassay (Figure 15 a and b).

These results thus further demonstrate that inhibiting PLA2GIB can be used to treat immunodeficiencies and to restore CD4 activity.

5 Example 14: Soluble PLA2GIB receptor inhibits PLA2 GIB effects on CD4 T cells.

As a further demonstration that inhibitors of PLA2GIB can exert therapeutic effect, we tested a soluble form of a PLA2GIB receptor.

In a first series of experiment, we used, the soluble murine receptor specific for PLA2 GIB having the following amino acid sequence (SEQ ID NO: 22):

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10 MVQWLAMLQLLWLQQLLLLGIHQGIAQDLTHIQEPSLEWRDKGIFIIQSESLKTCIQAGK
SVLTLENCKQPNEHMLWKWVSDDHLFNVGGSGCLGLNISALEQPLKLYECDSTLISLRWH
CDRKMIEGPLQYKVQVKSNDNTVVARKQIHRWIAYTSSGGDICEHPSRDLYTLKGNAHGMP
CVFPPQFKGHHHDCIREGQKEHLLWCATTSRYEEDKKGWFCPDPTSMKVFCDATWQRNG
SSRICYQFNLLSSLSWNQAHSSCLMQGGALLSIADEDEEDFIRKHLKVVKEVWIGLNQL
15 DEKAGWQWSDGTPLSYLNWSQEITPGPFVEHHCGTLEVVSAAWRSRDCESTLPYICKRDL
NHTAQGILEKDSWKYHATHCDPDWTFPNRKCCKLKKDRKSWLGALHSCQSNDSVLMDVAS
LAEVEFLVSLLRDENASETWIGLSSNKIPVSFEWSSGSSVIFTNWYPLEPRILPNRRQLC
VSAEESDGRWKVKDCCKERLFYICKKAGQVPADEQSGCPAGWERHGRFCYKIDTVLRSFEE
ASSGYCSPALLTITSRFEQAFITSLISSVAEKDSYFWIALQDQNNNTGEYTWKTVGQREP
20 VQYTYWNTRQPSNRGGCVVVRGGSSSLGRWEVKDCSDFKAMSLCKTPVKIWEKTELEERP
FHPCYMDWESATGLASCFKVFHSEKVLKRSWREAEAFCEEFGAHLASFHIEEENFVNE
LLHSKFNWTQERQFWIGFNRRNPLNAGSWAWSGSPVVSFLDNAYFEEDAKNCAVYKAN
KTLLPSNCASKHEWICRIPRDVRPKFPDWYQYDAPWLFYQNAEYLFHTHPAEWATFEFVC
GWLRSDFLTIYSAQEQEFIHISKIKGLTKYGVKWWIGLEEGGARDQIQWSNGSPVIFQNWD
25 KGREERVDSQRKRCVFISITGLWGTENCSVPLPSICKRVKIWVIEKEKPPTQPGTCPKG
WLYFNYKCFLV TIPKDPRELKTWTGAQEFCAVAGGTLVSIKSELEQAFITMNLFGQTTNV
WIGLQSTNHEKWVNGKPLVYSNWSPSDIINIPSYNTTEFQKHIPLCALMSSNPNFHTGK
WYFDDCGKEGYGFVCEKMQDTLEHHVNVSDTSAIPSTLEYGNRTYKIIRGNMTWYAAGKS
CRMHRAELASIPDAFHQAFLTVLLSRLGHTHWIGLSTTDNGQTFDWSGDKSPFTYWKDE
30 ESAFLGDCAFADTNGRWHSTACESFLQGAICHVVTETKA FEHPGLCSETSVPIKFKGNC
YSFSTVLDSRSFEDAHEFCKSEGSNLLAIRDAEENSFLLEELLAFGSSVQMVLNAQFDN
NNKTLRWFDTGTPTEQSNWGLRKPDMDHLKPHPCVVLRIPEGIWHFTPCEDKKGFICKMEA
GIPAVTAQPEKGLSHSIVPVTVTTLTIIALGIFMLCFWIYKQKSDIFQRLTGSRGSSYYPT
LNFSTAHLEENILISDLEKNTNDEEVRDAPATESKRGHKGRPICISP

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The inhibitor was tested in the bioassay described in example 9, at a concentration of 100nM. The results are presented in Figure 16. They show that a recombinant PLA2 soluble receptor can be used as a potent antagonist and that such molecule is able to significantly block the negative effect of PLA2sGIB on the NT of pSTAT5 (figure 16).

- 5 Similar results can be obtained in further sets of experiments using PLA2-GIB-binding polypeptides comprising the sequence of SEQ ID NO: 25 or 28.

Example 15: Overexpression of GIBsPLA2 induces immunological deficiency

- 10 It has been previously shown that Highly Active Anti-Retroviral Therapy (HAART) which reduced viral load also induces a CD4 count increase in most patients. However, in some patients, despite the fact that HIV becomes undetectable, the CD4 counts do not increase. We have previously studied this clinical situation and we have shown that in these patients called CD4 Non Responders (CD4-NR) a strong and persistent defects of the CD4 T lymphocytes population is found.

- 15 Figure 17 shows that the plasma of CD4-NR patients do contains more PLA2 GIB activity than plasma from a viremic patient taken as control. This was first measured by the induction of abnormal MMD per cells. These data were also confirmed by measuring the ability to inhibit IL-7-induced pSTAT5 nuclear translocation.

- 20 Altogether, the results show that the plasma of CD4-NR patients contains hundred times more PLA2 GIB activity than the plasma from viremic patients.

Discussion

- Our results show that PLA2 GIB induces an immunosuppression similar to that which characterizes CD4 T cells from viremic patients, including the inability to respond to IL-2
25 (anergy) and to IL-7 (central mechanism towards CD4 lymphopenia). Therefore, expression

of GIBsPLA2 during HIV infection plays a central role in the pathophysiology of the immune disease that characterizes these patients. These defects are cell-type specific since CD8 T lymphocytes from HIV patients do not exhibit abnormal MMD and continue to respond to IL-7 (data not shown). The mode of action of PLA2 GIB is probably the
5 consequence of its enzymatic activity. By attacking the membrane of CD4 lymphocyte, it modifies its fluidity and probably allows the formation of abnormal and very large MMD.

Inflammatory reactions play an important role during HIV infection. However, their exact role in HIV pathogenesis remains to be elucidated. Taking into account our data, one can hypothesize that HIV infection induces a very peculiar type of inflammation which
10 includes GIBsPLA2. Furthermore, one can speculate that after PLA2 GIB induction, its secretion escape to normal regulatory processes therefore leading to a chronic production and to the immunological disorders which are the direct consequence of the CD4 T lymphocytes dysfunction. As an indirect consequence of the CD4 T lymphocytes dysfunction, other defects can also be observed. For instance, diminished production of
15 Interferon gamma will decrease the functions of monocytes/macrophages and of natural killers.

Correlation between the recovery of plasmatic PLA2 GIB activity and the characteristics of different groups of patients is also very informative. "HIV controllers" are very rare patients which maintain an undetectable viral load and quasi normal CD4 counts over the
20 years. Our results show that they do not express PLA2 GIB activity in their plasma. By contrast, in most patients, this enzyme is expressed and represents the negative side of the inflammation which leads to the immunological disease. Altogether, this clearly establishes that PLA2 GIB is a very critical parameter in the pathophysiology of HIV infection.

HAART viral load decrease is followed by an immune restoration including CD4 counts
25 increase. During this treatment, PLA2 GIB activity disappears in the plasma of the patients. Since, HAART is considered to decrease the inflammatory reactions this further suggests that PLA2 GIB is part of these inflammatory processes. More importantly, we describe here the case of the CD4-NR patients which remain with very low CD4 counts while HAART

control their viral load. The overproduction of PLA2 GIB found in these individuals may explain the persistence of the immune disease that characterizes this clinical status. Therefore, after HAART, there is a strong correlation between the decrease production of PLA2 GIB leading to immune restoration or its persistent overproduction leading to the
5 irreversibility of the immune disease.

The therapeutic consequences and utilities of this discovery are huge. Inhibition of PLA2 GIB may indeed be used to prevent or cure the immunological disease of HIV patients as well as, more generally, of immunodepressed subjects. Applied early during infection, inhibitors of PLA2 GIB lead the patients toward a HIV controller status. Applied later,
10 alone or in conjunction/alternance with HAART, they accelerate the recovery of the CD4 T lymphocytes functions and by boosting host defenses, inhibitors of PLA2 GIB lead to an equilibrium between the virus and the immune system like in many other viral chronic infection. Therefore, inhibitors of PLA2 GIB represent very potent agents for use, alone or in combination, to treat disorders associated with an abnormal immune response or activity.
15 They can also help in sparing HAART and could lead to the interruption of these treatments which are known for their severe detrimental effects.

Furthermore, since a lack of GIBsPLA2 expression (as in mice KO for the corresponding gene) is well tolerated, transient or permanent suppression of GIBsPLA2 using inhibitors or through vaccination, represents a strong and valid immunotherapy of immune diseases,
20 particularly HIV patients.

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CLAIMS

1. A compound that modulates the amount or activity of GIBsPLA2, for use to modulate an immune response in a subject in need thereof.
- 5 2. The compound for use of claim 1, wherein the compound is a GIBsPLA2 inhibitor or ligand.
3. The compound for use of claim 1, wherein the compound induces or stimulates said immune response.
4. The compound for use of claim 2, wherein the GIBsPLA2 inhibitor or ligand is
10 selected from an anti-GIBsPLA2 antibody or a derivative thereof, an inhibitory nucleic acid, a soluble receptor, a peptide, or a small drug.
5. The compound for use of claim 4, wherein the GIBsPLA2 inhibitor or ligand is selected from anti-GIBsPLA2 polyclonal antibodies, monoclonal antibodies, fragments thereof selected from F(ab')₂ and Fab fragments, single-chain variable
15 fragments (scFvs), single-domain antibody fragments (VHHs or Nanobodies), bivalent antibody fragments (diabodies), as well as recombinantly and synthetically produced binding partners, human antibodies or humanized antibodies or fragments thereof.
6. The compound of anyone of claims 1 to 5, for use to induce or stimulate CD4 T
20 cells in the subject.
7. The compound for use of anyone of claims 1 to 6, wherein the subject is immuno-deficient or immuno-depressed.
8. The compound for use of anyone of claims 1 to 6, wherein the subject has an infectious disease.
- 25 9. The compound for use of claim 8, wherein the subject has a viral infection.
10. The compound of anyone of the preceding claims, for use for treating AIDS in a HIV-infected subject.
11. The compound for use of claim 10, to suppress or reverse HIV-mediated immunodeficiency.
- 30 12. The compound for use of anyone of claims 1 to 6, wherein the subject has a cancer.

13. The compound for use of claim 1, wherein the compound is a GIBsPLA2 agonist or activator and said compound decreases an immune response.
14. The compound for use of claim 13, wherein the GIBsPLA2 agonist or activator is a GIBsPLA2 protein or a fragment thereof.
- 5 15. The compound for use of claims 13 or 14, wherein the subject has a disease caused by a pathologic or abnormal immune response, preferably selected from an autoimmune disorder, an inflammatory disease, a cancer, an urticaria, an eczema, an allergy, or asthma.
- 10 16. The compound of anyone of claims 1 or 13-15, for use to reduce graft rejection or to reduce GVHD in a subject.
17. The compound for use of anyone of the preceding claims, wherein the compound is administered by injection, preferably intramuscular, subcutaneous, transdermal, intraveinuous or intraarterial; by nasal, oral, mucosal,rectal administration or by inhalation.
- 15 18. A pharmaceutical composition comprising a GIBsPLA2 modulator and a pharmaceutically acceptable carrier or excipient.
19. An immunogen that induces an anti-GIBsPLA2 immune response, for use to modulate the immune system in a subject in need thereof.
- 20 20. The immunogen for use of claim 19, wherein the immunogen comprises a human or animal GIBsPLA2 protein, protein fragment or peptide, or an antigenic fragment or mimotope thereof.
21. The immunogen for use of claim 19 or 20, wherein the immunogen is in free form, polymerized, or chemically or physically modified, and/or linked to a carrier.
22. The immunogen for use of anyone of claims 19-21, wherein the immunogen is combined with an adjuvant.
- 25 23. The immunogen for use of anyone of claims 19-22, wherein the immunogen induces neutralizing antibodies.
24. A vaccine composition comprising an immunogen inducing an anti-GIBsPLA2 immune response, a pharmaceutically acceptable carrier or excipient and, optionally, an adjuvant.
- 30

25. The composition of claim 23, wherein the immunogen comprises a GIBsPLA2 protein or peptide, or an antigenic fragment or mimotope thereof.
26. The composition of claim 24, wherein the GIBsPLA2 protein or antigenic fragment or mimotope thereof is in free form, polymerized, or chemically or physically modified, or linked to a carrier and, optionally combined with an adjuvant.
- 5 27. A method for diagnosing human immunodeficiency associated with T cell alteration, comprising:
- 10 (a) providing a sample containing body fluid or a tissue fragment or cells from a subject, and
- (b) detecting or quantifying GIBsPLA2 in the sample.
28. A recombinant cell, wherein said cell or an ancestor thereof has been modified to contain a nucleic acid encoding a GIBsPLA2.
29. A method for producing GIBsPLA2, comprising cultivating a cell of claim 28 under conditions allowing expression of GIBsPLA2, and collecting GIBsPLA2.