

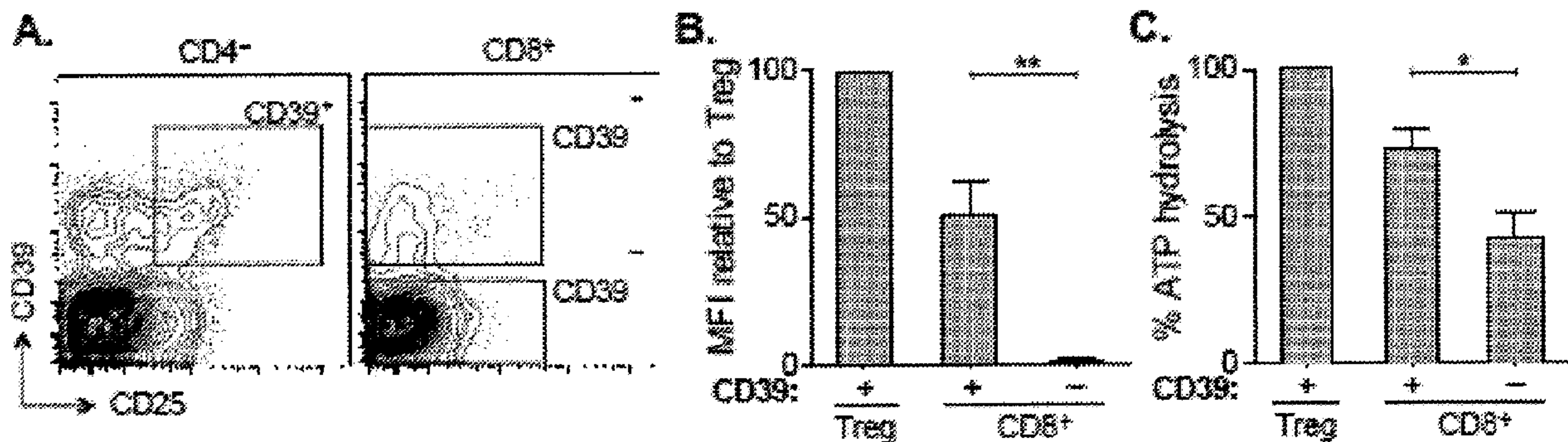


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(54) Title: COMPOSITIONS AND METHODS FOR IDENTIFICATION, ASSESSMENT, PREVENTION, AND TREATMENT
OF T-CELL EXHAUSTION USING CD39 BIOMARKERS AND MODULATORS

Figure 3



(57) Abrégé/Abstract:

The present invention is based on the identification, of compositions and methods for the identification, assessment, prevention, and treatment of T-cell exhaustion using CD39 biomarkers and modulators.



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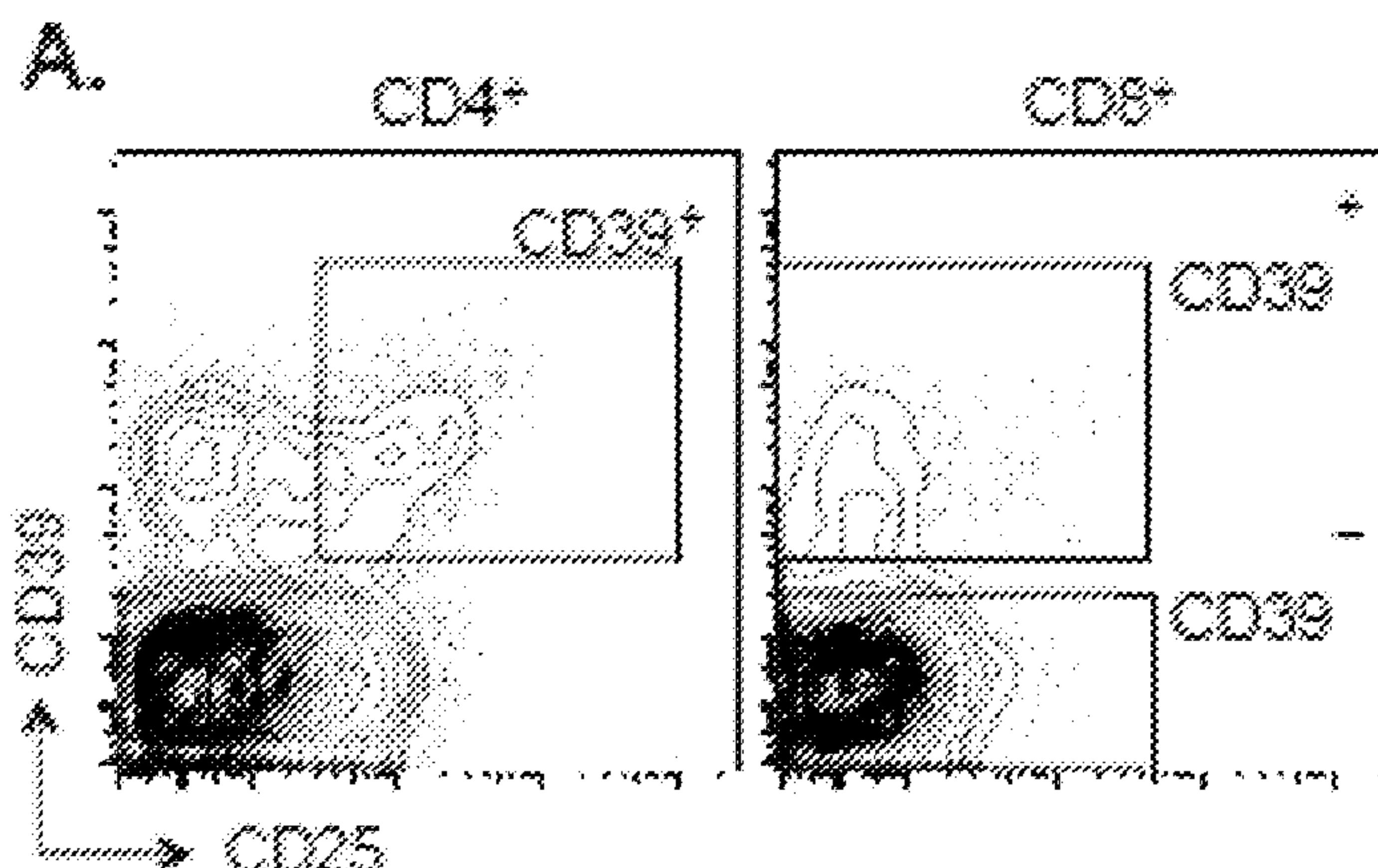
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Figure 3



(57) Abstract: The present invention is based on the identification, of compositions and methods for the identification, assessment, prevention, and treatment of T-cell exhaustion using CD39 biomarkers and modulators.

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COMPOSITIONS AND METHODS FOR IDENTIFICATION, ASSESSMENT, PREVENTION, AND TREATMENT OF T-CELL EXHAUSTION USING CD39 BIOMARKERS AND MODULATORS

Cross-Reference to Related Applications

This application claims the benefit of U.S. Provisional Application No. 62/065,192, filed on 17 October 2014; the entire contents of said application are incorporated herein in their entirety by this reference.

Statement of Rights

This invention was made with government support under Grant Numbers 5U19 AI082630 and AI091493 awarded by the National Institutes of Health. The U.S. government has certain rights in the invention. This statement is included solely to comply with 37 C.F.R. § 401.14(a)(f)(4) and should not be taken as an assertion or admission that the application discloses and/or claims only one invention.

Background of the Invention

In acute infections, antigen-specific T cells differentiate into activated effector cells and then into memory T cells which rapidly gain effector functions and re-expand on subsequent encounter with the same pathogen (Kaech and (2012) *Nat. Rev. Immunol.* 12:749-761). In contrast, during chronic infections, pathogen-specific T cells gradually lose effector function, fail to expand, and can eventually become physically deleted (Wherry (2011) *Nat. Immunol.* 12:492-499). These traits are collectively termed "T cell exhaustion" and have been described both in animal models of chronic viral infection, as well as in human infections with Hepatitis C virus (HCV) and Human immunodeficiency virus (HIV) (Wherry (2011) *Nat. Immunol.* 12:492-499; Day *et al.* (2006) *Nature* 443:350-354; Lechner *et al.* (2000) *J. Exp. Med.* 191:1499-1512).

Prolonged or high-level expression of multiple inhibitory receptors, such as PD-1, Lag3, and CD244 (2B4), is a cardinal feature of exhausted T cells in both animal models and human disease (Wherry *et al.* (2007) *Immunity* 27:670-684; Barber *et al.* (2006) *Nature* 439:682-687; Kroy *et al.* (2014) *Gastroenterol.* 146:550-561). Expression of PD-1 appears to be a particularly important feature of exhausted CD8⁺ T cells, as the majority of exhausted cells in mouse models of chronic infection express this receptor, and blockade of the PD-1:PD-L1 axis can restore the function of exhausted CD8⁺ T cells in humans and

mouse models (Wherry (2011) *Nat. Immunol.* 12:492-499; Barber *et al.* (2006) *Nature* 439:682-687). However, in humans, many inhibitory receptors can also be expressed by a large fraction of fully functional memory CD8⁺ T cells. PD-1, for instance, can be expressed by as much as 60% of memory CD8⁺ T cells in healthy individuals, making it challenging to use this marker to identify exhausted CD8⁺ T cells in humans, particularly when the antigen-specificity of potentially exhausted CD8⁺ T cells is not known (Duraisswamy *et al.* (2011) *J. Immunol.* 186:4200-4212).

Studies in mice and humans suggest that exhausted CD8⁺ T cells are not a homogeneous population, but instead include at least two subpopulations of T cells that differ in the expression of the transcription factors T-bet and Eomesodermin (Eomes) (Paley *et al.* (2012) *Science* 338:1220-1225; Buggert *et al.* (2014) *PLoS Pathogens* 10:e1004251). T-bet^{high} CD8⁺ T cells represent a progenitor subset with proliferative potential that give rise to Eomes^{high} CD8⁺ T cells, which are terminally differentiated and can no longer proliferate in response to antigen or be rescued by PD-1 blockade (Paley *et al.* (2012) *Science* 338:1220-1225; Blackburn *et al.* (2008) *Proc. Natl. Acad. Sci. U.S.A.* 105:15016-15021). Both populations express PD-1, but Eomes^{high} exhausted cells express the highest levels of PD-1. However, no specific markers of this terminally differentiated population of exhausted cells have thus far been identified.

The identification of exhausted T cells is important because such immune repertoire components mount ineffective responses against immunological targets. In particular, identifying reversible mechanisms of T cell exhaustion is a major goal in medicine. Moreover, these cell populations are dysfunctional in many important scenarios where mounting effective immune responses are desired to increase human health, such as in response to chronic immune disorders. However, neither biomarkers useful for identifying exhausted T cell populations, nor methods of use thereof to identify exhausted T cell populations or identify the mechanisms by which such cells are functionally impaired in immune disorders, such as in chronic infections, are known in the art. Accordingly, there is a great need in the art to identify such biomarkers, as well as diagnostic, prognostic, and therapeutic uses thereof.

Summary of the Invention

The present invention is based, at least in part, on the discovery that the ectonucleotidase CD39 is a specific marker of exhausted T cells (*e.g.*, CD8⁺ T cells) and

that CD39-mediated production of adenosine tonically suppresses T cell effector function and inflammation in chronic immune disorders (*e.g.*, viral infections like HIV and HCV). In contrast to CD8⁺ T cells from healthy donors, antigen-specific CD8⁺ T cells responding to chronic viral infection in humans and a mouse model express high levels of biochemically active CD39. CD39⁺ CD8⁺ T cells co-express PD-1 and are enriched for a gene signature of T cell exhaustion. Thus, CD8⁺ T cells that are specific for such chronic immune disorders express high levels of CD39, in contrast to T cells specific for acute immune disorders, such as influenza, or latent immune disorders, such as CMV infections, which do not. The ecto-enzyme is biochemically active and hydrolyzes ATP to adenosine, a known inhibitor of T cell activation. For example, cellular and transcriptional analysis of CD39⁺ CD8⁺ T cells in HCV and HIV infection showed that CD39 is co-expressed with PD-1, and CD39 expression correlates with viral load. In a mouse model of chronic immune infection, CD39 was selectively expressed by exhausted CD8⁺ T cells and identifies terminally exhausted Eomes(hi) CD8⁺ T cells. It has been determined herein that high CD39 expression identifies the most terminally exhausted T cells and can be used to distinguish between reversible versus irreversible T cell exhaustion, as well as to determine T cell function during chronic immune disorders, such as a chronic viral infection, in subjects prior to treatment, during treatment, and/or post-treatment. Animals lacking CD39 showed marked exacerbation of T cell activation and immunopathology during chronic viral infection. In addition, it is demonstrated herein that exhausted T cells are not only believed to be passive recipients of inhibitory signals, but contribute to the inhibitory microenvironment by increasing the local abundance of the soluble inhibitory mediator, adenosine. Thus, CD39 provides a specific, pathological marker of exhausted CD8⁺ T cells in chronic viral infection in humans and mouse models of chronic viral infection and is particularly useful for determining T cell function because other markers, such as immune checkpoint receptors, are widely expressed and are thus not useful for discerning the functional status of a T cell.

In one aspect, a method of identifying exhausted CD8⁺ T cells, the method comprising a) determining the presence, copy number, amount, and/or activity of at least one biomarker listed in Table 1 in a biological sample comprising CD8⁺ T cells; b) determining the presence, copy number, amount, and/or activity of the at least one biomarker in a control; and c) comparing the presence, copy number, amount, and/or activity of said at least one biomarker detected in steps a) and b); wherein the presence or a

significant increase in the copy number, amount, and/or activity of the at least one biomarker in the biological sample relative to the control indicates that the biological sample comprises exhausted CD8⁺ T cells, is provided. In one embodiment, the method further comprises determining the presence, copy number, amount, and/or activity of at least one T cell exhaustion biomarker in the biological sample; determining the presence, copy number, amount, and/or activity of the at least one T cell exhaustion biomarker in a control; and comparing the presence, copy number, amount, and/or activity of said at least one T cell exhaustion biomarker, wherein the presence or a significant increase in the copy number, amount, and/or activity of the at least one T cell exhaustion biomarker in the biological sample relative to the control indicates that the biological sample comprises exhausted CD8⁺ T cells. In another embodiment, the T cell exhaustion biomarker is selected from the group consisting of CD39, inhibitory receptors, co-solidermin, T-bet, and combinations thereof. In still another embodiment, the immune checkpoint inhibitor is selected from the group consisting of PD-1, PD-L1, PD-L2, LAG-3, TIM-1, CTLA-4, VISTA, B7-H2, B7-H3, B7-H4, B7-H6, 2B4, ICOS, HVEM, CD160, gp49B, PIR-B, KIR family receptors, TIM-1, TIM-4, BTLA, SIRPalpha (CD47), CD48, 2B4 (CD244), B7.1, B7.2, ILT-2, ILT-4, TIGIT, and A2aR. In yet another embodiment, the control is a sample comprising CD8⁺ T cells obtained from a subject not afflicted with a chronic immune condition. In another embodiment, the control is a copy number, amount, and/or activity value determined from a population of CD8⁺ T cells not afflicted with a chronic immune condition or obtained with a subject not afflicted with a chronic immune condition. In still another embodiment, the method further comprises determining responsiveness of the subject from which the biological samples was obtained to anti-chronic immune condition therapy measured by at least one criteria selected from the group consisting of clinical benefit rate, survival until mortality, pathological complete response, semi-quantitative measures of pathologic response, clinical complete remission, clinical partial remission, clinical stable disease, recurrence-free survival, metastasis free survival, disease free survival, circulating tumor cell decrease, circulating marker response, and RECIST criteria.

In another aspect, a method of reducing CD8⁺ T cell exhaustion comprising contacting exhausted CD8⁺ T cells with an agent that inhibits CD39, is provided. In one embodiment, the method further comprises contacting the exhausted CD8⁺ T cells with one or more agents that inhibit an immune checkpoint inhibitor. In another embodiment, the immune checkpoint inhibitor is selected from the group consisting of PD-1, PD-L1, PD-L2,

LAG-3, TIM-1, CTLA-4, VISTA, B7-H2, B7-H3, B7-H4, B7-H6, 2B4, ICOS, HVEM, CD160, gp49B, PIR-B, KIR family receptors, TIM-1, TIM-4, BTLA, SIRPalpha (CD47), CD48, 2B4 (CD244), B7.1, B7.2, ILT-2, ILT-4, TIGIT, and A2aR. In still another embodiment, the exhausted CD8⁺ T cells are contacted with the agent(s) *in vitro*, *ex vivo*, or *in vivo*. In yet another embodiment, the exhausted CD8⁺ T cells are contacted with the agent(s) *in vivo*. In another embodiment, the exhausted CD8⁺ T cells are contacted *in vivo* with a therapeutically effective amount of a pharmaceutical composition comprising the agent(s) in a subject in need thereof.

In still another aspect, a method of treating a subject afflicted with a chronic immune condition, comprising administering to the subject a therapeutically effective amount of a pharmaceutical composition comprising an agent that inhibits CD39 is provided. In one embodiment, the method further comprises administering to the subject a therapeutically effective amount of a pharmaceutical composition comprising one or more anti-chronic immune condition agents. In another embodiment, the one or more anti-chronic immune condition agents is one or more agents that inhibit an immune checkpoint inhibitor. In still another embodiment, the immune checkpoint inhibitor is selected from the group consisting of PD-1, PD-L1, PD-L2, LAG-3, TIM-1, CTLA-4, VISTA, B7-H2, B7-H3, B7-H4, B7-H6, 2B4, ICOS, HVEM, CD160, gp49B, PIR-B, KIR family receptors, TIM-1, TIM-4, BTLA, SIRPalpha (CD47), CD48, 2B4 (CD244), B7.1, B7.2, ILT-2, ILT-4, TIGIT, and A2aR.

In yet another aspect, a method of assessing the efficacy of an agent for reducing CD8⁺ T cell exhaustion, comprising a) detecting in a first sample comprising exhausted CD8⁺ T cells and maintained in the presence of the agent the presence, copy number, amount, and/or activity of at least one biomarker listed in Table 1; b) detecting the presence, copy number, amount, and/or activity of the at least one biomarker listed in Table 1 in a second sample comprising exhausted CD8⁺ T cells and maintained in the absence of the test agent; and c) comparing the presence, copy number, amount, and/or activity of the at least one biomarker listed in Table 1 from steps a) and b), wherein the presence or a significantly increased copy number, amount, and/or activity of the at least one biomarker listed in Table 1 in the first sample relative to the second sample, indicates that the agent reduces CD8⁺ T cell exhaustion, is provided. In one embodiment, the method further comprises determining the effect of the test agent on the copy number, level of expression, and/or level of activity of at least one immune checkpoint inhibitor in the first sample;

determining the effect of the test agent on the copy number, level of expression, and/or level of activity of the at least one immune checkpoint inhibitor in the second sample; and comparing the differences in the copy number, level of expression, and/or level of activity of the at least one immune checkpoint inhibitor between the samples, wherein a significant decrease in the copy number, level of expression, and/or level of activity of the at least one immune checkpoint inhibitor in the first sample relative to the second sample further indicates that the agent reduces CD8⁺ T cell exhaustion. In another embodiment, the method further comprises determining T cell effector function of the CD8⁺ T cells in the first sample; determining T cell effector function of the CD8⁺ T cells in the second sample; and comparing the T cell effector function determinations, wherein a significant increase in the T cell effector function of the CD8⁺ T cells in the first sample relative to the second sample further indicates that the agent reduces CD8⁺ T cell exhaustion. In still another embodiment, one or both samples are obtained from a source selected from the group consisting of an animal model of a chronic immune disorder, a subject afflicted with a chronic immune disorder, and purified population of CD8⁺ T cells. In yet another embodiment, maintaining the cells of the sample in the presence or absence of the test agent occurs *in vivo*, *ex vivo*, or *in vitro*. In another embodiment, the method further comprises determining the ability of the test agent to bind to the at least one biomarker listed in Table 1 before or after determining the effect of the test agent on the copy number, level of expression, or level of activity of the at least one biomarker listed in Table 1.

In another aspect, a method of monitoring the progression of a chronic immune disorder in a subject, comprising a) detecting at a first point in time the presence, copy number, amount, and/or activity of at least one biomarker listed in Table 1 in CD8⁺ T cells from a subject sample; b) repeating step a) during at least one subsequent point in time after administration of a therapeutic agent; and c) comparing the presence, copy number, amount, and/or activity detected in steps a) and b), wherein the presence or a significantly increased copy number, amount, and/or activity of the at least one biomarker listed in Table 1 in the CD8⁺ T cells from the first subject sample relative to at least one subsequent subject sample, indicates that the agent treats the chronic immune disorder in the subject, is provided. In one embodiment, the method further comprises determining the copy number, level of expression, and/or level of activity of at least one immune checkpoint inhibitor in the CD8⁺ T cells from the first subject sample; determining the copy number, level of expression, and/or level of activity of the at least one immune checkpoint inhibitor in the

CD8+ T cells from the at least one subsequent subject sample; and comparing the differences in the copy number, level of expression, and/or level of activity of the at least one immune checkpoint inhibitor between the samples, wherein a significant decrease in the copy number, level of expression, and/or level of activity of the at least one immune checkpoint inhibitor in the at least one subsequent subject sample relative to the first subject sample further indicates that the agent treats the chronic immune disorder in the subject. In another embodiment, the method further comprises determining T cell effector function of the CD8+ T cells in the first subject sample; determining T cell effector function of the CD8+ T cells in the at least one subsequent subject sample; and comparing the T cell effector function determinations, wherein a significant increase in the T cell effector function of the CD8+ T cells in the at least one subsequent subject sample relative to the first subject sample further indicates that the agent treats the chronic immune disorder in the subject. In still another embodiment, the subject has undergone treatment, completed treatment, and/or is in remission for the chronic immune disorder in between the first point in time and the subsequent point in time. In yet another embodiment, the subject has undergone anti-immune checkpoint inhibitor therapy in between the first point in time and the subsequent point in time. In another embodiment, the first and/or at least one subsequent sample is selected from the group consisting of *ex vivo* and *in vivo* samples. In still another embodiment, the first and/or at least one subsequent sample is obtained from an animal model of the chronic immune disorder. In yet another embodiment, the first and/or at least one subsequent sample is a portion of a single sample or pooled samples obtained from the subject.

Numerous embodiments are further provided that can be applied to any aspect of the present invention described herein. For example, in one embodiment, the sample is selected from the group consisting of cells, cell lines, histological slides, paraffin embedded tissue, fresh frozen tissue, fresh tissue, biopsies, blood, plasma, serum, buccal scrape, saliva, cerebrospinal fluid, urine, stool, mucus, bone marrow, and samples obtained from a subject. In another embodiment, the presence or copy number is assessed by whole exome sequencing, microarray, quantitative PCR (qPCR), high-throughput sequencing, comparative genomic hybridization (CGH), or fluorescent *in situ* hybridization (FISH). In still another embodiment, the amount of the at least one biomarker is assessed by detecting the presence in the samples of a polynucleotide molecule encoding the biomarker or a portion of said polynucleotide molecule. In yet another embodiment, the polynucleotide

molecule is a mRNA, cDNA, or functional variants or fragments thereof. In another embodiment, the step of detecting further comprises amplifying the polynucleotide molecule. In still another embodiment, the amount of the at least one biomarker is assessed by annealing a nucleic acid probe with the sample of the polynucleotide encoding the one or more biomarkers or a portion of said polynucleotide molecule under stringent hybridization conditions. In yet another embodiment, the amount of the at least one biomarker is assessed by detecting the presence a polypeptide of the at least one biomarker. In another embodiment, the presence of said polypeptide is detected using a reagent which specifically binds with said polypeptide. In still another embodiment, the reagent is selected from the group consisting of an antibody, an antibody derivative, and an antibody fragment. In yet another embodiment, the activity of the at least one biomarker is assessed by determining the magnitude of enzymatic activity, cellular proliferation, cell death, or cytokine production. In another embodiment, the agent or therapy is selected from the group consisting of a blocking antibody, small molecule, antisense nucleic acid, interfering RNA, shRNA, siRNA, piwiRNA, aptamer, ribozyme, dominant-negative protein, and combinations thereof. In still another embodiment, the agent or anti-immune checkpoint inhibitor therapy is a blocking antibody of PD-1, PD-L1, PD-L2, LAG-3, TIM-1, CTLA-4, VISTA, B7-H2, B7-H3, B7-H4, B7-H6, 2B4, ICOS, HVEM, CD160, gp49B, PIR-B, KIR family receptors, TIM-1, TIM-4, BTLA, SIRPalpha (CD47), CD48, 2B4 (CD244), B7.1, B7.2, ILT-2, ILT-4, TIGIT, A2aR, and combinations thereof. In yet another embodiment, the agent or anti-immune checkpoint inhibitor therapy is selected from the group consisting of inhibitors of PD-1, PD-L1, PD-L2, CTLA-4, and combinations thereof. In another embodiment, the chronic immune disorder is a chronic infection or cancer. In still another embodiment, the infection is caused by an agent selected from the group consisting of human immunodeficiency virus (HIV), hepatitis C virus (HCV), hepatitis B virus (HBV), adenovirus, cytomegalovirus, Epstein-Barr virus, herpes simplex virus 1, herpes simplex virus 2, human herpesvirus 6, varicella-zoster virus, hepatitis B virus, hepatitis D virus, papilloma virus, parvovirus B19, polyoma virus BK, polyoma virus JC, measles virus, rubella virus, human T cell leukemia virus I, human T cell leukemia virus II, *Leishmania*, *Toxoplasma*, *Trypanosoma*, *Plasmodium*, *Schistosoma*, and *Encephalitozoon*. In yet another embodiment, the chronic infection is not a latent infection. In another embodiment, the cancer is a hematological cancer or a solid cancer. In still another embodiment, the solid cancer is selected from the group consisting of lung cancer, non-small cell lung cancer

(NSCLC), skin cancer, melanoma, cervical cancer, uterine cancer, ovarian cancer, breast cancer, pancreatic cancer, stomach cancer, esophageal cancer, colorectal cancer, liver cancer, prostate cancer, kidney cancer, bladder cancer, head and neck cancer, sarcoma, lymphoma, and brain cancer. In yet another embodiment, the subject is a mammal, such as a human or an animal model of a chronic immune disorder.

Brief Description of the Drawings

Figure 1 includes 5 panels, identified as panels A, B, C, D, and E, which show that CD39 is highly expressed by viral-specific CD8⁺ T cells in chronic viral infection. Panel A shows the expression of CD39 by virus-specific CD8⁺ T cells. Plots are gated on CD8⁺. Panel B shows the fraction of total or antigen-specific CD8⁺ T cells expressing CD39. In Panels 1A-1B, 11 CMV and 10 EBV samples were tested. Panels 1C-1D show a comparison of CD39 protein expression by total CD8⁺ T cells to virus-specific CD8⁺ T cells from patients with HCV (Panel 1C) and HIV (Panel 1D) infections. Panel 1E shows the fraction of total CD8⁺ T cells expressing CD39 in healthy, HIV, or HCV infected donors. Error bars represent the standard error of the mean (SEM). Statistical significance was assessed by one-way ANOVA (Panel 1A), paired (Panels 1C-1D), or unpaired (Panel 1E) Student's t-test. ***P* < 0.01, ****P* < 0.001, *****P* < 0.0001.

Figure 2 shows that CD39 is expressed by few CD8⁺ T cells in health donors. The fraction of CD39⁺ cells in naïve CD8⁺ T and central memory (CM), effector memory (EM) and effector memory RA⁺ (EMRA) subpopulations of CD8⁺ T cells from 18 healthy human donors is shown. Error bars represent SEM. Statistical significance was assessed by one-way ANOVA. ***P* < 0.01, ****P* < 0.001.

Figure 3 includes 3 panels, identified as panels A, B, and C, which show that CD39 on CD8⁺ T cells in HCV infection is enzymatically active. Panel A shows the results of flow cytometry sorting gates of CD39⁺ and CD39⁺ CD8⁺ T cells and CD39⁺ CD25⁺ CD4⁺ Tregs used for reverse-phase high performance liquid chromatography (rpHPLC) analysis of CD39 activity. Panel B shows a summary of CD39 expression level from cells in Panel A relative to Tregs in the same subjects. Panel C shows the results of ATP hydrolysis by CD8⁺ T cell populations relative to Tregs. Data represent 6 patients with chronic evolving HCV infection. Error bars represent SEM. Statistical significance was assessed by paired Student's t-test (Panels B-C). **P* < 0.05, ***P* < 0.01.

Figure 4 includes 5 panels, identified as panels A, B, C, D, and E, which show that CD39 is a marker of CD8⁺ T cell exhaustion in chronic viral infection and correlates with clinical parameters. Panel A shows the results of CD39 and PD-1 expression in chronic HCV (left) and HIV infections (right). Representative plots demonstrate total (gray) and virus-specific CD8⁺ T cells. Panel B shows the correlation between CD39 and PD-1 expression of HCV- (left) and HIV-specific (right) CD8⁺ T cells. Forty samples with HIV (21 chronic progressors, 7 viraemic controllers, and 5 elite controllers) and 39 patients with HCV (21 chronically infected and 13 resolvers) infection were tested. Panel C shows the fraction of CD39⁺ PD-1⁺ virus-specific CD8⁺ T cells in HCV (left) or HIV (right) infection. Panel D shows the correlation between CD39 expression by virus-specific CD8⁺ T cells and viral load count in HCV (left) or HIV (right) infection. Data are from 28 chronic HCV and 21 progressor HIV infection samples. Panel E shows the correlation between PD-1 expression by virus-specific CD8⁺ T cells and viral load count in HCV (left) or HIV (right) infection from Panel D. Statistical significance was assessed by linear regression (Panels B, D, and E) or unpaired Student's t-test (Panel C). ***P* < 0.01. MFI; mean fluorescence intensity.

Figure 5 includes 2 panels, identified as panels A and B, which show the results of CD39 and PD-1 co-expression in HCV and HIV. The fraction of HCV (Panel A) or HIV (Panel B) virus-specific CD8⁺ T cells expressing PD-1, CD39, or both, in patients with chronic disease (black) or patients that resolve virus (grey) are shown. Statistical significance was assessed by one-way ANOVA. **P* < 0.05.

Figure 6 shows the cell sorting strategy for the microarray experiment. The gating strategy for CD39⁺ and CD39⁻ live non-naïve CD8⁺ T cells from HCV-infected patients is shown.

Figure 7 includes 4 panels, identified as panels A, B, C, and D, which show the results of transcriptional analysis of CD39⁺ and CD39⁻ CD8⁺ T cells in HCV infection. Panel A shows a consensus hierarchical clustering of expression profiles from CD39⁺ (black) and CD39⁻ (grey) CD8⁺ T cells from 8 HCV infected patients. Clustering is based on the top 10% of genes by variance across the dataset. Sample similarity (1-Pearson correlation coefficient) is annotated with color from low (white) to high (dark). Panel B shows a gene set enrichment map displaying Gene Ontology gene sets enriched (FDR < 0.1) in CD39⁺ CD8⁺ T cells from Panel A. Nodes are sized in proportion to gene set size and the connecting line thickness represents extent of gene member overlap between gene

sets. Panel C shows the results of gene set enrichment analysis of a signature of 200 genes up-regulated in exhausted CD8⁺ T cells from the mouse model of chronic viral infection versus acute infection (day 30 post infection) in the ranked list of genes differentially expressed in CD39⁺ vs. CD39⁻ CD8⁺ T cells. Leading edge genes are indicated by symbols. Panel D shows a volcano plot of all genes (grey) or exhausted leading edge genes (dark).

Figure 8 includes 2 panels, identified as panels A and B, which show that CD39 is highly upregulated by exhausted CD8 T cells in a mouse model of chronic infection. The expression of CD39 and PD-1 on CD44⁺ naive CD8⁺ T cells (Panel A) and in CD8⁺ T cells at indicated times following LCMV Armstrong (acute) or Clone 13 (chronic) infection (Panel B) is shown. Representative plots show total (black) and H-2Db GP₂₇₆₋₂₈₆ tetramer-specific CD8⁺ T cells. Summary of results in 5 mice per group is shown in bar-graphs on the right. Statistical significance was assessed with unpaired student's t-test. * $P < 0.5$, ** $P < 0.01$, *** $P < 0.001$, **** $P < 0.0001$.

Figure 9 includes 6 panels, identified as panels A, B, C, D, E, and F, which show that CD39 identifies terminally exhausted CD8⁺ T cells in a mouse model of chronic infection. Panel A shows the expression of CD39 on CD44⁺ CD8⁺ T cells in spleens of mice 30-35 days following LCMV Armstrong (left) or Clone 13 (right) infection. Representative histograms (left) of CD127 (Panel B) and PD-1 (Panel C) expression by CD39^{high} and CD39^{int} CD8⁺ T cells from Clone 13 and CD39^{int} from Armstrong (filled gray) infected mice on d35 p.i. (left) are shown. The fraction of CD127⁺ (Panel B) and MFI of PD-1 in PD-1⁺ cells (Panel C) is shown on the right. Results are from 5 mice. Panel D shows the fraction of CD39^{high} and CD39^{int} CD44⁺ CD8⁺ T cells expressing different combinations of co-inhibitory receptors PD-1, 2B4, and Lag3. Panel E shows the average number of co-inhibitory receptors expressed by CD39^{int} (left) or CD39^{high} (right) CD8⁺ T cells at d35 p.i. following LCMV Clone 13 infection. Panel F shows representative plots of T-bet and Eomes expression in CD39^{int} (left) and CD39^{high} (right) cells as in Panel A. A summary of results is shown on the right. The data are representative of three experiments of 5 mice per group. Statistical significance was assessed with Student's t-test (Panels B-C and F) with Holm-Sidak multiple comparison correction (Panel D). ** $P < 0.01$, **** $P < 0.0001$.

Figure 10 includes 3 panels, identified as panels A, B, and C, which show a comparison of T-bet and Eomes expression by CD39⁺ and CD39⁻ CD8⁺ T cells in HIV

infection. Panel A shows the expression of CD39 in CD8⁺ T cells in patients infected with HIV. Panel B shows the expression of transcription factors T-bet and Eomes on CD39⁺ and CD39⁻ populations identified in Panel A. Panel C shows a summary of the frequency of Eomes^{hi}/T-bet^{lo} T cells in CD39⁺ and CD39⁻ CD8⁺ T cells in HIV infection. Statistical significance was assessed with paired Student's t-test. **P* < 0.05.

Figure 11 includes 6 panels, identified as panels A, B, C, D, E, and F, which show that terminally exhausted CD8⁺ T cells marked by high levels of CD39 are most impaired in their effector function. Panel A shows representative plots showing the production of IFN- γ and TNF α in CD39^{int} or CD39^{high} CD8⁺ T cells 36 days following LCMV Clone 13 infection. Panel B shows quantification of cells in panel A that produce both TNF α and IFN- γ relative to IFN- γ only. Panels C and D show cytokine production by P14 cells (panel C) gated from an infection as in panel A and summary of IFN- γ and TNF α producing cells (panel D). Panels E and F show the mean fluorescence intensity (MFI) of IFN- γ in IFN- γ positive endogenous (panel E) and transferred P14 cells (panel F). Statistical significance was assessed with paired Student's t-test. **P* < 0.05, ***P* < 0.01, ****P* < 0.001, *****P* < 0.0001.

Figure 12 includes 5 panels, identified as panels A, B, C, D and E, which show that CD39 is highly expressed by dysfunctional tumor infiltrating lymphocytes (TILs). Panel A shows representative plots showing the presence of CD39^{int} and CD39^{high} CD8⁺ T cells in MC38 and B16 tumors 21 days following tumor inoculation. Panel B shows overlap of CD39^{hi} and PD-1^{hi} staining on CD8⁺ T cells in the MC38 and B16 tumor models. Panel C shows a quantification of % receptor positive (left) and mean fluorescence intensity (right) of the coinhibitory receptors PD-1, Tim-3, Lag-3, and CD244 on CD8⁺ T cells as in panel A from MC38 and B16 tumors. Panel D shows a quantification of T-bet, Tox, and Eomes positivity in CD8⁺ CD44⁻ cells, CD8⁺ CD44⁻ CD39⁺ cells, CD8⁺ CD44⁺ CD39^{hi} cells, and CD8⁺ CD44⁺ CD39^{int} cells in MC38 tumors 21 days following tumor inoculation. Panel E shows quantification of cells as in panel A that produce the cytokine TNF α (left panel), TNF α and IFN γ (middle panel), and IL-2 (right panel) in MC38 tumors 21 days following tumor inoculation. MFI refers to the mean fluorescence intensity. Statistical significance was assessed with a two-way ANOVA. **P* < 0.05, ***P* < 0.01, ****P* < 0.001, *****P* < 0.0001.

Figure 13 includes 4 panels, identified as panels A, B, C, and D, which show that CD39 deficient mice exhibit increased mortality to LCMV-Clone 13 due to exacerbated

immune response in target organs. Panel A shows the results of mortality of CD39 knockout and wild-type mice following LCMV Clone 13 infection and indicate that a significant proportion of knockout animals succumb to LCMV-Clone 13 infection in the first 10 days of infection. Panels B-D show histopathological analyses (H&E) of target organs 8-9 days following LCMV-Clone 13 infection. Panel B shows representative lung (top) and liver (bottom) images with quantification of lung edema (Panel C, top) and liver leukocytosis (Panel C, bottom). Panel D shows the severity of leukocyte infiltration in lung (top) and liver (middle) and monocytic infiltration in the lymph nodes (bottom). Statistical analysis was done using Mantel-Cox test (Panel A), Chi-square test (Panel C), or Mann Whitney test (Panel D), * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$. Data are representative of two independent experiments with 4-6 mice per group.

For any figure showing a bar histogram, curve, or other data associated with a legend, the bars, curve, or other data presented from left to right for each indication correspond directly and in order to the boxes from top to bottom of the legend.

Detailed Description of the Invention

The present invention is based, at least in part, on the discovery that CD39 is a specific marker of exhausted T cells (*e.g.*, CD8⁺ T cells) and that CD39-mediated production of adenosine tonically suppresses T cell effector function and inflammation in chronic immune disorders (*e.g.*, viral infections like HIV and HCV). In contrast to T cells specific for acute immune disorders or immune disorders in a latent phase (*e.g.*, infections with influenza or cytomegalovirus, respectively), CD8⁺ T cells specific for chronic immune disorders express high levels of CD39. Such expression of the CD39 ectonucleotidase is demonstrated herein to be biochemically active in order to yield adenosine, an inhibitor of T cell activation. In addition, CD39 is co-expressed with immune checkpoint inhibitors, such as PD-1, and such co-expression correlates with chronic immune disorder status (*e.g.*, viral load).

Accordingly, the present invention relates, in part, to methods for identifying exhausted T cells (*e.g.*, CD8⁺ T cells) and diagnosing or prognosing chronic immune disorders associated with exhausted T cells based upon a determination and analysis of specific biomarkers described herein. In addition, such analyses can be used in order to identify and provide useful agents and treatment regimens for reducing exhaustion in

exhausted T cells (*e.g.*, CD8⁺ T cells) and for treating chronic immune disorders associated with exhausted T cells.

I. Definitions

The articles “a” and “an” are used herein to refer to one or to more than one (*i.e.* to at least one) of the grammatical object of the article. By way of example, “an element” means one element or more than one element.

The term “altered amount” or “altered level” refers to increased or decreased copy number (*e.g.*, germline and/or somatic) of a biomarker nucleic acid, *e.g.*, increased or decreased expression level in a chronic immune disorder sample, as compared to the expression level or copy number of the biomarker nucleic acid in a control sample. The term “altered amount” of a biomarker also includes an increased or decreased protein level of a biomarker protein in a sample, *e.g.*, a chronic immune disorder sample, as compared to the corresponding protein level in a normal, control sample. Furthermore, an altered amount of a biomarker protein may be determined by detecting posttranslational modification such as methylation status of the marker, which may affect the expression or activity of the biomarker protein.

The amount of a biomarker in a subject is “significantly” higher or lower than the normal amount of the biomarker, if the amount of the biomarker is greater or less, respectively, than the normal level by an amount greater than the standard error of the assay employed to assess amount, and preferably at least 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, 100%, 150%, 200%, 300%, 350%, 400%, 500%, 600%, 700%, 800%, 900%, 1000% or than that amount. Alternately, the amount of the biomarker in the subject can be considered “significantly” higher or lower than the normal amount if the amount is at least about two, and preferably at least about three, four, or five times, higher or lower, respectively, than the normal amount of the biomarker. Such “significance” can also be applied to any other measured parameter described herein, such as for expression, inhibition, cytotoxicity, cell growth, and the like.

The term “altered level of expression” of a biomarker refers to an expression level or copy number of the biomarker in a test sample, *e.g.*, a sample derived from a patient suffering from a chronic immune disorder, that is greater or less than the standard error of the assay employed to assess expression or copy number, and is preferably at least twice, and more preferably three, four, five or ten or more times the expression level or copy

number of the biomarker in a control sample (e.g., sample from a healthy subjects not having the associated disease) and preferably, the average expression level or copy number of the biomarker in several control samples. The altered level of expression is greater or less than the standard error of the assay employed to assess expression or copy number, and is preferably at least twice, and more preferably three, four, five or ten or more times the expression level or copy number of the biomarker in a control sample (e.g., sample from a healthy subjects not having the associated disease) and preferably, the average expression level or copy number of the biomarker in several control samples.

The term “altered activity” of a biomarker refers to an activity of the biomarker which is increased or decreased in a disease state, e.g., in a chronic immune disorder sample, as compared to the activity of the biomarker in a normal, control sample. Altered activity of the biomarker may be the result of, for example, altered expression of the biomarker, altered protein level of the biomarker, altered structure of the biomarker, or, e.g., an altered interaction with other proteins involved in the same or different pathway as the biomarker or altered interaction with transcriptional activators or inhibitors.

The term “altered structure” of a biomarker refers to the presence of mutations or allelic variants within a biomarker nucleic acid or protein, e.g., mutations which affect expression or activity of the biomarker nucleic acid or protein, as compared to the normal or wild-type gene or protein. For example, mutations include, but are not limited to substitutions, deletions, or addition mutations. Mutations may be present in the coding or non-coding region of the biomarker nucleic acid.

Unless otherwise specified here within, the terms “antibody” and “antibodies” broadly encompass naturally-occurring forms of antibodies (e.g. IgG, IgA, IgM, IgE) and recombinant antibodies such as single-chain antibodies, chimeric and humanized antibodies and multi-specific antibodies, as well as fragments and derivatives of all of the foregoing, which fragments and derivatives have at least an antigenic binding site. Antibody derivatives may comprise a protein or chemical moiety conjugated to an antibody.

The term “antibody” as used herein also includes an “antigen-binding portion” of an antibody (or simply “antibody portion”). The term “antigen-binding portion”, as used herein, refers to one or more fragments of an antibody that retain the ability to specifically bind to an antigen (e.g., a biomarker polypeptide, fragment thereof, or biomarker metabolite). It has been shown that the antigen-binding function of an antibody can be performed by fragments of a full-length antibody. Examples of binding fragments

encompassed within the term "antigen-binding portion" of an antibody include (i) a Fab fragment, a monovalent fragment consisting of the VL, VH, CL and CH1 domains; (ii) a F(ab')₂ fragment, a bivalent fragment comprising two Fab fragments linked by a disulfide bridge at the hinge region; (iii) a Fd fragment consisting of the VH and CH1 domains; (iv) a Fv fragment consisting of the VL and VH domains of a single arm of an antibody, (v) a dAb fragment (Ward *et al.*, (1989) *Nature* 341:544-546), which consists of a VH domain; and (vi) an isolated complementarity determining region (CDR). Furthermore, although the two domains of the Fv fragment, VL and VH, are coded for by separate genes, they can be joined, using recombinant methods, by a synthetic linker that enables them to be made as a single protein chain in which the VL and VH regions pair to form monovalent polypeptides (known as single chain Fv (scFv); see *e.g.*, Bird *et al.* (1988) *Science* 242:423-426; and Huston *et al.* (1988) *Proc. Natl. Acad. Sci. USA* 85:5879-5883; and Osbourn *et al.* 1998, *Nature Biotechnology* 16: 778). Such single chain antibodies are also intended to be encompassed within the term "antigen-binding portion" of an antibody. Any VH and VL sequences of specific scFv can be linked to human immunoglobulin constant region cDNA or genomic sequences, in order to generate expression vectors encoding complete IgG polypeptides or other isotypes. VH and VL can also be used in the generation of Fab, Fv or other fragments of immunoglobulins using either protein chemistry or recombinant DNA technology. Other forms of single chain antibodies, such as diabodies are also encompassed. Diabodies are bivalent, bispecific antibodies in which VH and VL domains are expressed on a single polypeptide chain, but using a linker that is too short to allow for pairing between the two domains on the same chain, thereby forcing the domains to pair with complementary domains of another chain and creating two antigen binding sites (see *e.g.*, Holliger *et al.* (1993) *Proc. Natl. Acad. Sci. U.S.A.* 90:6444-6448; Poljak *et al.* (1994) *Structure* 2:1121-1123).

Still further, an antibody or antigen-binding portion thereof may be part of larger immunoadhesion polypeptides, formed by covalent or noncovalent association of the antibody or antibody portion with one or more other proteins or peptides. Examples of such immunoadhesion polypeptides include use of the streptavidin core region to make a tetrameric scFv polypeptide (Kipriyanov, S.M., *et al.* (1995) *Human Antibodies and Hybridomas* 6:93-101) and use of a cysteine residue, biomarker peptide and a C-terminal polyhistidine tag to make bivalent and biotinylated scFv polypeptides (Kipriyanov, S.M., *et al.* (1994) *Mol. Immunol.* 31:1047-1058). Antibody portions, such as Fab and F(ab')₂

fragments, can be prepared from whole antibodies using conventional techniques, such as papain or pepsin digestion, respectively, of whole antibodies. Moreover, antibodies, antibody portions and immunoadhesion polypeptides can be obtained using standard recombinant DNA techniques, as described herein.

Antibodies may be polyclonal or monoclonal; xenogeneic, allogeneic, or syngeneic; or modified forms thereof (*e.g.* humanized, chimeric, etc.). Antibodies may also be fully human. Preferably, antibodies of the invention bind specifically or substantially specifically to a biomarker polypeptide or fragment thereof. The terms “monoclonal antibodies” and “monoclonal antibody composition,” as used herein, refer to a population of antibody polypeptides that contain only one species of an antigen binding site capable of immunoreacting with a particular epitope of an antigen, whereas the term “polyclonal antibodies” and “polyclonal antibody composition” refer to a population of antibody polypeptides that contain multiple species of antigen binding sites capable of interacting with a particular antigen. A monoclonal antibody composition typically displays a single binding affinity for a particular antigen with which it immunoreacts.

Antibodies may also be “humanized”, which is intended to include antibodies made by a non-human cell having variable and constant regions which have been altered to more closely resemble antibodies that would be made by a human cell. For example, by altering the non-human antibody amino acid sequence to incorporate amino acids found in human germline immunoglobulin sequences. The humanized antibodies of the invention may include amino acid residues not encoded by human germline immunoglobulin sequences (*e.g.*, mutations introduced by random or site-specific mutagenesis *in vitro* or by somatic mutation *in vivo*), for example in the CDRs. The term “humanized antibody”, as used herein, also includes antibodies in which CDR sequences derived from the germline of another mammalian species, such as a mouse, have been grafted onto human framework sequences.

The term “assigned score” refers to the numerical value designated for each of the biomarkers after being measured in a patient sample. The assigned score correlates to the absence, presence or inferred amount of the biomarker in the sample. The assigned score can be generated manually (*e.g.*, by visual inspection) or with the aid of instrumentation for image acquisition and analysis. In certain embodiments, the assigned score is determined by a qualitative assessment, for example, detection of a fluorescent readout on a graded scale, or quantitative assessment. In one embodiment, an “aggregate score,” which refers to

the combination of assigned scores from a plurality of measured biomarkers, is determined. In one embodiment the aggregate score is a summation of assigned scores. In another embodiment, combination of assigned scores involves performing mathematical operations on the assigned scores before combining them into an aggregate score. In certain, embodiments, the aggregate score is also referred to herein as the predictive score.”

The term “biomarker” refers to a measurable entity of the present invention that has been determined to be associated with a chronic immune disorder. Biomarkers can include, without limitation, nucleic acids, proteins, and metabolites, particularly those shown in Table 1.

For example, “CD39” or “ectonucleoside triphosphate diphosphohydrolase 1 (ENTPD1)” molecules are biomarkers of the present invention and refer to a membrane-bound (transmembrane) ectonucleotidase that hydrolyzes pericellular adenosine triphosphate (ATP) to its nucleoside monophosphate AMP, which is then degraded to the nucleoside adenosine by the action of a membrane-bound or soluble ecto-5'-nucleotidase, CD73 (Junger (2011) *Nat. Rev. Immunol.* 11:201-212). Pericellular adenosine can modulate proinflammatory or proinhibitory signals in immune cells by binding various adenosine receptors (Ernst *et al.* (2010) *J. Immunol.* 185:1993-1998; Antonioli *et al.* (2013) *Trends Mol. Med.* 19:355-367; Parodi *et al.* (2013) *Cancer Immunol. Immunother.* 62:851-862; Boer *et al.* (2013) *Eur. J. Immunol.* 43:1925-1932; Xu *et al.* (2013) *Neuro-Oncol.* 15:1160-1172; U.S. Pat. Publ. 2013/0123345). For example, adenosine binds to A2A receptors expressed by lymphocytes causing accumulation of intracellular cAMP, preventing T cell activation and NK cytotoxicity (Zarek *et al.* (2008) *Blood* 111:251-259; Lokshin *et al.* (2006) *Canc. Res.* 66:7758-7765). CD39 was originally identified as an activation marker on human lymphocytes, but has subsequently been shown to be a hallmark feature of regulatory T cells (Kansas *et al.* (1991) *J. Immunol.* 146:2235-2244; Deaglio *et al.* (2007) *J. Exp. Med.* 204:1257-1265; Borsellino *et al.* (2007) *Blood* 110:1225-1232). Loss of CD39 in Tregs markedly impairs their ability to suppress T cell activation, suggesting that the juxtacrine activity of CD39 serves to negatively regulate T cell function (Deaglio *et al.* (2007) *J. Exp. Med.* 204:1257-1265). However, CD8⁺ T cells have generally been reported to be CD39⁻ (Kansas *et al.* (1991) *J. Immunol.* 146:2235-2244; Moncrieffe *et al.* (2010) *J. Immunol.* 185:134-143; Pulite *et al.* (2011) *Clin. Lymph. Myeloma Leuk.* 11:367-372; Boer *et al.* (2013) *Eur. J. Immunol.* 43:1925-1932), and the expression of this marker on exhausted T cells has not been examined.

The structure-function relationship CD39 proteins is well known in the art (reviewed, for example, by Antonioli *et al.* (2013) *Trends Mol. Med.* 19:355-367; Wang and Guidotti (1996) *J. Biol. Chem.* 271:9898-9901; Kaczmarek *et al.* (1996) *J. Biol. Chem.* 271:33116-33122). For example, human CD39 is an approximately 500-amino acid protein with approximately seven potential N-linked glycosylation sites, eleven Cys residues, and two transmembrane regions (Maliszewski *et al.* (1994) *J. Immunol.* 153:3574-3583) organized in the form of two transmembrane domains, a small cytoplasmic domain comprising the N- and C-terminal segments, and a large extracellular hydrophobic domain consisting of five highly conserved domains, known as apyrase conserved regions (ACR) 1-5, which are required for the enzyme's catabolic activity (Heine *et al.* (2001) *Eur. J. Biochem.* 268:364-373). The amino acid sequences of ACR 1 and ACR 5 contain a phosphate-binding motif (DXG), which is important for stabilizing the interaction between the enzyme and its nucleotide substrate during phosphate cleavage. In addition, two ACR residues, Glu 174 in ACR 3 and Ser 218 of ACR 4 are also required for enzymatic activity (Heine *et al.* (2001) *Eur. J. Biochem.* 268:364-373; Smith *et al.* (1998) *Biochim. Biophys. Acta* 1386:65-78). Upon cell surface expression, CD39 becomes catalytically active (Smith *et al.* (1998) *Biochim. Biophys. Acta* 1386:65-78).

Representative human CD39 cDNA and protein sequences are well-known in the art and are publicly available from the National Center for Biotechnology Information (NCBI). For example, at least seven human CD39 transcript variants are known encoding six different human CD39 isoforms. Human CD39 isoform 1 is available under accession numbers NM_001776.5 and NP_001767.3. The transcript variant represents the longest transcript and encodes isoform 1. Human CD39 isoform 2, available under accession numbers NM_001098175.1 and NP_001091645.1, uses an alternate 5' exon than transcript variant 1 that results in a distinct 5' untranslated region (UTR) and causes translation initiation at an alternate start codon leading to a longer and distinct N-terminus. Human CD39 isoform 3, available under accession numbers NM_001164178.1 and NP_001157650.1, uses an alternate 5' exon than transcript variant 1 that results in a distinct 5' UTR and causes translation initiation at an alternate start codon leading to a longer and distinct N-terminus. Human CD39 isoform 4, available under accession numbers NM_001164179.1 and NP_001157651.1, uses an alternate in-frame splice site as compared with transcript variant 1 resulting in a shorter isoform. Human CD39 isoform 5, available under accession numbers NM_001164181.1 and NP_001157653.1, uses an alternate exon

in the 5' region that results in a distinct 5' UTR and translation initiation at a downstream start codon relative to transcript variant 1 resulting in a shorter isoform. Human CD39 isoform 6, available under accession numbers NM_001164182.1 and NP_001157654.1, lacks an alternate exon that results in a distinct 5' UTR and causes translation initiation at a downstream start codon relative to transcript variant 1 resulting in a shorter isoform. Human CD39 isoform 6 is also encoded by another transcript variant, available under accession numbers NM_001164183.1 and NP_001157655.1, which lacks two alternate internal exons that results in a distinct 5' UTR and causes translation initiation at a downstream start codon relative to transcript variant 1 resulting in a shorter isoform.

Nucleic acid and polypeptide sequences of CD39 orthologs in organisms other than humans are well known and include, for example, mouse CD39 (NM_009848.3 and NP_033978.1), rat CD39 (NM_022587.1 and NP_072109.1), cow CD39 (NM_174536.2 and NP_776961.1), frog CD39 (NM_001006795.1 and NP_001006796.1), and zebrafish CD39 (NM_001003545.1 and NP_001003545.1). Representative CD39 sequences are presented below in Table 1.

CD39 activity modulators are well known in the art. For example, 6-*N,N*-Diethyl-D- β - γ -dibromomethylene adenosine triphosphate (ARL 67156) (Levesque *et al.* (2007) *Br. J. Pharmacol.* 152:141-150; Crack *et al.* (1959) *Br. J. Pharmacol.* 114: 475-481; Kennedy *et al.* (1996) *Semin. Neurosci.* 8:195-199) and 8-thiobutyladenosine 5'-triphosphate (8-Bu-S-ATP) are small molecule CD39 inhibitors (Gendron *et al.* (2000) *J. Med. Chem.* 43:2239-2247). Other small molecule CD39 inhibitors, such as polyoxymetate-1 (POM-1) and α,β -methylene)diphosphate (APCP), are also well known in the art (see, at least, U.S. Pat. Publs. 2010/204182 and 2013/0123345; U.S. Pat. 6,617,439). In addition, nucleic acid and antibody inhibitors of CD39 are also well known in the art (see, at least, U.S. Pat. Publ. 2013/0273062, 2010/0303828; Nikolova *et al.* (2011) *PLoS* DOI:10.1371/journal.ppat.1002110; Hausler *et al.* (2014) *Am. J. Transl. Res.* 6:129-139). Other CD39 activity modulators are known to a person skilled in the art including, but not limited to, allelic variants, splice variants, derivative variants, substitution variants, deletion variants, and/or insertion variants, fusion polypeptides, orthologs, and interspecies homologs. For example, the extensive glycosylation of CD39 is associated with its cell surface expression and activity such that deletion of glycosylated residues or mutations to non-glycosylatable residues results in significantly reduced CD39 activity (see, for example, deletion or mutation of glycosylatable residues 73 at the N terminus, 333 in the

middle, and/or 429 and/or 458 at the C terminus of rat CD39 or corresponding residues in orthologs thereof; Wu *et al.* (2005) *Mol. Biol. Cell.* 16:1661-1672). Similarly, mutations of conserved residues in the apyrase conserved region (ACR) of any one or more of ACRs 1-5 causes a reduction in CD39 activity (Schulte am Esch *et al.* (1999) *Biochem.* 38:2248-2258; Yang *et al.* (2001) *Biochem.* 40:3943-4940; Wang and Guidotti (1998) *J. Biol. Chem.* 273:11392-11399). Any combination of CD39 activity modulators is contemplated.

The modulation (*e.g.*, decrease) in CD39 activity can be measured in any number of ways (*e.g.*, according to measures described herein, including using controls, ratios, comparisons to baselines, and the like). For example, a CD39 activity modulator can decrease the catalytic activity of the ectonucleotidase or overall CD39 activity as compared to the level of such ectonucleotidase in the presence of a test agent. In one embodiment, CD39 activity is determined by analyzing the concentration of adenosine in a sample. The concentration can be assessed over time. In another embodiment, ATP is added in the sample tested and the concentration of AMP or adenosine is determined or assessed. A modulation in this context, such as a decrease, can mean a decrease of 1%, 5%, 10%, 20%, 25%, 30%, 35%, 40%, 45%, 50%, 55%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 95%, 100%, 120%, 150%, 200%, 500%, 1000%, or more. In an embodiment, said increase is detected over time.

It is to be noted that the biomarkers described herein can be used to refer to any combination of features described herein regarding any individual or combination of such biomarkers. For example, any combination of sequence composition, percentage identity, sequence length, domain structure, functional activity, mutation status, *etc.* can be used to describe a biomarker molecule of the present invention.

A “blocking” antibody or an antibody “antagonist” is one which inhibits or reduces at least one biological activity of the antigen(s) it binds. In certain embodiments, the blocking antibodies or antagonist antibodies or fragments thereof described herein substantially or completely inhibit a given biological activity of the antigen(s).

The term “body fluid” refers to fluids that are excreted or secreted from the body as well as fluid that are normally not (*e.g.*, bronchoalveolar lavage fluid, amniotic fluid, aqueous humor, bile, blood and blood plasma, cerebrospinal fluid, cerumen and earwax, cowper’s fluid or pre-ejaculatory fluid, chyle, chyme, stool, female ejaculate, interstitial fluid, intracellular fluid, lymph, menses, breast milk, mucus, pleural fluid, pus, saliva,

sebum, semen, serum, sweat, synovial fluid, tears, urine, vaginal lubrication, vitreous humor, vomit).

The terms "cancer" or "tumor" or "hyperproliferative" refer to the presence of cells possessing characteristics typical of cancer-causing cells, such as uncontrolled proliferation, immortality, metastatic potential, rapid growth and proliferation rate, and certain characteristic morphological features. In some embodiments, such cells exhibit such characteristics in part or in full due to exhausted immune cells characterized by the expression of a biomarker described herein and, in some embodiments, the co-expression and activity of immune checkpoint inhibitors, such as PD-1, PD-L1, PD-L2, and/or CTLA-4. Cancer cells are often in the form of a tumor, but such cells may exist alone within an animal, or may be a non-tumorigenic cancer cell, such as a leukemia cell. As used herein, the term "cancer" includes premalignant as well as malignant cancers. Cancers include, but are not limited to, B cell cancer, e.g., multiple myeloma, Waldenström's macroglobulinemia, the heavy chain diseases, such as, for example, alpha chain disease, gamma chain disease, and mu chain disease, benign monoclonal gammopathy, and immunocytic amyloidosis, melanomas, breast cancer, lung cancer, bronchus cancer, colorectal cancer, prostate cancer, pancreatic cancer, stomach cancer, ovarian cancer, urinary bladder cancer, brain or central nervous system cancer, peripheral nervous system cancer, esophageal cancer, cervical cancer, uterine or endometrial cancer, cancer of the oral cavity or pharynx, liver cancer, kidney cancer, testicular cancer, biliary tract cancer, small bowel or appendix cancer, salivary gland cancer, thyroid gland cancer, adrenal gland cancer, osteosarcoma, chondrosarcoma, cancer of hematologic tissues, and the like. Other non-limiting examples of types of cancers applicable to the methods encompassed by the present invention include human sarcomas and carcinomas, e.g., fibrosarcoma, myxosarcoma, liposarcoma, chondrosarcoma, osteogenic sarcoma, chordoma, angiosarcoma, endotheliosarcoma, lymphangiosarcoma, lymphangioendotheliosarcoma, synovioma, mesothelioma, Ewing's tumor, leiomyosarcoma, rhabdomyosarcoma, colon carcinoma, colorectal cancer, pancreatic cancer, breast cancer, ovarian cancer, prostate cancer, squamous cell carcinoma, basal cell carcinoma, adenocarcinoma, sweat gland carcinoma, sebaceous gland carcinoma, papillary carcinoma, papillary adenocarcinomas, cystadenocarcinoma, medullary carcinoma, bronchogenic carcinoma, renal cell carcinoma, hepatoma, bile duct carcinoma, liver cancer, choriocarcinoma, seminoma, embryonal carcinoma, Wilms' tumor, cervical cancer, bone cancer, brain tumor, testicular cancer, lung

carcinoma, small cell lung carcinoma, bladder carcinoma, epithelial carcinoma, glioma, astrocytoma, medulloblastoma, craniopharyngioma, ependymoma, pinealoma, hemangioblastoma, acoustic neuroma, oligodendroglioma, meningioma, melanoma, neuroblastoma, retinoblastoma; leukemias, *e.g.*, acute lymphocytic leukemia and acute myelocytic leukemia (myeloblastic, promyelocytic, myelomonocytic, monocytic and erythroleukemia); chronic leukemia (chronic myelocytic (granulocytic) leukemia and chronic lymphocytic leukemia); and polycythemia vera, lymphoma (Hodgkin's disease and non-Hodgkin's disease), multiple myeloma, Waldenström's macroglobulinemia, and heavy chain disease. In some embodiments, cancers are epithelial in nature and include but are not limited to, bladder cancer, breast cancer, cervical cancer, colon cancer, gynecologic cancers, renal cancer, laryngeal cancer, lung cancer, oral cancer, head and neck cancer, ovarian cancer, pancreatic cancer, prostate cancer, or skin cancer. In other embodiments, the cancer is breast cancer, prostate cancer, lung cancer, or colon cancer. In still other embodiments, the epithelial cancer is non-small-cell lung cancer, nonpapillary renal cell carcinoma, cervical carcinoma, ovarian carcinoma (*e.g.*, serous ovarian carcinoma), or breast carcinoma. The epithelial cancers may be characterized in various other ways including, but not limited to, serous, endometrioid, mucinous, clear cell, Brenner, or undifferentiated.

The term "coding region" refers to regions of a nucleotide sequence comprising codons which are translated into amino acid residues, whereas the term "noncoding region" refers to regions of a nucleotide sequence that are not translated into amino acids (*e.g.*, 5' and 3' untranslated regions).

The term "complementary" refers to the broad concept of sequence complementarity between regions of two nucleic acid strands or between two regions of the same nucleic acid strand. It is known that an adenine residue of a first nucleic acid region is capable of forming specific hydrogen bonds ("base pairing") with a residue of a second nucleic acid region which is antiparallel to the first region if the residue is thymine or uracil. Similarly, it is known that a cytosine residue of a first nucleic acid strand is capable of base pairing with a residue of a second nucleic acid strand which is antiparallel to the first strand if the residue is guanine. A first region of a nucleic acid is complementary to a second region of the same or a different nucleic acid if, when the two regions are arranged in an antiparallel fashion, at least one nucleotide residue of the first region is capable of base pairing with a residue of the second region. Preferably, the first region comprises a

first portion and the second region comprises a second portion, whereby, when the first and second portions are arranged in an antiparallel fashion, at least about 50%, and preferably at least about 75%, at least about 90%, or at least about 95% of the nucleotide residues of the first portion are capable of base pairing with nucleotide residues in the second portion. More preferably, all nucleotide residues of the first portion are capable of base pairing with nucleotide residues in the second portion.

The term "control" refers to any reference standard suitable to provide a comparison to the expression products in the test sample. In one embodiment, the control comprises obtaining a "control sample" from which expression product levels are detected and compared to the expression product levels from the test sample. Such a control sample may comprise any suitable sample, including but not limited to a sample from a control chronic immune disorder patient (can be stored sample or previous sample measurement) with a known outcome; normal tissue or cells isolated from a subject, such as a normal patient or the chronic immune disorder patient, cultured primary cells/tissues isolated from a subject such as a normal subject or the chronic immune disorder patient, adjacent normal cells/tissues obtained from the same organ or body location of the chronic immune disorder patient, a tissue or cell sample isolated from a normal subject, or a primary cells/tissues obtained from a depository. In another preferred embodiment, the control may comprise a reference standard expression product level from any suitable source, including but not limited to housekeeping genes, an expression product level range from normal tissue (or other previously analyzed control sample), a previously determined expression product level range within a test sample from a group of patients, or a set of patients with a certain outcome (for example, survival for one, two, three, four years, etc.) or receiving a certain treatment (for example, standard of care chronic immune disorder therapy). It will be understood by those of skill in the art that such control samples and reference standard expression product levels can be used in combination as controls in the methods of the present invention. In one embodiment, the control may comprise normal or non-chronic immune disordered cell/tissue sample. In another preferred embodiment, the control may comprise an expression level for a set of patients, such as a set of chronic immune disorder patients, or for a set of chronic immune disorder patients receiving a certain treatment, or for a set of patients with one outcome versus another outcome. In the former case, the specific expression product level of each patient can be assigned to a percentile level of expression, or expressed as either higher or lower than the mean or average of the reference

standard expression level. In another preferred embodiment, the control may comprise normal cells, cells from patients treated with combination chemotherapy, and cells from patients having a benign chronic immune disorder such as a benign cancer. In another embodiment, the control may also comprise a measured value for example, average level of expression of a particular gene in a population compared to the level of expression of a housekeeping gene in the same population. Such a population may comprise normal subjects, chronic immune disorder patients who have not undergone any treatment (*i.e.*, treatment naive), chronic immune disorder patients undergoing standard of care therapy, or patients having benign chronic immune disorder such as a benign cancer. In another preferred embodiment, the control comprises a ratio transformation of expression product levels, including but not limited to determining a ratio of expression product levels of two genes in the test sample and comparing it to any suitable ratio of the same two genes in a reference standard; determining expression product levels of the two or more genes in the test sample and determining a difference in expression product levels in any suitable control; and determining expression product levels of the two or more genes in the test sample, normalizing their expression to expression of housekeeping genes in the test sample, and comparing to any suitable control. In particularly preferred embodiments, the control comprises a control sample which is of the same lineage and/or type as the test sample. In another embodiment, the control may comprise expression product levels grouped as percentiles within or based on a set of patient samples, such as all patients with a chronic immune disorder. In one embodiment a control expression product level is established wherein higher or lower levels of expression product relative to, for instance, a particular percentile, are used as the basis for predicting outcome. In another preferred embodiment, a control expression product level is established using expression product levels from chronic immune disorder control patients with a known outcome, and the expression product levels from the test sample are compared to the control expression product level as the basis for predicting outcome. As demonstrated by the data below, the methods of the invention are not limited to use of a specific cut-point in comparing the level of expression product in the test sample to the control.

The "copy number" of a biomarker nucleic acid refers to the number of DNA sequences in a cell (*e.g.*, germline and/or somatic) encoding a particular gene product. Generally, for a given gene, a mammal has two copies of each gene. The copy number can be increased, however, by gene amplification or duplication, or reduced by deletion. For

example, germline copy number changes include changes at one or more genomic loci, wherein said one or more genomic loci are not accounted for by the number of copies in the normal complement of germline copies in a control (e.g., the normal copy number in germline DNA for the same species as that from which the specific germline DNA and corresponding copy number were determined). Somatic copy number changes include changes at one or more genomic loci, wherein said one or more genomic loci are not accounted for by the number of copies in germline DNA of a control (e.g., copy number in germline DNA for the same subject as that from which the somatic DNA and corresponding copy number were determined).

The “normal” copy number (e.g., germline and/or somatic) of a biomarker nucleic acid or “normal” level of expression of a biomarker nucleic acid, protein, or metabolite is the activity/level of expression or copy number in a biological sample, e.g., a sample containing tissue, whole blood, serum, plasma, buccal scrape, saliva, cerebrospinal fluid, urine, stool, and bone marrow, from a subject, e.g., a human, not afflicted with a chronic immune disorder, or from a corresponding non-chronic immune disordered tissue in the same subject who has a chronic immune disorder.

The term “determining a suitable treatment regimen for the subject” is taken to mean the determination of a treatment regimen (*i.e.*, a single therapy or a combination of different therapies that are used for the prevention and/or treatment of the chronic immune disorder in the subject) for a subject that is started, modified and/or ended based or essentially based or at least partially based on the results of the analysis according to the present invention. One example is determining whether to provide targeted therapy against a chronic immune disorder to provide immunotherapy that generally increases immune responses against the chronic immune disorder (e.g., anti-CD39 therapy with or without anti-immune checkpoint inhibitor therapy). Another example is starting an adjuvant therapy after surgery whose purpose is to decrease the risk of recurrence, another would be to modify the dosage of a particular chemotherapy. The determination can, in addition to the results of the analysis according to the present invention, be based on personal characteristics of the subject to be treated. In most cases, the actual determination of the suitable treatment regimen for the subject will be performed by the attending physician or doctor.

A molecule is “fixed” or “affixed” to a substrate if it is covalently or non-covalently associated with the substrate such that the substrate can be rinsed with a fluid (e.g. standard

saline citrate, pH 7.4) without a substantial fraction of the molecule dissociating from the substrate.

The term “expression signature” or “signature” refers to a group of two or more coordinately expressed biomarkers. For example, the genes, proteins, metabolites, and the like making up this signature may be expressed in a specific cell lineage, stage of differentiation, or during a particular biological response. The biomarkers can reflect biological aspects of the tumors in which they are expressed, such as the cell of origin of the chronic immune disorder, the nature of the non-chronic immune disordered cells in the biopsy, and the pathophysiological mechanisms responsible for the chronic immune disorder. Expression data and gene expression levels can be stored on computer readable media, *e.g.*, the computer readable medium used in conjunction with a microarray or chip reading device. Such expression data can be manipulated to generate expression signatures.

As used herein, the terms “high,” “low,” “intermediate,” and “negative” in connection with cellular biomarker expression refers to the amount of the biomarker expressed relative to the cellular expression of the biomarker by one or more reference cells. Biomarker expression can be determined according to any method described herein including, without limitation, an analysis of the cellular level, activity, structure, and the like, of one or more biomarker genomic nucleic acids, ribonucleic acids, and/or polypeptides. In one embodiment, the terms refer to a defined percentage of a population of cells expressing the biomarker at the highest, intermediate, or lowest levels, respectively. Such percentages can be defined as the top 0.1%, 0.5%, 1.0%, 1.5%, 2.0%, 2.5%, 3.0%, 3.5%, 4.0%, 4.5%, 5.0%, 5.5%, 6.0%, 6.5%, 7.0%, 7.5%, 8.0%, 8.5%, 9.0%, 9.5%, 10%, 11%, 12%, 13%, 14%, 15% or more, or any range in between, inclusive, of a population of cells that either highly express or weakly express the biomarker. The term “low” excludes cells that do not detectably express the biomarker, since such cells are “negative” for biomarker expression. The term “intermediate” includes cells that express the biomarker, but at levels lower than the population expressing it at the “high” level. In another embodiment, the terms can also refer to, or in the alternative refer to, cell populations of biomarker expression identified by qualitative or statistical plot regions. For example, cell populations sorted using flow cytometry can be discriminated on the basis of biomarker expression level by identifying distinct plots based on detectable moiety analysis, such as based on mean fluorescence intensities and the like, according to well-known methods in the art. Such plot regions can be refined according to number, shape,

overlap, and the like based on well-known methods in the art for the biomarker of interest. In still another embodiment, the terms can also be determined according to the presence or absence of expression for additional biomarkers. For example, T-bet(low) cells can, in some embodiments, require the absence of Eomes expression. Similarly, CD39(high) cells can, in some embodiments, require the co-expression of PD-1.

“Homologous” as used herein, refers to nucleotide sequence similarity between two regions of the same nucleic acid strand or between regions of two different nucleic acid strands. When a nucleotide residue position in both regions is occupied by the same nucleotide residue, then the regions are homologous at that position. A first region is homologous to a second region if at least one nucleotide residue position of each region is occupied by the same residue. Homology between two regions is expressed in terms of the proportion of nucleotide residue positions of the two regions that are occupied by the same nucleotide residue. By way of example, a region having the nucleotide sequence 5'-ATTGCC-3' and a region having the nucleotide sequence 5'-TATGGC-3' share 50% homology. Preferably, the first region comprises a first portion and the second region comprises a second portion, whereby, at least about 50%, and preferably at least about 75%, at least about 90%, or at least about 95% of the nucleotide residue positions of each of the portions are occupied by the same nucleotide residue. More preferably, all nucleotide residue positions of each of the portions are occupied by the same nucleotide residue.

The term “immune cell” refers to cells that play a role in the immune response. Immune cells are of hematopoietic origin, and include lymphocytes, such as B cells and T cells; natural killer cells; myeloid cells, such as monocytes, macrophages, eosinophils, mast cells, basophils, and granulocytes.

The term “immune checkpoint inhibitor” means a group of molecules on the cell surface of CD4+ and/or CD8+ T cells that fine-tune immune responses by down-modulating or inhibiting an anti-tumor immune response. Immune checkpoint inhibitor proteins are well known in the art and include, without limitation, CTLA-4, PD-1, VISTA, B7-H2, B7-H3, PD-L1, B7-H4, B7-H6, 2B4, ICOS, HVEM, PD-L2, CD160, gp49B, PIR-B, KIR family receptors, TIM-1, TIM-3, TIM-4, LAG-3, BTLA, SIRPalpha (CD47), CD48, 2B4 (CD244), B7.1, B7.2, ILT-2, ILT-4, TIGIT, and A2aR (see, for example, WO 2012/177624). “Anti-immune checkpoint inhibitor therapy” refers to the use of agents that inhibit immune checkpoint inhibitors. Inhibition of one or more immune checkpoint inhibitors can block or otherwise neutralize inhibitory signaling to thereby upregulate an

immune response in order to more efficaciously treat chronic immune disorder. Exemplary agents useful for inhibiting immune checkpoint inhibitors include antibodies, small molecules, peptides, peptidomimetics, natural ligands, and derivatives of natural ligands, that can either bind and/or inactivate or inhibit immune checkpoint proteins, or fragments thereof, as well as RNA interference, antisense, nucleic acid aptamers, etc. that can downregulate the expression and/or activity of immune checkpoint inhibitor nucleic acids, or fragments thereof. Exemplary agents for upregulating an immune response include antibodies against one or more immune checkpoint inhibitor proteins block the interaction between the proteins and its natural receptor(s); a non-activating form of one or more immune checkpoint inhibitor proteins (e.g., a dominant negative polypeptide); small molecules or peptides that block the interaction between one or more immune checkpoint inhibitor proteins and its natural receptor(s); fusion proteins (e.g. the extracellular portion of an immune checkpoint inhibition protein fused to the Fc portion of an antibody or immunoglobulin) that bind to its natural receptor(s); nucleic acid molecules that block immune checkpoint inhibitor nucleic acid transcription or translation; and the like. Such agents can directly block the interaction between the one or more immune checkpoint inhibitors and its natural receptor(s) (e.g., antibodies) to prevent inhibitory signaling and upregulate an immune response. Alternatively, agents can indirectly block the interaction between one or more immune checkpoint proteins and its natural receptor(s) to prevent inhibitory signaling and upregulate an immune response. For example, a soluble version of an immune checkpoint protein ligand such as a stabilized extracellular domain can binding to its receptor to indirectly reduce the effective concentration of the receptor to bind to an appropriate ligand. In one embodiment, anti-PD-1 antibodies, anti-PD-L1 antibodies, and anti-CTLA-4 antibodies, either alone or in combination, are used to inhibit immune checkpoint inhibitors.

“PD-1” is an immune checkpoint inhibitor that refers to a member of the immunoglobulin gene superfamily that functions as a co-inhibitory receptor having PD-L1 and PD-L2 as known ligands. PD-1 was previously identified using a subtraction cloning based approach to select for proteins involved in apoptotic cell death. PD-1 is a member of the CD28/CTLA-4 family of molecules based on its ability to bind to PD-L1. Like CTLA-4, PD-1 is rapidly induced on the surface of T-cells in response to anti-CD3 (Agata *et al.* 25 (1996) *Int. Immunol.* 8:765). In contrast to CTLA-4, however, PD-1 is also induced on the surface of B-cells (in response to anti-IgM). PD-1 is also expressed on a subset of

thymocytes and myeloid cells (Agata *et al.* (1996) *supra*; Nishimura *et al.* (1996) *Int. Immunol.* 8:773).

The nucleic acid and amino acid sequences of a representative human PD-1 biomarker is available to the public at the GenBank database under NM_005018.2 and NP_005009.2 (see also Ishida *et al.* (1992) 20 *EMBO J* 11:3887; Shinohara *et al.* (1994) *Genomics* 23:704; U.S. Patent 5,698,520). PD-1 has an extracellular region containing immunoglobulin superfamily domain, a transmembrane domain, and an intracellular region including an immunoreceptor tyrosine-based inhibitory motif (ITIM) (Ishida *et al.* (1992) *EMBO J.* 11:3887; Shinohara *et al.* (1994) *Genomics* 23:704; and U.S. Patent 5,698,520). These features also define a larger family of polypeptides, called the immunoinhibitory receptors, which also includes gp49B, PIR-B, and the killer inhibitory receptors (KIRs) (Vivier and Daeron (1997) *Immunol. Today* 18:286). It is often assumed that the tyrosyl phosphorylated ITIM motif of these receptors interacts with SH2-domain containing phosphatases, which leads to inhibitory signals. A subset of these immunoinhibitory receptors bind to MHC polypeptides, for example the KIRs, and CTLA4 binds to B7-1 and B7-2. It has been proposed that there is a phylogenetic relationship between the MHC and B7 genes (Henry *et al.* (1999) *Immunol. Today* 20(6):285-8). Nucleic acid and polypeptide sequences of PD-1 orthologs in organisms other than humans are well known and include, for example, mouse PD-1 (NM_008798.2 and NP_032824.1), rat PD-1 (NM_001106927.1 and NP_001100397.1), dog PD-1 (XM_543338.3 and XP_543338.3), cow PD-1 (NM_001083506.1 and NP_001076975.1), and chicken PD-1 (XM_422723.3 and XP_422723.2).

PD-1 polypeptides are inhibitory receptors capable of transmitting an inhibitory signal to an immune cell to thereby inhibit immune cell effector function, or are capable of promoting costimulation (*e.g.*, by competitive inhibition) of immune cells, *e.g.*, when present in soluble, monomeric form. Preferred PD-1 family members share sequence identity with PD-1 and bind to one or more B7 family members, *e.g.*, B7-1, B7-2, PD-1 ligand, and/or other polypeptides on antigen presenting cells.

The term "PD-1 activity" includes the ability of a PD-1 polypeptide to modulate an inhibitory signal in an activated immune cell, *e.g.*, by engaging a natural PD-1 ligand on an antigen presenting cell. PD-1 transmits an inhibitory signal to an immune cell in a manner similar to CTLA4. Modulation of an inhibitory signal in an immune cell results in modulation of proliferation of, and/or cytokine secretion by, an immune cell. Thus, the

term “PD-1 activity” includes the ability of a PD-1 polypeptide to bind its natural ligand(s), the ability to modulate immune cell costimulatory or inhibitory signals, and the ability to modulate the immune response.

The term “PD-1 ligand” refers to binding partners of the PD-1 receptor and includes both PD-L1 (Freeman *et al.* (2000) *J. Exp. Med.* 192:1027) and PD-L2 (Latchman *et al.* (2001) *Nat. Immunol.* 2:261). At least two types of human PD-1 ligand polypeptides exist. PD-1 ligand proteins comprise a signal sequence, and an IgV domain, an IgC domain, a transmembrane domain, and a short cytoplasmic tail. Both PD-L1 (See Freeman *et al.* (2000) *J. Exp. Med.* 192:1027 for sequence data) and PD-L2 (See Latchman *et al.* (2001) *Nat. Immunol.* 2:261 for sequence data) are members of the B7 family of polypeptides. Both PD-L1 and PD-L2 are expressed in placenta, spleen, lymph nodes, thymus, and heart. Only PD-L2 is expressed in pancreas, lung and liver, while only PD-L1 is expressed in fetal liver. Both PD-1 ligands are upregulated on activated monocytes and dendritic cells, although PD-L1 expression is broader. For example, PD-L1 is known to be constitutively expressed and upregulated to higher levels on murine hematopoietic cells (*e.g.*, T cells, B cells, macrophages, dendritic cells (DCs), and bone marrow-derived mast cells) and non-hematopoietic cells (*e.g.*, endothelial, epithelial, and muscle cells), whereas PD-L2 is inducibly expressed on DCs, macrophages, and bone marrow-derived mast cells (see, Butte *et al.* (2007) *Immunity* 27:111).

PD-1 ligands comprise a family of polypeptides having certain conserved structural and functional features. The term “family” when used to refer to proteins or nucleic acid molecules, is intended to mean two or more proteins or nucleic acid molecules having a common structural domain or motif and having sufficient amino acid or nucleotide sequence homology, as defined herein. Such family members can be naturally or non-naturally occurring and can be from either the same or different species. For example, a family can contain a first protein of human origin, as well as other, distinct proteins of human origin or alternatively, can contain homologues of non-human origin. Members of a family may also have common functional characteristics. PD-1 ligands are members of the B7 family of polypeptides. The term “B7 family” or “B7 polypeptides” as used herein includes costimulatory polypeptides that share sequence homology with B7 polypeptides, *e.g.*, with B7-1 (CD80), B7-2 (CD86), inducible costimulatory ligand (ICOS-L), B7-H3, B7-H4, VISTA, B7-H6, B7h (Swallow *et al.* (1999) *Immunity* 11:423), and/or PD-1 ligands (*e.g.*, PD-L1 or PD-L2). For example, human B7-1 and B7-2 share approximately 26%

amino acid sequence identity when compared using the BLAST program at NCBI with the default parameters (Blosun62 matrix with gap penalties set at existence 11 and extension 1 (see the NCBI website). The term B7 family also includes variants of these polypeptides which are capable of modulating immune cell function. The B7 family of molecules share a number of conserved regions, including signal domains, IgV domains and the IgC domains. IgV domains and the IgC domains are art-recognized Ig superfamily member domains. These domains correspond to structural units that have distinct folding patterns called Ig folds. Ig folds are comprised of a sandwich of two β sheets, each consisting of anti-parallel β strands of 5-10 amino acids with a conserved disulfide bond between the two sheets in most, but not all, IgC domains of Ig, TCR, and MHC molecules share the same types of sequence patterns and are called the C1-set within the Ig superfamily. Other IgC domains fall within other sets. IgV domains also share sequence patterns and are called V set domains. IgV domains are longer than IgC domains and contain an additional pair of β strands.

The term "PD-L1" refers to a specific PD-1 ligand. Two forms of human PD-L1 molecules have been identified. One form is a naturally occurring PD-L1 soluble polypeptide, *i.e.*, having a short hydrophilic domain at the COOH-terminal end and no transmembrane domain, and is referred to herein as PD-L1S. The second form is a cell-associated polypeptide, *i.e.*, having a transmembrane and cytoplasmic domain, referred to herein as PD-L1M. The nucleic acid and amino acid sequences of representative human PD-L1 biomarkers regarding PD-L1M are also available to the public at the GenBank database under NM_014143.3 and NP_054862.1. PD-L1 proteins comprise a signal sequence, and an IgV domain and an IgC domain. The signal sequence is from about amino acid 1 to about amino acid 18. The signal sequence is from about amino acid 1 to about amino acid 18. The IgV domain is from about amino acid 19 to about amino acid 134 and the IgV domain is from about amino acid 19 to about amino acid 134. The IgC domain is from about amino acid 135 to about amino acid 227 and the IgC domain of SEQ ID NO: 6 is shown from about amino acid 135 to about amino acid 227. The hydrophilic tail of PD-L1 comprises a hydrophilic tail shown from about amino acid 228 to about amino acid 245. The PD-L1 polypeptide comprises a transmembrane domain shown from about amino acids 239 to about amino acid 259 and a cytoplasmic domain shown of about 30 amino acids from 260 to about amino acid 290. In addition, nucleic acid and polypeptide sequences of PD-L1 orthologs in organisms other than humans are well known and include, for example,

mouse PD-L1 (NM_021893.3 and NP_068693.1), rat PD-L1 (NM_001191954.1 and NP_001178883.1), dog PD-L1 (XM_541302.3 and XP_541302.3), cow PD-L1 (NM_001163412.1 and NP_001156884.1), and chicken PD-L1 (XM_424811.3 and XP_424811.3).

The term "PD-L2" refers to another specific PD-1 ligand. PD-L2 is a B7 family member expressed on various APCs, including dendritic cells, macrophages and bone-marrow derived mast cells (Zhong *et al.* (2007) *Eur. J. Immunol.* 37:2405). APC-expressed PD-L2 is able to both inhibit T cell activation through ligation of PD-1 and costimulate T cell activation, through a PD-1 independent mechanism (Shin *et al.* (2005) *J. Exp. Med.* 201:1531). In addition, ligation of dendritic cell-expressed PD-L2 results in enhanced dendritic cell cytokine expression and survival (Radhakrishnan *et al.* (2003) *J. Immunol.* 37:1827; Nguyen *et al.* (2002) *J. Exp. Med.* 196:1393). The nucleic acid and amino acid sequences of representative human PD-L2 biomarkers are well known in the art and are also available to the public at the GenBank database under NM_025239.3 and NP_079515.2. PD-L2 proteins are characterized by common structural elements. In some embodiments, PD-L2 proteins include at least one or more of the following domains: a signal peptide domain, a transmembrane domain, an IgV domain, an IgC domain, an extracellular domain, a transmembrane domain, and a cytoplasmic domain. For example, amino acids 1-19 comprise a signal sequence. As used herein, a "signal sequence" or "signal peptide" serves to direct a polypeptide containing such a sequence to a lipid bilayer, and is cleaved in secreted and membrane bound polypeptides and includes a peptide containing about 15 or more amino acids which occurs at the N-terminus of secretory and membrane bound polypeptides and which contains a large number of hydrophobic amino acid residues. For example, a signal sequence contains at least about 10-30 amino acid residues, preferably about 15- 25 amino acid residues, more preferably about 18-20 amino acid residues, and even more preferably about 19 amino acid residues, and has at least about 35-65%, preferably about 38-50%, and more preferably about 40-45% hydrophobic amino acid residues (e.g., valine, leucine, isoleucine or phenylalanine). In another embodiment, amino acid residues 220-243 of the native human PD-L2 polypeptide and amino acid residues 201-243 of the mature polypeptide comprise a transmembrane domain. As used herein, the term "transmembrane domain" includes an amino acid sequence of about 15 amino acid residues in length which spans the plasma membrane. More preferably, a transmembrane domain includes about at least 20, 25, 30, 35, 40, or 45 amino

acid residues and spans the plasma membrane. Transmembrane domains are rich in hydrophobic residues, and typically have an alpha-helical structure. In a preferred embodiment, at least 50%, 60%, 70%, 80%, 90%, 95% or more of the amino acids of a transmembrane domain are hydrophobic, e.g., leucines, isoleucines, tyrosines, or tryptophans. Transmembrane domains are described in, for example, Zagotta *et al.* (1996) *Annu. Rev. Neurosci.* 19: 235-263. In still another embodiment, amino acid residues 20-120 of the native human PD-L2 polypeptide and amino acid residues 1-101 of the mature polypeptide comprise an IgV domain. Amino acid residues 121-219 of the native human PD-L2 polypeptide and amino acid residues 102-200 of the mature polypeptide comprise an IgC domain. As used herein, IgV and IgC domains are recognized in the art as Ig superfamily member domains. These domains correspond to structural units that have distinct folding patterns called Ig folds. Ig folds are comprised of a sandwich of two β sheets, each consisting of antiparallel (3 strands of 5-10 amino acids with a conserved disulfide bond between the two sheets in most, but not all, domains. IgC domains of Ig, TCR, and MHC molecules share the same types of sequence patterns and are called the C1 set within the Ig superfamily. Other IgC domains fall within other sets. IgV domains also share sequence patterns and are called V set domains. IgV domains are longer than C-domains and form an additional pair of strands. In yet another embodiment, amino acid residues 1-219 of the native human PD-L2 polypeptide and amino acid residues 1-200 of the mature polypeptide comprise an extracellular domain. As used herein, the term "extracellular domain" represents the N-terminal amino acids which extend as a tail from the surface of a cell. An extracellular domain of the present invention includes an IgV domain and an IgC domain, and may include a signal peptide domain. In still another embodiment, amino acid residues 244-273 of the native human PD-L2 polypeptide and amino acid residues 225-273 of the mature polypeptide comprise a cytoplasmic domain. As used herein, the term "cytoplasmic domain" represents the C-terminal amino acids which extend as a tail into the cytoplasm of a cell. In addition, nucleic acid and polypeptide sequences of PD-L2 orthologs in organisms other than humans are well known and include, for example, mouse PD-L2 (NM_021396.2 and NP_067371.1), rat PD-L2 (NM_001107582.2 and NP_001101052.2), dog PD-L2 (XM_847012.2 and XP_852105.2), cow PD-L2 (XM_586846.5 and XP_586846.3), and chimpanzee PD-L2 (XM_001140776.2 and XP_001140776.1).

The term “PD-L2 activity,” “biological activity of PD-L2,” or “functional activity of PD-L2,” refers to an activity exerted by a PD-L2 protein, polypeptide or nucleic acid molecule on a PD-L2-responsive cell or tissue, or on a PD-L2 polypeptide binding partner, as determined *in vivo*, or *in vitro*, according to standard techniques. In one embodiment, a PD-L2 activity is a direct activity, such as an association with a PD-L2 binding partner. As used herein, a “target molecule” or “binding partner” is a molecule with which a PD-L2 polypeptide binds or interacts in nature, such that PD-L2-mediated function is achieved. In an exemplary embodiment, a PD-L2 target molecule is the receptor RGMb. Alternatively, a PD-L2 activity is an indirect activity, such as a cellular signaling activity mediated by interaction of the PD-L2 polypeptide with its natural binding partner, *e.g.*, RGMb. The biological activities of PD-L2 are described herein. For example, the PD-L2 polypeptides of the present invention can have one or more of the following activities: 1) bind to and/or modulate the activity of the receptor RGMb, PD-1, or other PD-L2 natural binding partners, 2) modulate intra-or intercellular signaling, 3) modulate activation of immune cells, *e.g.*, T lymphocytes, and 4) modulate the immune response of an organism, *e.g.*, a mouse or human organism.

The term “immune response” includes T cell-mediated and/or B cell-mediated immune responses. Exemplary immune responses include T cell responses, *e.g.*, cytokine production and cellular cytotoxicity. In addition, the term immune response includes immune responses that are indirectly effected by T cell activation, *e.g.*, antibody production (humoral responses) and activation of cytokine responsive cells, *e.g.*, macrophages.

The term “immune response” refers to a response by a cell of the immune system, such as a B cell, T cell (CD4 or CD8), regulatory T cell, antigen-presenting cell, dendritic cell, monocyte, macrophage, NKT cell, NK cell, basophil, eosinophil, or neutrophil, to a stimulus. In one embodiment, the response is specific for a particular antigen (an “antigen-specific response”), and refers to a response by a CD4 T cell, CD8 T cell, or B cell via their antigen-specific receptor. In another embodiment, an immune response is a T cell response, such as a CD4+ response or a CD8+ response. Such responses by these cells can include, for example, cytotoxicity, proliferation, cytokine or chemokine production, trafficking, or phagocytosis, and can be dependent on the nature of the immune cell undergoing the response. In still another embodiment, an immune response is an effector T cell response, such as occurs when a cytotoxic CD8+ cell produces an antigen-specific response.

“Exhaustion” or “unresponsiveness” refers to a state of a cell where the cell does not perform its usual function or activity in response to normal input signals, and includes refractivity of immune cells to stimulation, such as stimulation via an activating receptor or a cytokine. Such a function or activity includes, but is not limited to, proliferation or cell division, entrance into the cell cycle, cytokine production, cytotoxicity, trafficking, phagocytotic activity, or any combination thereof. Normal input signals can include, but are not limited to, stimulation via a receptor (e.g., T cell receptor, B cell receptor, co-stimulatory receptor, and the like).

Exhausted immune cells can have a reduction of at least 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45%, 50%, 55%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 95%, 99% or more in cytotoxic activity, cytokine production, proliferation, trafficking, phagocytotic activity, or any combination thereof, relative to a corresponding control immune cell of the same type. In one embodiment, a cell that is exhausted is a CD8⁺ T cell (e.g., an effector CD8⁺ T cell that is antigen-specific). CD8 cells normally proliferate (e.g., clonally expand) in response to T cell receptor and/or co-stimulatory receptor stimulation, as well as in response to cytokines such as IL-2. Thus, an exhausted CD8 T cell is one which does not proliferate and/or produce cytokines in response to normal input signals. It is well known that the exhaustion of effector functions can be delineated according to several stages, which eventually lead to terminal or full exhaustion and, ultimately, deletion (Yi *et al.* (2010) *Immunol.* 129:474-481; Wherry and Ahmed (2004) *J. Virol.* 78:5535-5545). In the first stage, functional T cells enter a “partial exhaustion I” phase characterized by the loss of a subset of effector functions, including loss of IL-2 production, reduced TNF α production, and reduced capacity for proliferation and/or *ex vivo* lysis ability. In the second stage, partially exhausted T cells enter a “partial exhaustion II” phase when both IL-2 and TNF α production ceases following antigenic stimulation and IFN γ production is reduced. “Full exhaustion” or “terminal exhaustion” occurs when CD8⁺ T cells lose all effector functions, including the lack of production of IL-2, TNF α , and IFN γ and loss of *ex vivo* lytic ability and proliferative potential, following antigenic stimulation. A fully exhausted CD8⁺ T cell is one which does not proliferate, does not lyse target cells (cytotoxicity), and/or does not produce appropriate cytokines, such as IL-2, TNF α , or IFN γ , in response to normal input signals. Such lack of effector functions can occur when the antigen load is high and/or CD4 help is low. This hierarchical loss of function is also associated with the expression of co-inhibitor immune receptors, such as PD-1, TIM-3, LAG-3, and the like

(Day *et al.* (2006) *Nature* 443:350-4; Trautmann *et al.* (2006) *Nat. Med.* 12:1198-202; and Urbani *et al.* (2006) *J. Virol.* 80:1398-1403). Other molecular markers distinguish the hierarchical stages of immune cell exhaustion, such as highomesodermin (EOMES) and low TBET expression as a marker of terminally exhausted T cells (Paley *et al.* (2012) *Science* 338:1220-1225). Additional markers of exhausted T cells, such as the reduction of Bcl-b and the increased production of BLIMP-1 (Pdrml).

The term "reducing exhaustion" or "reducing unresponsiveness" refers to a given treatment or set of conditions that leads to increased T cell activity, responsiveness, and/or ability or receptiveness, with regards to activation. Methods of measuring T cell activity are well known in the art. Modulation of one or more of any of the immune cell exhaustion parameters described above can be assayed. For example, T cell activity can be measured by contacting T cells with recall antigen, anti-CD3 in the absence of costimulation, and/or ionomycin. Also, proliferation of T cells can be measured in the presence of a relevant antigen assayed, e.g. by a ³H-thymidine incorporation assay or cell number. Markers of T cell activation after exposure to the relevant antigen can also be assayed, e.g. flow cytometry analysis of cell surface markers indicative of T cell activation (e.g., CD69, CD30, CD25, and HLA-DR) and/or T cell exhaustion. In some embodiments, the assays can be *in vivo* assays, such as through challenging immune cells with antigen *in vivo*. For example, animal models expressing homogeneous populations of T cells from TCR transgenic and other transgenic mice can be transferred into hosts that constitutively express an antigen recognized by the transferred T cells, e.g., the H-Y antigen TCR transgenic; pigeon cytochrome C antigen TCR transgenic; or hemagglutinin (HA) TCR transgenic. In such models, T cells expressing the TCR specific for the antigen constitutively or inducibly expressed by the recipient mice typically undergo an immediate expansion and proliferative phase, followed by a period of unresponsiveness, which is reversed when the antigen is removed and/or antigen expression is inhibited. Accordingly, if the T cells proliferate or expand, show cytokine activity, etc. significantly more in an assay (e.g., with or without additional treatment of immunomodulatory agents) than control T cells, then T cell exhaustion is reduced. Such measurements of proliferation can occur *in vivo* using T cells labeled with BrDU, CFSE or another intravital dye that allows tracking of proliferation prior to transferring to a recipient animal expressing the antigen, or cytokine reporter T cells, or using *ex vivo* methods to analyze cellular proliferation and/or cytokine production, such as thymidine proliferation assays, ELISA, cytokine bead assays, and the like.

Moreover, reduction of immune cell exhaustion can be assessed by examination of tumor infiltrating lymphocytes or T lymphocytes within lymph nodes that drain from an established tumor. Such T cells exhibit features of exhaustion through expression of cell surface molecules, such as immunoinhibitory receptors described above, for example, and decreased secretion of cytokines, such as those described above. Accordingly, if increased quantities and/or activities of T cells are observed with, for example, 1) antigen specificity for tumor associated antigens (e.g., as determined by major histocompatibility complex class I or class II tetramers which contain tumor associated peptides) and/or 2) that are capable of secreting high levels of appropriate cytokines and cytolytic effector molecules such as granzyme-B, then T cell exhaustion has been reduced.

The term "acute immune disorder" refers to conditions that can be resolved by an appropriate immune response that eradicates a targeted antigen and host comprising such a targeted antigen, such as a cancer or an infection agent like a virus, bacteria, parasite, mycoplasma, fungus, and the like. Such conditions are relatively brief and last on the order of a few days to a few weeks.

By contrast, the term "chronic immune disorders" refers to those conditions that are not effectively cleared or eliminated by the induction of a host immune response. In chronic immune disorders, a targeted antigen (and/or host comprising the targeted antigen), such as an infectious agent or cancer cell, and the immune response reach equilibrium such that the subject maintains the targeted antigen or host comprising the targeted antigen (e.g., remains infectious or afflicted with cancer) over a long period of time (i.e., a time period of months to years or even a lifetime) without necessarily expressing symptoms. Chronic immune disorders can involve stages of both silent and productive targeted antigen maintenance without rapidly killing or even producing excessive damage of the host cells. Detection of the targeted antigen or host comprising the targeted antigen can be made according to any one of many well known methods in the art and described, for example, in U.S. Patent Nos. 6,368,832, 6,579,854, and 6,808,710 and U.S. Patent Application Publication Nos. 20040137577, 20030232323, 20030166531, 20030064380, 20030044768, 20030039653, 20020164600, 20020160000, 20020110836, 20020107363, and 200201067. In some embodiments, chronic immune disorders are the result of infection, such as an infection with a virus including, but not limited to, human immunodeficiency viruses (HIV), hepatitis C viruses (HCV), T-cell leukemia viruses, Epstein-Barr virus, cytomegalovirus, herpesviruses, varicella-zoster virus, measles, papovaviruses, prions,

hepatitis viruses, adenoviruses, parvoviruses, papillomaviruses, prions, and the like. Chronic immune disorders include, for example, chronic conditions and latent conditions. As used herein, chronic immune disorders can be limited to chronic conditions, latent conditions, or both.

In a "chronic condition," the targeted antigen can be detected in the subject at all times regardless of whether the signs and symptoms of the disease are present or absent, even for an extended period of time. Non-limiting examples of chronic conditions resulting from infection include hepatitis B (caused by hepatitis B virus (HBV)) and hepatitis C (caused by hepatitis C virus (HCV)) adenovirus, cytomegalovirus, Epstein-Barr virus, herpes simplex virus 1, herpes simplex virus 2, human herpesvirus 6, varicella-zoster virus, hepatitis B virus, hepatitis D virus, papilloma virus, parvovirus B19, polyoma virus BK, polyoma virus JC, measles virus, rubella virus, human immunodeficiency virus (HIV), human T cell leukemia virus I, and human T cell leukemia virus II. Parasitic persistent infections can arise as a result of infection by, for example, *Leishmania*, *Toxoplasma*, *Trypanosoma*, *Plasmodium*, *Schistosoma*, and *Encephalitozoon*.

A particular type of chronic condition involving infections is known as a "latent condition," where the infectious agent (such as a virus) is seemingly inactive and dormant such that the subject does not always exhibit signs or symptoms. In a latent viral infection, the virus remains in equilibrium with the host for long periods of time before symptoms again appear; however, the actual viruses cannot typically be detected until reactivation of the disease occurs. Infection latency is the ability of a pathogenic infection agent, such as a virus, to lie dormant within a cell. For example, a latent viral infection is a phase in the life cycle of certain viruses in which after initial infection, virus production ceases. However, the virus genome is not fully eradicated. The result of this is that the virus can reactivate and begin producing large amounts of viral progeny (the lytic part of the viral life cycle) without the host being infected by a new virus. The virus may stay within the host indefinitely. In one embodiment, virus latency is not identical to clinical latency, in which the virus is undergoing an incubation period but is not dormant. Non-limiting examples of latent infections include infections caused by herpes simplex virus (HSV)-1 (fever blisters), HSV-2 (genital herpes), and varicella zoster virus VZV (chickenpox-shingles).

The term "immunotherapeutic agent" can include any molecule, peptide, antibody or other agent which can stimulate a host immune system to generate an immune response

against the chronic immune disorder in the subject. Various immunotherapeutic agents are useful in the compositions and methods described herein.

The term “inhibit” includes the decrease, limitation, or blockage, of, for example a particular action, function, or interaction. In some embodiments, a chronic immune disorder is “inhibited” if at least one symptom of the chronic immune disorder is alleviated, terminated, slowed, or prevented. As used herein, a chronic immune disorder is also “inhibited” if recurrence or metastasis of the chronic immune disorder is reduced, slowed, delayed, or prevented.

The term “interaction”, when referring to an interaction between two molecules, refers to the physical contact (*e.g.*, binding) of the molecules with one another. Generally, such an interaction results in an activity (which produces a biological effect) of one or both of said molecules.

An “isolated protein” refers to a protein that is substantially free of other proteins, cellular material, separation medium, and culture medium when isolated from cells or produced by recombinant DNA techniques, or chemical precursors or other chemicals when chemically synthesized. An “isolated” or “purified” protein or biologically active portion thereof is substantially free of cellular material or other contaminating proteins from the cell or tissue source from which the antibody, polypeptide, peptide or fusion protein is derived, or substantially free from chemical precursors or other chemicals when chemically synthesized. The language “substantially free of cellular material” includes preparations of a biomarker polypeptide or fragment thereof, in which the protein is separated from cellular components of the cells from which it is isolated or recombinantly produced. In one embodiment, the language “substantially free of cellular material” includes preparations of a biomarker protein or fragment thereof, having less than about 30% (by dry weight) of non-biomarker protein (also referred to herein as a “contaminating protein”), more preferably less than about 20% of non-biomarker protein, still more preferably less than about 10% of non-biomarker protein, and most preferably less than about 5% non-biomarker protein. When antibody, polypeptide, peptide or fusion protein or fragment thereof, *e.g.*, a biologically active fragment thereof, is recombinantly produced, it is also preferably substantially free of culture medium, *i.e.*, culture medium represents less than about 20%, more preferably less than about 10%, and most preferably less than about 5% of the volume of the protein preparation.

A “kit” is any manufacture (*e.g.* a package or container) comprising at least one reagent, *e.g.* a probe or small molecule, for specifically detecting and/or affecting the expression of a marker of the invention. The kit may be promoted, distributed, or sold as a unit for performing the methods of the present invention. The kit may comprise one or more reagents necessary to express a composition useful in the methods of the present invention. In certain embodiments, the kit may further comprise a reference standard, *e.g.*, a nucleic acid encoding a protein that does not affect or regulate signaling pathways controlling cell growth, division, migration, survival or apoptosis. One skilled in the art can envision many such control proteins, including, but not limited to, common molecular tags (*e.g.*, green fluorescent protein and beta-galactosidase), proteins not classified in any of pathway encompassing cell growth, division, migration, survival or apoptosis by GeneOntology reference, or ubiquitous housekeeping proteins. Reagents in the kit may be provided in individual containers or as mixtures of two or more reagents in a single container. In addition, instructional materials which describe the use of the compositions within the kit can be included.

The term “neoadjuvant therapy” refers to a treatment given before the primary treatment. Examples of neoadjuvant therapy can include chemotherapy, radiation therapy, and hormone therapy. For example, in treating breast cancer, neoadjuvant therapy can allow patients with large breast cancer to undergo breast-conserving surgery.

The “normal” level of expression of a biomarker is the level of expression of the biomarker in cells of a subject, *e.g.*, a human patient, not afflicted with a chronic immune disorder. An “over-expression” or “significantly higher level of expression” of a biomarker refers to an expression level in a test sample that is greater than the standard error of the assay employed to assess expression, and is preferably at least twice, and more preferably 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, 2.9, 3, 3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7, 7.5, 8, 8.5, 9, 9.5, 10, 10.5, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20 times or more higher than the expression activity or level of the biomarker in a control sample (*e.g.*, sample from a healthy subject not having the biomarker associated disease) and preferably, the average expression level of the biomarker in several control samples. A “significantly lower level of expression” of a biomarker refers to an expression level in a test sample that is at least twice, and more preferably 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, 2.9, 3, 3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7, 7.5, 8, 8.5, 9, 9.5, 10, 10.5, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20 times or more lower than the expression level of the biomarker in a control sample (*e.g.*, sample from a healthy subject

not having the biomarker associated disease) and preferably, the average expression level of the biomarker in several control samples.

An “over-expression” or “significantly higher level of expression” of a biomarker refers to an expression level in a test sample that is greater than the standard error of the assay employed to assess expression, and is preferably at least 10%, and more preferably 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2.0, 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, 2.9, 3, 3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7, 7.5, 8, 8.5, 9, 9.5, 10, 10.5, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20 times or more higher than the expression activity or level of the biomarker in a control sample (*e.g.*, sample from a healthy subject not having the biomarker associated disease) and preferably, the average expression level of the biomarker in several control samples. A “significantly lower level of expression” of a biomarker refers to an expression level in a test sample that is at least 10%, and more preferably 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2.0, 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, 2.9, 3, 3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7, 7.5, 8, 8.5, 9, 9.5, 10, 10.5, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20 times or more lower than the expression level of the biomarker in a control sample (*e.g.*, sample from a healthy subject not having the biomarker associated disease) and preferably, the average expression level of the biomarker in several control samples.

The term “predictive” includes the use of a biomarker nucleic acid, protein, and/or metabolite status, *e.g.*, over- or under- activity, emergence, expression, growth, remission, recurrence or resistance of tumors before, during or after therapy, for determining the likelihood of response of a chronic immune disorder to treatment, such as anti-CD39 therapy with or without anti-immune checkpoint inhibitor treatment (*e.g.*, therapeutic antibodies against PD-1, PD-L1, PD-L2, and/or CTLA-4). Such predictive use of the biomarker may be confirmed by, *e.g.*, (1) increased or decreased copy number (*e.g.*, by FISH, FISH plus SKY, single-molecule sequencing, *e.g.*, as described in the art at least at J. Biotechnol., 86:289-301, or qPCR), overexpression or underexpression of a biomarker nucleic acid (*e.g.*, by ISH, Northern Blot, or qPCR), increased or decreased biomarker protein (*e.g.*, by IHC) and/or biomarker metabolite, or increased or decreased activity (determined by, for example, modulation of biomarkers, *e.g.*, in more than about 5%, 6%, 7%, 8%, 9%, 10%, 11%, 12%, 13%, 14%, 15%, 20%, 25%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, 95%, 100%, or more of assayed relevant human chronic immune disorder types or samples; (2) its absolute or relatively modulated presence or absence in a biological sample, *e.g.*, a sample containing tissue, whole blood, serum, plasma, buccal scrape, saliva,

cerebrospinal fluid, urine, stool, or bone marrow, from a subject, e.g. a human, afflicted with the chronic immune disorder; (3) its absolute or relatively modulated presence or absence in clinical subset of patients with the chronic immune disorder (e.g., those responding to a particular anti-CD39 therapy with or without anti-immune checkpoint inhibitor therapy or those developing resistance thereto).

The terms “prevent,” “preventing,” “prevention,” “prophylactic treatment,” and the like refer to reducing the probability of developing a disease, disorder, or condition in a subject, who does not have, but is at risk of or susceptible to developing a disease, disorder, or condition.

The term “probe” refers to any molecule which is capable of selectively binding to a specifically intended target molecule, for example, a nucleotide transcript or protein encoded by or corresponding to a biomarker nucleic acid. Probes can be either synthesized by one skilled in the art, or derived from appropriate biological preparations. For purposes of detection of the target molecule, probes may be specifically designed to be labeled, as described herein. Examples of molecules that can be utilized as probes include, but are not limited to, RNA, DNA, proteins, antibodies, and organic molecules.

The term “prognosis” includes a prediction of the probable course and outcome of chronic immune disorder or the likelihood of recovery from the disease. In some embodiments, the use of statistical algorithms provides a prognosis of a chronic immune disorder in an individual. For example, the prognosis can be surgery, development of a clinical subtype of cancer (e.g., solid tumors, such as lung cancer, melanoma, and renal cell carcinoma), development of one or more clinical factors, development of intestinal cancer, or recovery from the disease.

The term “response to therapy” relates to any response of a chronic immune disorder to therapy, such as anti-CD39 and/or anti-immune checkpoint inhibitor therapy, preferably to a change in symptoms such as reduced infection or viral load, tumor mass and/or volume after initiation of neoadjuvant or adjuvant chemotherapy, and the like. Hyperproliferative disorder response may be assessed, for example for efficacy or in a neoadjuvant or adjuvant situation, where the size of a tumor after systemic intervention can be compared to the initial size and dimensions as measured by CT, PET, mammogram, ultrasound or palpation. Responses may also be assessed by caliper measurement or pathological examination of the tumor after biopsy or surgical resection. Response may be recorded in a quantitative fashion like percentage change in tumor volume or in a

qualitative fashion like “pathological complete response” (pCR), “clinical complete remission” (cCR), “clinical partial remission” (cPR), “clinical stable disease” (cSD), “clinical progressive disease” (cPD) or other qualitative criteria. Assessment of hyperproliferative disorder response may be done early after the onset of neoadjuvant or adjuvant therapy, e.g., after a few hours, days, weeks or preferably after a few months. A typical endpoint for response assessment is upon termination of neoadjuvant chemotherapy or upon surgical removal of residual tumor cells and/or the tumor bed. This is typically three months after initiation of neoadjuvant therapy. In some embodiments, clinical efficacy of the therapeutic treatments described herein may be determined by measuring the clinical benefit rate (CBR). The clinical benefit rate is measured by determining the sum of the percentage of patients who are in complete remission (CR), the number of patients who are in partial remission (PR) and the number of patients having stable disease (SD) at a time point at least 6 months out from the end of therapy. The shorthand for this formula is $CBR = CR + PR + SD$ over 6 months. In some embodiments, the CBR for a particular cancer therapeutic regimen is at least 25%, 30%, 35%, 40%, 45%, 50%, 55%, 60%, 65%, 70%, 75%, 80%, 85%, or more. Additional criteria for evaluating the response to cancer therapies are related to “survival,” which includes all of the following: survival until mortality, also known as overall survival (wherein said mortality may be either irrespective of cause or tumor related); “recurrence-free survival” (wherein the term recurrence shall include both localized and distant recurrence); metastasis free survival; disease free survival (wherein the term disease shall include cancer and diseases associated therewith). The length of said survival may be calculated by reference to a defined start point (e.g., time of diagnosis or start of treatment) and end point (e.g., death, recurrence or metastasis). In addition, criteria for efficacy of treatment can be expanded to include response to chemotherapy, probability of survival, probability of metastasis within a given time period, and probability of tumor recurrence. For example, in order to determine appropriate threshold values, a particular cancer therapeutic regimen can be administered to a population of subjects and the outcome can be correlated to biomarker measurements that were determined prior to administration of any cancer therapy. The outcome measurement may be pathologic response to therapy given in the neoadjuvant setting. Alternatively, outcome measures, such as overall survival and disease-free survival can be monitored over a period of time for subjects following cancer therapy for whom biomarker measurement values are known. In certain embodiments, the doses administered are standard doses

known in the art for cancer therapeutic agents. The period of time for which subjects are monitored can vary. For example, subjects may be monitored for at least 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 25, 30, 35, 40, 45, 50, 55, or 60 months. Biomarker measurement threshold values that correlate to outcome of a cancer therapy can be determined using well-known methods in the art, such as those described in the Examples section.

The term “resistance” refers to an acquired or natural resistance of a chronic immune disorder sample or a mammal to a chronic immune disorder therapy (*i.e.*, being nonresponsive to or having reduced or limited response to the therapeutic treatment), such as having a reduced response to a therapeutic treatment by 25% or more, for example, 30%, 40%, 50%, 60%, 70%, 80%, or more, to 2-fold, 3-fold, 4-fold, 5-fold, 10-fold, 15-fold, 20-fold or more. The reduction in response can be measured by comparing with the same chronic immune disorder sample or mammal before the resistance is acquired, or by comparing with a different chronic immune disorder sample or a mammal who is known to have no resistance to the therapeutic treatment. A typical acquired resistance to chemotherapy is called “multidrug resistance.” The multidrug resistance can be mediated by P-glycoprotein or can be mediated by other mechanisms, or it can occur when a mammal is infected with a multi-drug-resistant microorganism or a combination of microorganisms. The determination of resistance to a therapeutic treatment is routine in the art and within the skill of an ordinarily skilled clinician, for example, can be measured by cell proliferative assays and cell death assays as described herein as “sensitizing.” In some embodiments, the term “reverses resistance” means that the use of a second agent in combination with a primary chronic immune disorder therapy (*e.g.*, anti-immune checkpoint inhibitor, chemotherapeutic, and/or radiation therapy) is able to produce a significant decrease in chronic immune disordered tissue at a level of statistical significance (*e.g.*, $p < 0.05$) when compared to chronic immune disordered tissue in the circumstance where the primary therapy alone is unable to produce a statistically significant decrease. For example, this generally applies to tumor volume measurements made at a time when the untreated tumor is growing log rhythmically.

The terms “response” or “responsiveness” refers to an anti-chronic immune disorder response, *e.g.* in the sense of reduction of tumor size or inhibiting tumor growth or a cancer or reduction of infectious agent load or number of affected cells. The terms can also refer to an improved prognosis, for example, as reflected by an increased time to recurrence, which is the period to first recurrence censoring for second primary chronic immune

disorder as a first event or death without evidence of recurrence, or an increased overall survival, which is the period from treatment to death from any cause. To respond or to have a response means there is a beneficial endpoint attained when exposed to a stimulus. Alternatively, a negative or detrimental symptom is minimized, mitigated or attenuated on exposure to a stimulus. It will be appreciated that evaluating the likelihood that a tumor or subject will exhibit a favorable response is equivalent to evaluating the likelihood that the tumor or subject will not exhibit favorable response (*i.e.*, will exhibit a lack of response or be non-responsive).

An "RNA interfering agent" as used herein, is defined as any agent which interferes with or inhibits expression of a target biomarker gene by RNA interference (RNAi). Such RNA interfering agents include, but are not limited to, nucleic acid molecules including RNA molecules which are homologous to the target biomarker gene of the invention, or a fragment thereof, short interfering RNA (siRNA), and small molecules which interfere with or inhibit expression of a target biomarker nucleic acid by RNA interference (RNAi).

"RNA interference (RNAi)" is an evolutionally conserved process whereby the expression or introduction of RNA of a sequence that is identical or highly similar to a target biomarker nucleic acid results in the sequence specific degradation or specific post-transcriptional gene silencing (PTGS) of messenger RNA (mRNA) transcribed from that targeted gene (see Coburn, G. and Cullen, B. (2002) *J. of Virology* 76(18):9225), thereby inhibiting expression of the target biomarker nucleic acid. In one embodiment, the RNA is double stranded RNA (dsRNA). This process has been described in plants, invertebrates, and mammalian cells. In nature, RNAi is initiated by the dsRNA-specific endonuclease Dicer, which promotes processive cleavage of long dsRNA into double-stranded fragments termed siRNAs. siRNAs are incorporated into a protein complex that recognizes and cleaves target mRNAs. RNAi can also be initiated by introducing nucleic acid molecules, *e.g.*, synthetic siRNAs or RNA interfering agents, to inhibit or silence the expression of target biomarker nucleic acids. As used herein, "inhibition of target biomarker nucleic acid expression" or "inhibition of marker gene expression" includes any decrease in expression or protein activity or level of the target biomarker nucleic acid or protein encoded by the target biomarker nucleic acid. The decrease may be of at least 30%, 40%, 50%, 60%, 70%, 80%, 90%, 95% or 99% or more as compared to the expression of a target biomarker nucleic acid or the activity or level of the protein encoded by a target biomarker nucleic acid which has not been targeted by an RNA interfering agent.

The term "sample" used for detecting or determining the presence or level of at least one biomarker is typically whole blood, plasma, serum, saliva, urine, stool (*e.g.*, feces), tears, and any other bodily fluid (*e.g.*, as described above under the definition of "body fluids"), or a tissue sample (*e.g.*, biopsy) such as a small intestine, colon sample, or surgical resection tissue. In certain instances, the method of the present invention further comprises obtaining the sample from the individual prior to detecting or determining the presence or level of at least one marker in the sample.

The term "sensitize" means to alter chronic immune disordered cells such as cancer cells in a way that allows for more effective treatment of the associated chronic immune disorder with a therapy (*e.g.*, anti-immune checkpoint inhibitor, chemotherapeutic, and/or radiation therapy). In some embodiments, normal cells are not affected to an extent that causes the normal cells to be unduly injured by the therapy. An increased sensitivity or a reduced sensitivity to a therapeutic treatment is measured according to a known method in the art for the particular treatment and methods described herein below, including, but not limited to, cell proliferative assays (Tanigawa N, Kern D H, Kikasa Y, Morton D L, *Cancer Res* 1982; 42: 2159-2164), cell death assays (Weisenthal L M, Shoemaker R H, Marsden J A, Dill P L, Baker J A, Moran E M, *Cancer Res* 1984; 94: 161-173; Weisenthal L M, Lippman M E, *Cancer Treat Rep* 1985; 69: 615-632; Weisenthal L M, In: Kaspers G J L, Pieters R, Twenymman P R, Weisenthal L M, Veerman A J P, eds. *Drug Resistance in Leukemia and Lymphoma*. Langhorne, P A: Harwood Academic Publishers, 1993: 415-432; Weisenthal L M, *Contrib Gynecol Obstet* 1994; 19: 82-90). The sensitivity or resistance may also be measured in animal by measuring chronic immune disorder symptom reduction over a period of time, for example, 6 month for human and 4-6 weeks for mouse. A composition or a method sensitizes response to a therapeutic treatment if the increase in treatment sensitivity or the reduction in resistance is 25% or more, for example, 30%, 40%, 50%, 60%, 70%, 80%, or more, to 2-fold, 3-fold, 4-fold, 5-fold, 10-fold, 15-fold, 20-fold or more, compared to treatment sensitivity or resistance in the absence of such composition or method. The determination of sensitivity or resistance to a therapeutic treatment is routine in the art and within the skill of an ordinarily skilled clinician. It is to be understood that any method described herein for enhancing the efficacy of a cancer therapy can be equally applied to methods for sensitizing hyperproliferative or otherwise cancerous cells (*e.g.*, resistant cells) to cancer therapy.

The term “synergistic effect” refers to the combined effect of two or more chronic immune disorder, such as an anti-CD39 therapy and anti-immune checkpoint inhibitor therapy can be greater than the sum of the separate effects of the agents alone.

“Short interfering RNA” (siRNA), also referred to herein as “small interfering RNA” is defined as an agent which functions to inhibit expression of a target biomarker nucleic acid, *e.g.*, by RNAi. An siRNA may be chemically synthesized, may be produced by *in vitro* transcription, or may be produced within a host cell. In one embodiment, siRNA is a double stranded RNA (dsRNA) molecule of about 15 to about 40 nucleotides in length, preferably about 15 to about 28 nucleotides, more preferably about 19 to about 25 nucleotides in length, and more preferably about 19, 20, 21, or 22 nucleotides in length, and may contain a 3' and/or 5' overhang on each strand having a length of about 0, 1, 2, 3, 4, or 5 nucleotides. The length of the overhang is independent between the two strands, *i.e.*, the length of the overhang on one strand is not dependent on the length of the overhang on the second strand. Preferably the siRNA is capable of promoting RNA interference through degradation or specific post-transcriptional gene silencing (PTGS) of the target messenger RNA (mRNA).

In another embodiment, an siRNA is a small hairpin (also called stem loop) RNA (shRNA). In one embodiment, these shRNAs are composed of a short (*e.g.*, 19-25 nucleotide) antisense strand, followed by a 5-9 nucleotide loop, and the analogous sense strand. Alternatively, the sense strand may precede the nucleotide loop structure and the antisense strand may follow. These shRNAs may be contained in plasmids, retroviruses, and lentiviruses and expressed from, for example, the pol III U6 promoter, or another promoter (*see, e.g.*, Stewart, *et al.* (2003) *RNA* Apr;9(4):493-501 incorporated by reference herein).

RNA interfering agents, *e.g.*, siRNA molecules, may be administered to a patient having or at risk for having a chronic immune disorder, to inhibit expression of a biomarker gene which is overexpressed in the chronic immune disorder and thereby treat, prevent, or inhibit the chronic immune disorder in the subject.

The term “subject” refers to any healthy animal, mammal or human, or any animal, mammal or human afflicted with a chronic immune disorder. The term “subject” is interchangeable with “patient.”

The term “survival” includes all of the following: survival until mortality, also known as overall survival (wherein said mortality may be either irrespective of cause or

tumor related); "recurrence-free survival" (wherein the term recurrence shall include both localized and distant recurrence); metastasis free survival; disease free survival (wherein the term disease shall include chronic immune disorders such as cancer and infections). The length of said survival may be calculated by reference to a defined start point (e.g. time of diagnosis or start of treatment) and end point (e.g. death, recurrence or metastasis). In addition, criteria for efficacy of treatment can be expanded to include response to therapy, probability of survival, probability of metastasis within a given time period, and probability of tumor recurrence.

The term "therapeutic effect" refers to a local or systemic effect in animals, particularly mammals, and more particularly humans, caused by a pharmacologically active substance. The term thus means any substance intended for use in the diagnosis, cure, mitigation, treatment or prevention of disease or in the enhancement of desirable physical or mental development and conditions in an animal or human. The phrase "therapeutically-effective amount" means that amount of such a substance that produces some desired local or systemic effect at a reasonable benefit/risk ratio applicable to any treatment. In certain embodiments, a therapeutically effective amount of a compound will depend on its therapeutic index, solubility, and the like. For example, certain compounds discovered by the methods of the present invention may be administered in a sufficient amount to produce a reasonable benefit/risk ratio applicable to such treatment.

The terms "therapeutically-effective amount" and "effective amount" as used herein means that amount of a compound, material, or composition comprising a compound of the present invention which is effective for producing some desired therapeutic effect in at least a sub-population of cells in an animal at a reasonable benefit/risk ratio applicable to any medical treatment. Toxicity and therapeutic efficacy of subject compounds may be determined by standard pharmaceutical procedures in cell cultures or experimental animals, e.g., for determining the LD₅₀ and the ED₅₀. Compositions that exhibit large therapeutic indices are preferred. In some embodiments, the LD₅₀ (lethal dosage) can be measured and can be, for example, at least 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, 100%, 200%, 300%, 400%, 500%, 600%, 700%, 800%, 900%, 1000% or more reduced for the agent relative to no administration of the agent. Similarly, the ED₅₀ (i.e., the concentration which achieves a half-maximal inhibition of symptoms) can be measured and can be, for example, at least 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, 100%, 200%, 300%, 400%, 500%, 600%, 700%, 800%, 900%, 1000% or more increased for the agent relative to

no administration of the agent. Also, Similarly, the IC_{50} (*i.e.*, the concentration which achieves a half-maximal effect, such as cytotoxic or cytostatic effect on cancer cells or inhibition of viral replication or load) can be measured and can be, for example, at least 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, 100%, 200%, 300%, 400%, 500%, 600%, 700%, 800%, 900%, 1000% or more increased for the agent relative to no administration of the agent. In some embodiments, an effect in an assay can be inhibited by at least about 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45%, 50%, 55%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 95%, or even 100%. In another embodiment, at least about a 10% , 15%, 20%, 25%, 30%, 35%, 40%, 45%, 50%, 55%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 95%, or even 100% decrease in a malignancy or viral load can be achieved.

A “transcribed polynucleotide” or “nucleotide transcript” is a polynucleotide (*e.g.* an mRNA, hnRNA, a cDNA, or an analog of such RNA or cDNA) which is complementary to or homologous with all or a portion of a mature mRNA made by transcription of a biomarker nucleic acid and normal post-transcriptional processing (*e.g.* splicing), if any, of the RNA transcript, and reverse transcription of the RNA transcript.

There is a known and definite correspondence between the amino acid sequence of a particular protein and the nucleotide sequences that can code for the protein, as defined by the genetic code (shown below). Likewise, there is a known and definite correspondence between the nucleotide sequence of a particular nucleic acid and the amino acid sequence encoded by that nucleic acid, as defined by the genetic code.

GENETIC CODE

Alanine (Ala, A)	GCA, GCC, GCG, GCT
Arginine (Arg, R)	AGA, ACG, CGA, CGC, CGG, CGT
Asparagine (Asn, N)	AAC, AAT
Aspartic acid (Asp, D)	GAC, GAT
Cysteine (Cys, C)	TGC, TGT
Glutamic acid (Glu, E)	GAA, GAG
Glutamine (Gln, Q)	CAA, CAG
Glycine (Gly, G)	GGA, GGC, GGG, GGT
Histidine (His, H)	CAC, CAT
Isoleucine (Ile, I)	ATA, ATC, ATT
Leucine (Leu, L)	CTA, CTC, CTG, CTT, TTA, TTG
Lysine (Lys, K)	AAA, AAG

Methionine (Met, M)	ATG
Phenylalanine (Phe, F)	TTC, TTT
Proline (Pro, P)	CCA, CCC, CCG, CCT
Serine (Ser, S)	AGC, AGT, TCA, TCC, TCG, TCT
Threonine (Thr, T)	ACA, ACC, ACG, ACT
Tryptophan (Trp, W)	TGG
Tyrosine (Tyr, Y)	TAC, TAT
Valine (Val, V)	GTA, GTC, GTG, GTT
Termination signal (end)	TAA, TAG, TGA

An important and well known feature of the genetic code is its redundancy, whereby, for most of the amino acids used to make proteins, more than one coding nucleotide triplet may be employed (illustrated above). Therefore, a number of different nucleotide sequences may code for a given amino acid sequence. Such nucleotide sequences are considered functionally equivalent since they result in the production of the same amino acid sequence in all organisms (although certain organisms may translate some sequences more efficiently than they do others). Moreover, occasionally, a methylated variant of a purine or pyrimidine may be found in a given nucleotide sequence. Such methylations do not affect the coding relationship between the trinucleotide codon and the corresponding amino acid.

In view of the foregoing, the nucleotide sequence of a DNA or RNA encoding a biomarker nucleic acid (or any portion thereof) can be used to derive the polypeptide amino acid sequence, using the genetic code to translate the DNA or RNA into an amino acid sequence. Likewise, for polypeptide amino acid sequence, corresponding nucleotide sequences that can encode the polypeptide can be deduced from the genetic code (which, because of its redundancy, will produce multiple nucleic acid sequences for any given amino acid sequence). Thus, description and/or disclosure herein of a nucleotide sequence which encodes a polypeptide should be considered to also include description and/or disclosure of the amino acid sequence encoded by the nucleotide sequence. Similarly, description and/or disclosure of a polypeptide amino acid sequence herein should be considered to also include description and/or disclosure of all possible nucleotide sequences that can encode the amino acid sequence.

Finally, nucleic acid and amino acid sequence information for the loci and biomarkers of the present invention (e.g., biomarkers listed in Table 1) are well known in

the art and readily available on publicly available databases, such as the National Center for Biotechnology Information (NCBI). For example, exemplary nucleic acid and amino acid sequences derived from publicly available sequence databases are provided below.

Table 1**SEQ ID NO: 1 Human CD39 (transcript variant 1) cDNA sequence**

```

1 atggaagata caaaggagtc taacgtgaag acattttgct ccaagaatat cctagccatc
61 cttggcttct cctctatcat agctgtgata gctttgcttg ctgtgggggt gaccacagac
121 aaagcattgc cagaaaacgt taagtatggg attgtgctgg atgcgggttc ttctcacaca
181 agtttataca tctataagtg gccagcagaa aaggagaatg acacaggcgt ggtgcatcaa
241 gtagaagaat gcagggttaa aggtcctgga atctcaaaat ttgttcagaa agtaaatgaa
301 ataggcattt acctgactga ttgcatggaa agagctaggg aagtgattcc aaggctccag
361 caccagaga caccggttta cctgggagcc aaggcaggca tgggggtgct caggatggaa
421 agtgaagagt tggcagacag ggttctggat gtggtggaga ggagcctcag caactacccc
481 tttagacttc aggggtgccag gatcattact ggccaagagg aagggtgcta tggctggatt
541 actatcaact atctgctggg caaatccagt cagaaaacaa ggtgggtcag catagtccca
601 tatgaaccca ataactcagga aacctatgga gctttggacc ttgggggagc ctctacacaa
661 gtcacttttg taacccaaaa ccagactatc gagtccccag ataactctct gcaatttcgc
721 ctctatggca aggactacaa tgtctacaca catagcttct tgtgctatgg gaaggatcag
781 gcactctggc agaaactggc caaggacatt cagggttgcaa gtaatgaaat tctcagggac
841 ccatgctttc atcctggata taagaaggta gtgaacgtaa gtgaccttta caagaccccc
901 tgcaccaaga gatttgagat gactcttcca ttccagcagt ttgaaatcca gggatattga
961 aactatcaac aatgccatca aagcatcctg gagctcttca acaccagtta ctgcccttac
1021 tcccagtgtg ccttcaatgg gattttcttg ccaccaatcc agggggattt tggggcattt
1081 tcagcttttt accttgctgat gaagttttta aacttgacat cagagaaagt ctctcaggaa
1141 aagggtgactg agatgatgaa aaagttctgt gctcagcctt gggaggagat aaaaacatct
1201 tacgtctggg taaaggagaa gtacctgagt gaatactgct tttctggtaa ctacattctc
1261 tccctccttc tgcaaggcta tcaatttcaca gctgattcct gggagcacat ccatttcatt
1321 ggcaagatcc agggcagcga cgcggctgg actttgggct acatgctgaa cctgacaaac
1381 atgatccag ctgagcaacc atgtccaca cctctctccc actccacata tgtctctctc
1441 atggttctat tctccctggt ccttttcaca gtggccatca taggcttgct tatctttcac
1501 aagccttcac atttctggaa agatatgcta tag

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SEQ ID NO: 2 Human CD39 (isoform 1) amino acid sequence

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1 medtkesnvk tfsknllai lgfssliavi allavgitqn kalpenvkyy ivldagsaht
61 slyiykwpa kndtgvvhq veecrvkpg iskfvkvne igiyltdome rareviprsq
121 hgetpvyiga tagmrllzme seeladrvid vversisnyp fdfqgariit ggeegaygwi
181 tinyllgkfs qktrwfsivp yetangetfg aldlggastg vtfvpqngti espdnalqfr
241 lygkdyvvyt hsficygkdq alwqklakdi gvasneilrd pcfhpgykvk vnvedlyktp
301 ctkrfemtsp fggfelqgig nyqqchqsil elfntsyrcpy sqcafngifl pplqgdfgaf
361 safyfvmkfl nltsekvsge kvtemmkkfc agpweeikts yagvkekyls eycfsgtyil
421 siliqgyhft adswelihfi gkiqgsdagw tlgymnltn mipaeqplst plshstyvfl
481 mvlfsvlvft valigllifh kpsyfwkdmv

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SEQ ID NO: 3 Human CD39 (transcript variant 2) cDNA sequence

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1 atgaagggaa ccaaggacot gacaagccag cagaaggagt ctaacgtgaa gacattttgc
61 tccaagaata tcttagccat ccttggtctt tctctatca tagctgtgat agctttgctt
121 gctgtggggg tgaccacaga caaagcattg ccagaaaaacg ttaagtatgg gattgtgctg
181 gatgggggtt cttctcacac aagtttatac atctataagt ggcagcaga aaaggagaat
241 gacacaggcg tgggtgcatca agtagaagaa tgcagggtta aaggctcctg aatctcaaaa

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301 ttgtgttcaga aagtaaatga aataggcatt tacctgactg attgcatgga aagagctagg
361 gaagtgattc caaggtccca gcaccaagag acaccggtt accgtggagc cacggcaggc
421 atgctggctgc tcaggatgga aagtgaagag ttggcagaca ggggtctgga tgggtggag
481 aggagcctca gnaactaccc ctttgacttc cagggtgcca ggatcattac tggccaagag
541 gaaggtgctt atggctggat tactatcaac tatctgctgg gcaaatcag tcagaaaaaa
601 aggtgggtca gcatagtccc atatgaacc aataatcagg aaacctttgg agctttggac
661 cttgggggag cctctacaca agtcactttt gtaccccaaa accagactat cgagtcacca
721 gataatgctc tgcaatttct cctctatggc aaggactaca atgtctacac acatagcttc
781 ttgtgctatg ggaaggatca ggcactctgg cagaaactgg ccaaggacat tcaggttgca
841 agtaaatgaaa ttctcaggga cccatgcttt catctggat ataagaaggt agtgaacgta
901 agtgaccttt acaagacccc ctgcaccaag agatttgaga tgactcttcc attccagcag
961 tttgaaatcc aggggtattgg aaactatcaa caatgccac aaagcatctt ggagctcttc
1021 aacaccagtt actgccccta ctcccagtg gtcttcaatg ggattttctt gccaccctc
1081 caggggggatt tgggggcatt ttcagctttt tactttgtga tgaagttttt aaacttgaca
1141 tcagagaaaq tctctcagga aaaggtgact gagatgata aaaagttctg tgcctcagct
1201 tgggaggaga taaaaacatc ttacgctgga gtaaggaga agtacctgag tgaatactgc
1261 tttctctggtt cctacattct ctcccctctt ctgcaaggct atcatttcaa agctgattcc
1321 tgggagcaca tccatttcat tggcaagatc cagggcagcg acccggctg gactttgggc
1381 tacatgctga acctgaccaa catgatccca gctgagcaac caatgtccac acctctctcc
1441 cactccacct atgtcttctt caaggttcta ttctccctgg ccttttccac agtggccatc
1501 ataggcttgc ttatcttcca caagccttca ttttctgga aagatatggt atag

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SEQ ID NO: 4 Human CD39 (isoform 2) amino acid sequence

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1 mkgtkdltsq qkesnvktfc sknilailgf ssilaviall avgltnkal penvkygivi
61 dagsshtsly iykwpaken dtgvvhqvee crvhgpgisk fvqkvneigi yltcmerar
121 eviprsqhqe tpvylgatag mrlrmesee ladrvldvve rslsnypfdf ggariitgqe
181 egaygwitin yllgkfsqkt rwsivpyet nngetfgald lggastqytf vpgnqtiesp
241 dnaiqfrlyg kdynvythsf lcygkdqaiw qklakdiqva sneilrdpcf hpgykkvvnv
301 sdlyktptck rfemtppfqq feiqgignyq qchqsilelf ntsycopysqc afngiflppi
361 qgdfgafsaaf yfvmkfintl sekvsqekvt emmkkfcaqp weeiktsyag vhekylseyc
421 fsqtyilsli lqgyhftads wehihfigki qgsdagwtlg ymlnlrmip aeqplstpls
481 hstyvfilmvl fslylftvai igilifbkps yfwkdmv

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SEQ ID NO: 5 Human CD39 (transcript variant 3) cDNA sequence

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1 atggggaggg aagaactggt cthgacttcc agtttctcga ggggggttcc aagagctaac
61 gtgaagacat ttgtctccaa gaatatctta gccatccttg gcttctctcc tatcatagct
121 gtgatagctt tgcctgctgt ggggttgacc cagaacaaaag cattgccaga aaacgttaag
181 tatgggattg tgcctggatgc ggggttcttc cacacaagtt tatacatcra taaggggcca
241 gcagaaaaag agaattgacac aggcgtggtg catcaagtag aagaatgcag ggttaaaggt
301 cctggaatct caaaatttct tcagaaaagta aatgaaatag gcatttaact gactgattgc
361 atggaaaagag ctagggaagt gattccaaag tcccagcacc aagagacacc cgttaccctg
421 ggagccacgg caggcatgct gttgctcagg atggaaagtg aagagttggc agacagggtt
481 ctggatgttg tggagaggag cctcagcaac tacccttttg acttccaggg tgcaggatc
541 attactggcc aagaggaagg tgcttatggc tggattacta tcaactatct gctgggcaaa
601 ttcagtcaga aaacaagggt gtccagcata gtcccatatg aaaccaataa tcaggaaacc
661 tntggagctt tggaccttgg gggagcctct acacaagtca cttttgtacc ccaaaaccag
721 actatcgagt ccccagataa tgctctgcaa tttcgctctt atggcaagga ctacaatgtc
781 tacacacana gcttcttctg ctatgggaag gatcaggcac tctggcagaa actggccaag
841 gacattcagg ttgcaagtaa tgaattcttc agggacccat gctttcatcc tggatataag
901 aaggtagtga acgtaagtga cttttacaag accccctgca ccaagagatt tgagatgact
961 cttccatccc agcagtttga aatccagggt attggaaact atcaacaatg ccatcaagc
1021 atcctggagc tcttcaacac cagttactgc ccttactccc agtgtgctct caatgggatt
1081 ttcttggcac cactccaggg ggattttggg gcattttcag ctttttactt tggatgaag

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1141 ttttttaaact tgacatcaga gaaagtctct caggaaaagg tgactgagat gatgaaaaag
1201 ttctgtgctc agccttgga ggagatataa acatcttaag ctggagtaaa ggagaagtac
1261 ctgagtgaat acgcttttc tggtaacctac attctctccc tctctctgca aggcctatcat
1321 ttcacagctg attcctggga gcacatccat tccattggca agatccaggg cagcgacgcc
1381 ggctggactt tgggtacat gctgaacctg accaaccatga tcccagctga gcaaccatg
1441 tccacacctc tcccacctc cactatgtc ttctcatgg ttctatctc cctggctcct
1501 ttcacagctg ccatcatagg ctgcttctc ttcacaaag cttcatattt ctggaaagat
1561 atggtatag

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SEQ ID NO: 6 Human CD39 (isoform 3) amino acid sequence

```

1 mgreelfltf sfssgfqesn vktfcsknll aillgfssila viallavglc qnkaiipenvk
61 yglvidagss htilylykwp aekendtgvv hqvveecrvkg pgiskfvqkv neigiyitdc
121 merarevipr sqhgetpvyl gatagmrllr meseeladrv ldvverslsc ypdfqgari
181 itgqeegayg witinyllgk fsqktrwfsi vpyetnnqet fgaldlggas tqvtfvpgnq
241 tiespdnalq frlyghdynv ythsficygk dqalwqklak diqvasneil rdpofhpgyk
301 kvvnvsdlyk tpeckrfemt lpfqgfelig ignyqgchqs ilelfntsyg pysqcafnqi
361 flpplqgdfg afsafyfvmk flnitsekvk gekvtemmkk fcagpweeik tsyagvkeky
421 lseycfsqty ilslilqgyh ftadswelhi flgkiqgsda gwtlgymlni tnmipaeepl
481 stplshstyv flmvlfslvl ftvaeliglli fhkpsyfwkd mv

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SEQ ID NO: 7 Human CD39 (transcript variant 4) cDNA sequence

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1 atggaagata caaaggagtc taangtgaag acatttttgc ccaagaatat cctagccatc
61 cttggcttct cctctatcat agctgtgata gcttttgcctg ctgtgggggtt gaccacagac
121 aaagcattgc cagaaaacgt taagtatggg attgtgctgg atgcgggttc ttctcacaca
181 agtttatata tctataagtg gccagcagaa aaggagaaatg acacaggcgt ggtgcaccaa
241 gtagaagaat gcagggttaa aggtccttga atctcaaaat ttgttcagaa agtaaatgaa
301 ataggcattt acctgactga ttgcattgaa agagctaggg aagtgttcc aaggtcccag
361 caccaagaga caccggttta cctgggagcc acggcaggca tggggttgc caggatggaa
421 agtgaagagt tggcagacag ggttctggat gtggtggaga ggagcctcag caactacccc
481 tttgacttcc aggggtgccag gatcattact ggccaagagg aaggtgccta tggctggatt
541 actatcaact atctgctggg caaattcagt cagaaaacaa ggtggttcag catagtccca
601 tatgaaacca ataatacaga aaccttttga gcttttgacc ttgggggagc ctctacacaa
661 gtcacttttg taccocaaaa ccagactatc gagtccccag ataattgctc gcaatttcgc
721 ctctatggca aggaactaaa tgtctacaca catagcttct tgtgctatgg gaaggatcag
781 gcactctggc agaaactggc caaggacatt cagcagtttg aaatccaggg tattggaaac
841 tatcaacaat gccatcaaaq catcctggag ctcttcaaca ccagttatcg ccttactcc
901 cagtgtgctt tcaatgggat ttctttgcca ccactccagg gggatttttg ggcattttca
961 gctttttact ttgtgatgaa gtttttaaac ttgacatcag agaaagtccc tcaggaaaag
1021 gtgactgaga tgatgaaaaa gttctgtgct cagccttggg aggagataaa aacacottac
1081 gctggagtaa aggagaagta cctgagttaa tactgctttt ctggtaacca cattctctcc
1141 ctctctctgc aaggctatca tttcacagct gatcctggg agcacatcca tttcattggc
1201 aagatccagg gcagcgacgc cggctggact ttgggtatca tgotgaacct gaccaacatg
1261 atcccagctg agcaaccatt gtccacacct ctctcccact ccacctatgt cttctcatg
1321 gttctattct cctgggtcct tttcacagt gccatcatag gcttgcctat ctttcacaaq
1381 ccttcatatt tctggaaaga tatggtatag

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SEQ ID NO: 8 Human CD39 (isoform 4) amino acid sequence

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1 medtkesnvk tfcsknllai lgfssilavi allavgltn kalpenvkyy ividagssht
61 slylykwpae kendtgvvhq veecrvkgpg iskfvqkvne igiyltdcma rareviprsq
121 hgetpvylga tagmrllrme seeladrvld vverslcnyp fdfqgarlit gqeegaygwi
181 tinyllgkfs qktrwfsivp yetnnqetfg aldlggastq vtfvpgnqti espdnalqfr
241 lyghdynvyt hsficygkdg alwqklakdi qgfeligiso yqgchqsile lfntsygpps
301 qcafnqiflp plqgdfgafg afyfvmkfln lusekvsgqk vtemmkkfca qpweeiktsy

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361 agvkekyise ycfsgtyils lliqgyhfta dswehihfig klggsdagwt lgyminltm
 421 ipaeqplstp lshstyvflm vlfsvlftv aligllifhk psyfwkdmv

SEQ ID NO: 9 Human CD39 (transcript variant 5) cDNA sequence

1 atggaaagag ctagggaagt gattccaagg tcccagcacc aagagacacc cgtttacctg
 61 ggagccacgg caggeatgag gttgctcagg atggaaagtg aagagttggc agacagggtt
 121 ctggatgtgg tggagaggag cctcagcaac taccctttg acttcagggt tgcaggatc
 181 attactggcc aagaggaagg tgccatggc tggattacta tcaactatct gctgggcaaa
 241 ttcagtcaga aaacaagggt gtccagcata gtcccatatg aaaccaataa tcaggaaacc
 301 tttggagctt tggacotttg gggagcctct acacaagtca cttttgtacc ccaaaaccag
 361 actatcgagt cccagataa tgctctgcaa ttctgctct atggcaagga ctacaatgtc
 421 tacacacata gcttcttgtg ctatgggaag gatcaggcac tctggcagaa actggccaag
 481 gacattcagg ttgcaagtaa tgaaattctc agggacccat gctttcatcc tggatataag
 541 aaggtagtga acgtaagtga cttttacaag acccctgca ccaagagatt tgagatgact
 601 cttccattcc agcagtttga aatccagggt attggaaact atcaacaatg ccatcaaagc
 661 atcctggagc tcttcaacac cagttactgc cttactccc agtgtgcctt caatgggatt
 721 ttcttgccac cactccaggg ggattttggg gcattttcag ctttttactt tgtgatgaag
 781 tttttaaaact tgacatcaga gaaagtctct caggaaaagg tgactgagat gatgaaaaag
 841 tctctgtctc agccttggga ggagataaaa acatcttacg ctggagttaa ggagaagtac
 901 ctgagtgaat actgcttttc tggtaacct acctctctcc tcttctgca aggcctatcat
 961 ttcacagctg attcctggga gcacatccat ttcattggca agatccaggg cagcgagcc
 1021 ggctggactt tgggctacat gctgaacctg accaaccatg tcccagctga gcaaccattg
 1081 tccacaacct tctccactc cactatgtc ttctcatgg ttctattctc cctggctcct
 1141 ttcacagtgg ccatcatagg cttgcttctc tttcacaagc cttcatattt ctggaaagat
 1201 atggtatag

SEQ ID NO: 10 Human CD39 (isoform 5) amino acid sequence

1 merarevipr sqhgetpvyl gatagmrllr meseeladrv ldvversaln ypfdfggari
 61 itggeegayg witinyllgk fsqktrwfsi vpyetnnet fgaldlqgas tqvtfvpcnq
 121 tiespdnalq friygdynv ythsficygk dqalwqlak diqvasneil rdpofhpqyk
 181 kvvnvsdlyk tpctkrfemt lpfqgfeiqg ignyqgchqs ilelfntsyv pysqcafnqi
 241 flpplqgdfg afsafyvmk flnltsekvs gekvtemmkk fcagpweeik tsyagvkeky
 301 lseycfsgty ilslilqgyh ftadswehih figkiggsda gwtlgymlnl tnmipaeqpl
 361 stplshstyv flmvlfsvl ftvailglli fhkpsyfwkd mv

SEQ ID NO: 11 Human CD39 (transcript variant 6) cDNA sequence

1 atggaaagtg aagagttggc agacagggtt ctggatgtgg tggagaggag cctcagcaac
 61 taccctttg acttcagggt tgcaggatc attactggcc aagaggaagg tgccatggc
 121 tggattacta tcaactatct gctgggcaaa ttcagtcaga aaacaagggt gtccagcata
 181 gtcccatatg aaaccaataa tcaggaaacc tttggagctt tggacotttg gggagcctct
 241 acacaagtca cttttgtacc ccaaaaccag actatcgagt cccagataa tgctctgcaa
 301 ttctgctct atggcaagga ctacaatgtc tacacacata gcttcttgtg ctatgggaag
 361 gatcaggcac tctggcagaa actggccaag gacattcagg ttgcaagtaa tgaaattctc
 421 agggacccat gctttcatcc tggatataag aaggtagtga acgtaagtga cttttacaag
 481 acccctgca ccaagagatt tgagatgact cttccattcc agcagtttga aatccagggt
 541 attggaaact atcaacaatg ccatcaaagc atcctggagc tcttcaacac cagttactgc
 601 cttactccc agtgtgcctt caatgggatt ttcttgccac cactccaggg ggattttggg
 661 gcattttcag ctttttactt tgtgatgaag tttttaaaact tgacatcaga gaaagtctct
 721 caggaaaagg tgactgagat gatgaaaaag tctctgtctc agccttggga ggagataaaa
 781 acatcttacg ctggagttaa ggagaagtac ctgagtgaat actgcttttc tggtaacctc
 841 attctctccc tcttctgca aggcctatcat ttcacagctg attcctggga gcacatccat
 901 ttcattggca agatccaggg cagcgagcc ggctggactt tgggctacat gctgaacctg

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961 accaaccatga tcccagctga gcaaccattg tccacacctc tctcccactc caccatctgtc
 1021 tctctcatgg ttctattctc cctgggtcctt ttcacagtgg ccacatagg cctgcttctc
 1081 ttccacaagc ctccatattt ctggaagat atggtatag

SEQ ID NO: 12 Human CD39 (transcript variant 7) cDNA sequence

1 atggaagtg aagagttggc agacagggtt ctggatgttg tggagaggag cctcagcaac
 61 taacccctttg acttccaggg tgccaggatc attactggcc aagaggaagg tgcctatggc
 121 tggattacta tcaactatct gctgggcaaa ttcagtcaga aaacaagggtg gttcagcata
 181 gtcccatatg aaaccaataa tcaggaaacc ttggagcctt tggaccttgg gggagcctct
 241 acacaagtca cttttgtacc ccaaaaccag actatccagt cccagataa tgcctctgaa
 301 ttccgctctc atggcaagga ctacaatgtc tacacacata gcttcttgtg ctatgggaag
 361 gatcaggcac tctggcagaa actggccaag gacattcagg ttgcaagtaa tgaattcttc
 421 agggacccat gcttccatcc tggatataag aaggtagtga acgtaagtga ccttcacaag
 481 aacccctgca ccaagagatt tgagatgaat ctccatctcc agcagtttga aatccagggt
 541 attggaacct atcaacaatg ccaccaaagc atccctggagc ccttcaaacac cagttactgc
 601 ccttactccc agtgtgctct caatgggcat ttcttgccac cactccaggg ggattttggg
 661 gcaatttcag ctttttactt tggatgaag tttttaaact tgacatcaga gaaagctctc
 721 caggaaaagg tgactgagat gatgaaaaag ttctgtgctc agccttggga ggagataaaa
 781 acatcttaag ctggagttaa ggagaagtac ctgagtgaat actgcttttc tggtaacctac
 841 attctctccc tcttctgca aggtatcat ttcacagctg attcctggga gcacatccat
 901 ttcattggca agatccaggg cagcgacgac ggctggactt tgggctacat gctgaacctg
 961 accaaccatga tcccagctga gcaaccattg tccacacctc tctcccactc caccatctgtc
 1021 tctctcatgg ttctattctc cctgggtcctt ttcacagtgg ccacatagg cctgcttctc
 1081 ttccacaagc ctccatattt ctggaagat atggtatag

SEQ ID NO: 13 Human CD39 (isoform 6/7) amino acid sequence

1 meseeladv ldvverslsn ypfdfggari itgqeegayg witinyllgk fsqktrwfsi
 61 vpyetnqet fgaldlggas tqvtfvpqng tiespdnalq frlygkdydv ythsfleygk
 121 dqalwqlak diqvasneil rdpctfbpgyk kvrvnsdlyk tpctkrfemt lpfqqfeiqg
 181 lgnyygchqs ilelfntsyv pysgcdfngi flpplqgdfg afsafyfvmk flnitsekvs
 241 qekvtemmkk fcaqpweeik tsyagvkeky lseycfsgty ilslilqgyh ftadswehnh
 301 figkiqgsda gwtlgymlni tnmipaeqpl stplshstyy flmvlfsllv ftvaliglli
 361 fhkpsyfwkd mv

SEQ ID NO: 14 Mouse CD39 cDNA sequence

1 atggaagata taaaggattc taagggtgaag agatttttgt ccaaaaatat tctgatcacc
 61 cttggtttca cctctatctt ggctgtgata gcttttgattg ctgtgggact gaccacagac
 121 aaacctttgc cagaaaatgt taagtatggg attgtgttgg atgcgggggc atctcacacc
 181 aacctgtaca tctacaagtg gccggccgag aaggagaatg acacaggggt ggtgcagcag
 241 ttagaggaat gccaagtga aggtcctgga atctcaaaat atgctcagaa aacagatgaa
 301 atcgggtggt acctggccga atgcattgaa ctgtccaccc aactgatacc aacatccaag
 361 catcaccaga ctctgtgata cctgggagcc acagcaggca tgcgcttgc tgaatggaa
 421 agcgaacaat cggcagacga ggtcctggct gcagtgtcaa caagccttaa gagctacccc
 481 tttgaacttc aggggtgcaa gatcatcact ggacaagagg aaggtgcta tgggtggatt
 541 actattaact atctgctggg cagattcact caggaacaga gttggctaag cctcatctca
 601 gacagtcaga aacaggaaac ctttggcgct ttggatctcg ggggagcctc cacacagatc
 661 accttctgtc cccaaaacag cactatagag tcccagaaa actctctgca attcgtctc
 721 tatggcgagg actatactgt gtacacacac agcttctgt gctatgggaa ggatcaggct
 781 ctctggcaga aactggccaa ggacattcag gtttcaagtg gtggcgctct taaggaccca
 841 tgctttaacc caggatacga gaaggttgtg aatgtaagtg agctctatgg cactcctgc
 901 accaaaagat tccaaaagaa gctaccattt gatcagtttc gaatccaggg cactggagac
 961 tacgaacagt gccaccagag catccttgag ctcttcaaca acagccactg ccttactcc

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1021 cagtgtgect tcaatggcgt cttcctgcca cctctccatg ggagtttttg ggcgttttct
1081 gctttctact ttgtgatgga ttttttcaag aaggtagcga aaaacagtgt catctctcag
1141 gagaaaatga ccgagataac aaaaaatttt tgcacaaaat cttgggaaga gacaaagaca
1201 tcttatcctt cagtaaagga gaagtacctg agtgagtact gcttcgcggg cgcctacatc
1261 ctctctctcc tgcgaaggct taacttcaca gacagctcct gggaacagat tcattttatg
1321 ggcaagatca aagacagcaa cgcggggtgg actttgggct acatgctgaa cttgaccaac
1381 atgatccag ctgaacagcc gttgtcccg cctctccctc actccacctc catcgccctc
1441 atggtctctt tctccctgct cttggttgct gtggccatca caggcctgtt catctatagc
1501 aagcttccat atttctgga agaggcagta tag

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SEQ ID NO: 15 Mouse CD39 amino acid sequence

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1 medikdskvk rfcsknllli lgftsllavi aliavgltn kplpenvkyy ivldagssht
61 nlyiykwpae kendtgvvqg leecqvkgpg iskyaqktde igaylaecme lsteliptsk
121 hhqtpvylga tagmrllrma seqsadevla avstlsksyp fdfqgakiit ggeegaygwi
181 tinyllgrft qeqawlslls dsqkqetfga ldlggastqi tfvpgnstie apenslqfrl
241 ygedytyvth sflcygkdqa lwqklakdiq vssggvikdp cfnpgyekvv nvselygtpe
301 tkrfekklpf dqfrigtgd yeqchgsile lfnshcpys gcafnqvflp plhgsfgafs
361 afyfmdffk kvaknsvisq ekmtettknf cskweetkt sypsvkekyl seycfsgayi
421 lsliqgynft dsaweqihfm gkikdanagw tlgymnltn mipaeqplsp plphstyigl
481 mvlfslilva vaigtgifiys kpsyfwkeav

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SEQ ID NO: 16 Rat CD39 cDNA sequence

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1 atggaagata taaaggattc taaggtaag agattttgct ccaaaaatat tctgacatc
61 cttggtttct cctctgtctt ggctgtgata gctttgattg ctgtgggact gacccacaac
121 aaaccattgc cagaaaatgt taagtatggg attgtgctgg atgcggggtc gtctcacacc
181 aacctgtaca tctacaagtg gccggctgag aaggagaatg atacaggagt ggtgcagctg
241 ttagaagaat gccaaagtga aggtcccgga atctcaaat acgctcagaa aacagatgaa
301 atagctgcac atctggctga atgcctgaaa atgtccactg agcggatacc agcgtccaaa
361 cagcaccaga caccgtgtga cctgggagcc accgggggca tgcgcttgct cagaatggaa
421 agcaagcaat cggcagacga agtccctggc gcagtgtcta ggagcctgaa gagctacccc
481 tttgacttcc agggcgccaa gatcatcaat gggcaggagg aagggggcctc tgggtggatt
541 actattaact atctgcctgg cagattcaat caggacaga gttggctaaa cttcatctca
601 gacagccaga aacaggcaac ctttggcgct ttggatcttg gggcagttc tacacaagtc
661 accttcgtgc cctaaatca gactctagag gcccagaaa cctccctgca gttccgtctc
721 taaggcacgg actacaccgt gtacacacac agctccctgt gctatgggaa ggtacaggca
781 ctctggcaga aactggccca ggacattcag gtttcaagt ggggattct caaggacccg
841 tgcttttacc caggatataa gaaggttgty aatgtaagcg aactctatgg cactccctgc
901 accaagagat ttgagaagaa gctaccgttt aatcagtttc aagttcaggg cactggagat
961 taagaacagt gccaccagag catcctcaag ttcttcaaca acagccactg ccttactcc
1021 cagtgtgect tcaacgggtg ctttttacc cctctccagg ggagtttttg ggcattttct
1081 gctttctact ttgtgatgga ctttttcaag aagatggcga acgacagtgt ctctctcag
1141 gagaaaatga ctgagataac aaaaaatttt tgcacaaaat cttgggaaga ggtaaaggca
1201 tcttatccca cagtaaagga gaagtacctg agtgaatact gtttctcggg gaactacatc
1261 ctgtctctcc ttctgcaagg ctataacncc accgggaact cctgggacca gattcatttt
1321 atgggcaaga tcaagacag caacgcaggg tggacttttg gctacatgct gaacttgacc
1381 aacatgatcc cagctgaaca gccattatcc cgcctctcc ctcaacccac ctacatcagc
1441 ctcatggctc tctctctcc cgtcttggtc gccatggtca tcacagggct gttcatcttt
1501 agcaagcctt cgtatttctg gaaagaggca gtatag

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SEQ ID NO: 17 Rat CD39 amino acid sequence

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1 medikdskvk rfcsknllli lgfssvlavi aliavglthn kplpenvkyy ivldagssht
61 nlyiykwpae kendtgvvqi leecqvkgpg iskyaqktde iaaylaecmk msteripask

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121 qhqtppvylga tagmrllrme skqsadevia aversiksyp fdfqgakiit ggeegaygwi
181 tinyllgrft qeqswlnfis dsqkqatfga ldlggstqvf tfvplnqtie apetslqfri
241 ygtdyvvyth sfloygkdga lwqklaqdlq vssggilkdp cfypgykkvv nvselygtpc
301 tkrfekkklpf nqfqvqgtgd yeqchqsilk ffnshcpys qcaingvflp plqgsfgafs
361 afyfvmddf kmandsvssg ekmteltknf oskpweevka syptvkekyl seycfsqtyi
421 lslllqggynf tgsawdqihf mgkikdsnag wtlygmnlc nmipaeqpiz pplphstyis
481 lmvlfslvly amvitglfif skpsyfweka v

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SEQ ID NO: 18 Cow CD39 cDNA sequence

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1 atggaagata gaaggggaatc tgaactgaag gtattttgct ctaaaaacat actgagcata
61 cttgggtttct cctgcacatc cgtgtgtgata gcattgctcg ctctgggggt gacccagaac
121 aaagcactgc cagaaaatgt taagtttggg attgtgctgg atgcggggct ctctcatacg
181 agtttgtaca tctatagatg gccggcagag aaggagaatg acacgggggt ggtgaactcag
241 atagaagaat cgaacgttaa aggtcccgga atctcaggct ttgctaaaaa agtaaatgaa
301 atcaatgttt atctgaaggc atgcattgaa agagcccaga aagtgaattcc gtcaatccag
361 cacatggaaa cactgtgtga cctgggagcc acggccggca tggcggttgc cgggatggaa
421 aataaacaga tggcagacaa gatcctgggt gcagttgcaa gcagcatcag caggtacccc
481 tttgacttcc aaggtgccag aatcaccagt ggccaggagg aaggtgccta tggctggatt
541 actgtcaact atttgctggg caaatccact cagaaattga gttggtttaa cctgaagcca
601 agcaaagacg aactccagga aacctatgga gcttttagac ttggggggag ctctacacaa
661 atcacttttg tgcacacaaa tgaacggacc gagtctccaa acaacaacct gtacttccgc
721 ctctatggca agaactacag tgtatacaca cacagcttcc tgtgctatgg gaaggaccac
781 gcacttttgc agaaactggc cctgggaact cagggtacaa atggaatcat ccattgagcca
841 tgccttccact caagatacat gaggaataa aagatgagcg tcttaaacga aggtttctgt
901 accaagagac atgagttgaa ttcttcattt tatccactcg ttgacattga aatccgtggc
961 gctggaaact tccaacgatg tggcgaagc atcattcaac tcttaaacac cagttactgc
1021 ccttactcca gtgctcctt caatgggggt ttottggcgc cactccatgg gcagtttggg
1081 gcattttcag ctcttactta tgtgatggag ttcttaaac ttacacacga ggaatcagta
1141 tctgtggaac agttgactga gaagtgggaa gagttctgcg cacagcgttg ggaagagggt
1201 cagaagaatt ttggtgaagt gaaggagaaa taactgagtg aatactgctt ttctggcacc
1261 tacatcctgg ttctcctcct gaatggctac cattttacag ctgagtcctg gaaaaatatt
1321 cacttcatga acaaggctcg gagcaccgac gttgggtgga ctttgggcta catgctgaac
1381 ctgacacaca agattccagc tgaagagcca atgtccccc cctcccccac ctccacctat
1441 gtcttctcca tggctcctct ctcctcgatc ctgctcgcag tgatcatcgt aggcatagtt
1501 gtctttcaca agccttcgta tttctggaaa gacatggtat ag

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SEQ ID NO: 19 Cow CD39 amino acid sequence

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1 medrreselk vfcaknilsi lgfscilavi allalgitqn kalpenvkfg ivldagssht
61 slyiyxwpa kndtgvtq leasnkvpgp isgfakkyne invyltacme raqkvipsiq
121 hmetppvylga tagmrllrme nhqmadkila avassiseyp fdfqgariis ggeegaygwi
181 tvnyllqkft qklswfnlkp skddtgetyg aldlggastq itfvpgnnet espnnnlyfr
241 lygknysvyt hsfloygkdq allqklalgi qgtnglihep cfhsrymrki kmsvinegfc
301 tkrhelnsff yplvdieirg agnfqrcrqs ilqlfnteyc pyseccfngv flppihgqfg
361 afsafyyvme flnltseesv sveqltekile efcagrweev qknfgevkek ylseycfsqt
421 yilvillingy hftaeswkni hfmnkvrstd vqwtlgymln ltnkipaeep mspplphsty
481 vflmvlfslil lavilvgiv vfhkpsyfkw dmw

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SEQ ID NO: 20 Frog CD39 cDNA sequence

```

1 atggacgaac caaaggctgc aaaacagaag aagacatggc acaaaaaagt cataatcttc
61 ctaggagctc tgtttgcttt ggggtgttato tctttagtcg caattgcagt agtgacgaat
121 aaacctcttc caaagaatat taagtatggc attgtgctgg acgtggttcc gtcccatacc
181 agtgtgtata tatatgaatg gccggcagaa aaggaaaatg acaccggtgt tgtacagcag

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241 ataaaagaggt gcaaaagtga aggcacaggt atatccagtt atggccacga gccactgaag
301 gccgggtcttt ctctacagaa gtgtatgaat aaagcccgto aggtcattcc tgagaagcag
361 caaaggaggaga caccagttta tttaggggcc acagcaggaa tgggtutgct caggctaact
421 aatgcaacaa tgggtgagga agtcctgtct tcagtggaaa atacgtgctg ttcctttcog
481 tttgattttc aggggtgccag aataattaca ggacaagaag aaggcgctta tggatggacc
541 acaattcaatt atctgcttgg aaactttatc caggattcag gttgggtcaa atatatacca
601 aatttcacaa ccaactgaaac ttccgggtgca ctggatcttg gaggtgcttc aacacagatc
661 acctttgagt ccaaaagaga gattgaatcc caagaaaatt ccttgcaactt ccgcctttat
721 ggtaaaatcct atgatattca tacacacagc tttctctgct atggaaagga ccaagctctg
781 cgccttcaga tagctaatag tataaaggat gcaacagatt ccatcctttt ggatccttgc
841 ttttaactcag gatatagaag gaagcagac accaatgacc tctacagtag tccctgcata
901 tctaaactga ggatacacaac agcaccacag ccttagataa ttagaggcac tggcaattat
961 cagctatgca agagaaatgt ccaggcaatc ttcaacagaa cacattgtac ttactacat
1021 tgcctctttta atgggggtttt tcaaccaagt ttggatggca catittggggc attctcagca
1081 tattattttg tnatgaattt tttaaacctt accaatgagc aaagtctctt tgacaaagta
1141 aaagagacgg tagaaagaca ctgctccaga ccatgggagc aggtaaaaaa agactttcca
1201 aaaattaaag aaaaataact gagtgaatac tgtttttctg gaacatatac attaaactct
1261 ctggaatatg gatacggctt tagctctgaa aactgggaag abatcagatt tttaggcaag
1321 atcaaaagaca gtgatgcagg atggacactt gggttatatg tgaacctgac caatatgac
1381 cctgcagagc tgccttattc tctccgctg tcccaogctg gttacactgg acttatggtc
1441 ttcttctcca ttttgttagt ctgcattatt ttgaacttgc ggtgagttt ccggaaacca
1501 aaatgtctac acaagggcac catctag

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SEQ ID NO: 21 Frog CD39 amino acid sequence

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1 mdepkaakqk ktwhkkviif lgalfvlgi slvalavvqn kplpkniky ivldagsst
61 svyiyewpae kendtgvvgg ineckvegng issyghelpk aglslgkcmn karqvipekq
121 gretpvylga tagmrllrlt natmaeevls sventlrsfp fdfgganlit ggeegaygwi
181 tinyllgafi qdsgwfkyp nfkptetega ldlggastgi tfeskreies gensihfrly
241 gksydiyths floygkdgal riqiansikd atdsilldpc fnsgyrnas tndlyzspci
301 sklrptaps tldirgtgny qlckrvqai fnrthctysh csfngvfqps ldgtfgafsa
361 yyfvmnflnl tneqmsldkv ketverhcsr pwdevkkdfp kikekylsey cfsqtyilnl
421 leygygfsse nwndirflgk ikdsdagwtl gymlnitnmi paelpysppl shagytglmv
481 ffsalllvcih ltowlsfrkp kclhkgil

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SEQ ID NO: 22 Zebrafish CD39 cDNA sequence

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1 atggaagtaa aagtcacaaa cccatggcac aggcgggttg tcatctttct gatggctgtt
61 gttgccgtgg ggattgtcat catgggtatc atttctgttg tccagcaca gcttttacc
121 caaaagtaca agtatggaat agtcctggat gccgggtcct ctacacactc tgtgtttatc
181 tataaatggc cagcagagaa agagaacaa acaggcatgg tacagcagca tcacacgtgc
241 aatgttaaa gcaaaaggcat ctccagttac ttcgataaac cccatggggc tgggtgcatc
301 ctggaggagt gcatgaagga ggccaaggag aaaataacctg ctacacagaa cagcgaaccc
361 cctgtctacc tgggagccac ggctggcatg agactgctca agatggagga tgaaatggcc
421 tcagaaaaag tgcctacctc cgttgccatc tcaactgaag cgtacccctt ctcttatcag
481 ggagctcgta tcttttcagg ccaagaggag ggagcttttg ggtggattac agtcaactac
541 cttagtgaat acttgagaaa gcccgccaggc actcttggag ctctggacct tgggtggagcc
601 tctactcaaa taaccttcgt acctcagcag attattgaat catctgacaa ttcgattgac
661 ttcagactgt atggaaatga ttatcatcta tacaccaca gctttctctg ttatgggaag
721 gaccaagctc tcaagcttgc tatgggtgag aaattgctgt caacacctga caagacagat
781 gccatcttgt taagggtatc ttgttttcat cctggatata acaccacca gacguttgaa
841 agtgtcaata caccatgtat gaaaccactg aaaatgcca aggagcagtt ctcccatgtg
901 gggcttggaa atgggtctca gtgccaagaa tcaatcagaa aggtttttta tactagccat
961 tgtccttatt caggctgctc attcaatggg gttttccaac ctactgttga aggaaaaatt
1021 ggggtctttt ctgctttctt ttttgaatg gactttttta atctgaaaaa cgattcatg

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1081 gacaaaacaa agcagagggt ggcaatgtac tgcctacccc catgggaaaa gattgtacaa
1141 gatcaccocaa aagtaaaaga gaagtacott totgaatact gcttctcagc aacatacatt
1201 ctcactccccc tggaaacatgg atacaatttc aactcagaca actggaacga catcaagctt
1261 atcaagaaga ttggagacag tgatgcaggg tggacttttag gttacatget taacctgacc
1321 aacatgatcc cggtgaaga tccagacaag ccaactgatgc ctcattggagg atacgtcaca
1381 tttatgatcc tctctcacc tttgatactc gtctcctca ttatggccta catttatccc
1441 cgtcgcttta ctaaaacagc ccagaaagac attatttag

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SEQ ID NO: 23 Zebrafish CD39 amino acid sequence

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1 mevkknph rpvviflmav vaqgivismv isvvqbkplp qhykygivid agshtsvfi
61 ykwpakenn tgmvgqghhc nvkgkgissy fdkphgagas leecmkeake kipahrhset
121 pvyigatagm rllkmedema sekvttsvab slktypfsyq garillsqgee gafgwitvny
181 lsenlrkpag tlqaldigga stqitfvpgg iiaessdnid frlygndyhl ythsficygk
241 dgaiklmaae klrtspdktd aillrdpcfh pgynttktle svntpcmkpl kmpkeqfshv
301 glgnwsqgqe sirkvfntsh cpysgcasng vfgptvegkf gafsafffvm dflnikndsl
361 dktkqrlamy cstpwgkivq dhpvkxekyl seyofsatyi ltllchgyntf tsdnwndikf
421 ikkigdsdag wtlygmint nmipaedpdk plmphggyvt fmilfsllil vliimayiyf
481 rrfkttagkd ii

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* Included in Table 1 are RNA nucleic acid molecules (e.g., thymines replaced with uridines), nucleic acid molecules encoding orthologs of the encoded proteins, as well as DNA or RNA nucleic acid sequences comprising a nucleic acid sequence having at least 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, 99.5%, or more identity across their full length with the nucleic acid sequence of any SEQ ID NO listed in Table 1, or a portion thereof. Such nucleic acid molecules can have a function of the full-length nucleic acid as described further herein. Such nucleic acid molecules can also be allelic variants, splice variants, derivative variants, substitution variants, deletion variants, insertion variants, fusion polypeptides, orthologs, interspecies homologs, and the like that modulate (e.g., decrease CD39 activity) or encode a CD39 with modulated (e.g., reduced) activity relative to wild-type CD39.

* Included in Table 1 are orthologs of the proteins, as well as polypeptide molecules comprising an amino acid sequence having at least 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, 99.5%, or more identity across their full length with an amino acid sequence of any SEQ ID NO listed in Table 1, or a portion thereof. Such polypeptides can have a function of the full-length polypeptide as described further herein. Such polypeptides can also be allelic variants, derivative variants, substitution variants, deletion variants, insertion variants, fusion polypeptides, orthologs, interspecies homologs, and the like that modulate (e.g., decrease CD39 activity) activity relative to wild-type CD39.

* In addition, any CD39 modulator, direct CD39 binding protein, or CD39 downstream adenosine receptor pathway component such as CD73, described herein is also included in Table 1. The nucleic acid and polypeptide descriptions provided above in the asterisked sections of Table 1 also apply.

* Included in Table 1 are biomarker metabolites, including, without limitation, AMP and adenosine. Moreover, Table 1 includes additional markers of T cell terminal exhaustion, such as one or more immune checkpoint regulators, such as PD-1, or other biomarkers of exhausted T cells, particularly terminally exhausted T cells, are included. For example, combinations, such as CD39^{hi} and PD-1; CD39^{hi}, PD-1, and 2B4; CD39^{hi}, PD-1, 2B4 and LAG-3; CD39^{hi}Eomes^{hi}Tbet^{lo}; and the like, are contemplated. The CD39^{hi} CD8 T cells express multiple inhibitory receptors, high levels of Eomes and low levels of T-bet, identify the most terminally exhausted T cells (*i.e.*, irreversible exhaustion).

II. Subjects

In one embodiment, the subject for whom exhausted CD8⁺ T cells are identified or for whom diagnosis, prognosis, or treatment of a chronic immune disorder is made, is a mammal (*e.g.*, mouse, rat, primate, non-human mammal, domestic animal such as dog, cat, cow, horse), and is preferably a human. Chronic immune disorders are described herein and the methods of the present invention can be applied to any one or more of such disorders.

In another embodiment of the methods of the invention, the subject has not undergone treatment, such as chemotherapy, radiation therapy, targeted therapy, and/or anti-immune checkpoint inhibitor therapy. In still another embodiment, the subject has undergone treatment, such as chemotherapy, radiation therapy, targeted therapy, and/or anti-immune checkpoint inhibitor therapy.

In certain embodiments, the subject has had surgery to remove chronic immune disordered tissue, such as infected, cancerous, or precancerous tissue. In other embodiments, such tissue has not been removed, *e.g.*, the cancerous tissue may be located in an inoperable region of the body, such as in a tissue that is essential for life, or in a region where a surgical procedure would cause considerable risk of harm to the patient.

III. Sample Collection, Preparation and Separation

In some embodiments, biomarker amount and/or activity measurement(s) in a sample from a subject is compared to a predetermined control (standard) sample. The sample from the subject is typically from a diseased tissue, such as cancer cells or tissues. The control sample can be from the same subject or from a different subject. The control sample is typically a normal, non-diseased sample. However, in some embodiments, such as for staging of disease or for evaluating the efficacy of treatment, the control sample can be from a diseased tissue. The control sample can be a combination of samples from several different subjects. In some embodiments, the biomarker amount and/or activity measurement(s) from a subject is compared to a pre-determined level. This pre-determined level is typically obtained from normal samples. As described herein, a "pre-determined" biomarker amount and/or activity measurement(s) may be a biomarker amount and/or activity measurement(s) used to, by way of example only, evaluate a subject that may be selected for treatment, evaluate a response to a therapy (e.g., anti-CD39 therapy with or without anti-immune checkpoint inhibitor therapy), and/or evaluate a response to a combination of therapies. A pre-determined biomarker amount and/or activity measurement(s) may be determined in populations of patients with or without a chronic immune disorder. The pre-determined biomarker amount and/or activity measurement(s) can be a single number, equally applicable to every patient, or the pre-determined biomarker amount and/or activity measurement(s) can vary according to specific subpopulations of patients. Age, weight, height, and other factors of a subject may affect the pre-determined biomarker amount and/or activity measurement(s) of the individual. Furthermore, the pre-determined biomarker amount and/or activity can be determined for each subject individually. In one embodiment, the amounts determined and/or compared in a method described herein are based on absolute measurements. In another embodiment, the amounts determined and/or compared in a method described herein are based on relative measurements, such as ratios (e.g., expression and/or activity of biomarkers to that of wild type biomarkers and expression and/or activity of a biomarker of interest normalized to that of a housekeeping gene).

The pre-determined biomarker amount and/or activity measurement(s) can be any suitable standard. For example, the pre-determined biomarker amount and/or activity measurement(s) can be obtained from the same or a different human for whom a patient selection is being assessed. In one embodiment, the pre-determined biomarker amount

and/or activity measurement(s) can be obtained from a previous assessment of the same patient. In such a manner, the progress of the selection of the patient can be monitored over time. In addition, the control can be obtained from an assessment of another human or multiple humans, *e.g.*, selected groups of humans, if the subject is a human. In such a manner, the extent of the selection of the human for whom selection is being assessed can be compared to suitable other humans, *e.g.*, other humans who are in a similar situation to the human of interest, such as those suffering from similar or the same condition(s) and/or of the same ethnic group.

In some embodiments of the present invention the change of biomarker amount and/or activity measurement(s) from the pre-determined level is about 0.5 fold, about 1.0 fold, about 1.5 fold, about 2.0 fold, about 2.5 fold, about 3.0 fold, about 3.5 fold, about 4.0 fold, about 4.5 fold, or about 5.0 fold or greater. In some embodiments, the fold change is less than about 1, less than about 5, less than about 10, less than about 20, less than about 30, less than about 40, or less than about 50. In other embodiments, the fold change in biomarker amount and/or activity measurement(s) compared to a predetermined level is more than about 1, more than about 5, more than about 10, more than about 20, more than about 30, more than about 40, or more than about 50.

Biological samples can be collected from a variety of sources from a patient including a body fluid sample, cell sample, or a tissue sample comprising nucleic acids and/or proteins. "Body fluids" refer to fluids that are excreted or secreted from the body as well as fluids that are normally not (*e.g.*, bronchoalveolar lavage fluid, amniotic fluid, aqueous humor, bile, blood and blood plasma, cerebrospinal fluid, cerumen and earwax, cowper's fluid or pre-ejaculatory fluid, chyle, chyme, stool, female ejaculate, interstitial fluid, intracellular fluid, lymph, menses, breast milk, mucus, pleural fluid, pus, saliva, sebum, semen, serum, sweat, synovial fluid, tears, urine, vaginal lubrication, vitreous humor, vomit). In a preferred embodiment, the subject and/or control sample is selected from the group consisting of cells, cell lines, histological slides, paraffin embedded tissues, biopsies, whole blood, nipple aspirate, serum, plasma, buccal scrape, saliva, cerebrospinal fluid, urine, stool, and bone marrow. In one embodiment, the sample is serum, plasma, or urine.

The samples can be collected from individuals repeatedly over a longitudinal period of time (*e.g.*, once or more on the order of days, weeks, months, annually, biannually, etc.). Obtaining numerous samples from an individual over a period of time can be used to verify

results from earlier detections and/or to identify an alteration in biological pattern as a result of, for example, disease progression, drug treatment, *etc.* For example, subject samples can be taken and monitored every month, every two months, or combinations of one, two, or three month intervals according to the invention. In addition, the biomarker amount and/or activity measurements of the subject obtained over time can be conveniently compared with each other, as well as with those of normal controls during the monitoring period, thereby providing the subject's own values, as an internal, or personal, control for long-term monitoring.

Sample preparation and separation can involve any of the procedures, depending on the type of sample collected and/or analysis of biomarker measurement(s). Such procedures include, by way of example only, concentration, dilution, adjustment of pH, removal of high abundance polypeptides (*e.g.*, albumin, gamma globulin, and transferrin, *etc.*), addition of preservatives and calibrants, addition of protease inhibitors, addition of denaturants, desalting of samples, concentration of sample proteins, extraction and purification of lipids.

The sample preparation can also isolate molecules that are bound in non-covalent complexes to other protein (*e.g.*, carrier proteins). This process may isolate those molecules bound to a specific carrier protein (*e.g.*, albumin), or use a more general process, such as the release of bound molecules from all carrier proteins via protein denaturation, for example using an acid, followed by removal of the carrier proteins.

Removal of undesired proteins (*e.g.*, high abundance, uninformative, or undetectable proteins) from a sample can be achieved using high affinity reagents, high molecular weight filters, ultracentrifugation and/or electrodialysis. High affinity reagents include antibodies or other reagents (*e.g.*, aptamers) that selectively bind to high abundance proteins. Sample preparation could also include ion exchange chromatography, metal ion affinity chromatography, gel filtration, hydrophobic chromatography, chromatofocusing, adsorption chromatography, isoelectric focusing and related techniques. Molecular weight filters include membranes that separate molecules on the basis of size and molecular weight. Such filters may further employ reverse osmosis, nanofiltration, ultrafiltration and microfiltration.

Ultracentrifugation is a method for removing undesired polypeptides from a sample. Ultracentrifugation is the centrifugation of a sample at about 15,000-60,000 rpm while monitoring with an optical system the sedimentation (or lack thereof) of particles.

Electrodialysis is a procedure which uses an electromembrane or semipermeable membrane in a process in which ions are transported through semi-permeable membranes from one solution to another under the influence of a potential gradient. Since the membranes used in electrodialysis may have the ability to selectively transport ions having positive or negative charge, reject ions of the opposite charge, or to allow species to migrate through a semipermeable membrane based on size and charge, it renders electrodialysis useful for concentration, removal, or separation of electrolytes.

Separation and purification in the present invention may include any procedure known in the art, such as capillary electrophoresis (*e.g.*, in capillary or on-chip) or chromatography (*e.g.*, in capillary, column or on a chip). Electrophoresis is a method which can be used to separate ionic molecules under the influence of an electric field. Electrophoresis can be conducted in a gel, capillary, or in a microchannel on a chip. Examples of gels used for electrophoresis include starch, acrylamide, polyethylene oxides, agarose, or combinations thereof. A gel can be modified by its cross-linking, addition of detergents, or denaturants, immobilization of enzymes or antibodies (affinity electrophoresis) or substrates (zymography) and incorporation of a pH gradient. Examples of capillaries used for electrophoresis include capillaries that interface with an electrospray.

Capillary electrophoresis (CE) is preferred for separating complex hydrophilic molecules and highly charged solutes. CE technology can also be implemented on microfluidic chips. Depending on the types of capillary and buffers used, CE can be further segmented into separation techniques such as capillary zone electrophoresis (CZE), capillary isoelectric focusing (CIEF), capillary isotachophoresis (cITP) and capillary electrochromatography (CEC). An embodiment to couple CE techniques to electrospray ionization involves the use of volatile solutions, for example, aqueous mixtures containing a volatile acid and/or base and an organic such as an alcohol or acetonitrile.

Capillary isotachophoresis (cITP) is a technique in which the analytes move through the capillary at a constant speed but are nevertheless separated by their respective mobilities. Capillary zone electrophoresis (CZE), also known as free-solution CE (FSCE), is based on differences in the electrophoretic mobility of the species, determined by the charge on the molecule, and the frictional resistance the molecule encounters during migration which is often directly proportional to the size of the molecule. Capillary isoelectric focusing (CIEF) allows weakly-ionizable amphoteric molecules, to be separated by electrophoresis in a pH gradient. CEC is a hybrid technique between traditional high

performance liquid chromatography (HPLC) and CE.

Separation and purification techniques used in the present invention include any chromatography procedures known in the art. Chromatography can be based on the differential adsorption and elution of certain analytes or partitioning of analytes between mobile and stationary phases. Different examples of chromatography include, but not limited to, liquid chromatography (LC), gas chromatography (GC), high performance liquid chromatography (HPLC), etc.

IV. Biomarker Nucleic Acids and Polypeptides

One aspect of the invention pertains to the use of isolated nucleic acid molecules that correspond to biomarker nucleic acids that encode a biomarker polypeptide or a portion of such a polypeptide. As used herein, the term "nucleic acid molecule" is intended to include DNA molecules (e.g., cDNA or genomic DNA) and RNA molecules (e.g., mRNA) and analogs of the DNA or RNA generated using nucleotide analogs. The nucleic acid molecule can be single-stranded or double-stranded, but preferably is double-stranded DNA.

An "isolated" nucleic acid molecule is one which is separated from other nucleic acid molecules which are present in the natural source of the nucleic acid molecule. Preferably, an "isolated" nucleic acid molecule is free of sequences (preferably protein-encoding sequences) which naturally flank the nucleic acid (*i.e.*, sequences located at the 5' and 3' ends of the nucleic acid) in the genomic DNA of the organism from which the nucleic acid is derived. For example, in various embodiments, the isolated nucleic acid molecule can contain less than about 5 kB, 4 kB, 3 kB, 2 kB, 1 kB, 0.5 kB or 0.1 kB of nucleotide sequences which naturally flank the nucleic acid molecule in genomic DNA of the cell from which the nucleic acid is derived. Moreover, an "isolated" nucleic acid molecule, such as a cDNA molecule, can be substantially free of other cellular material or culture medium when produced by recombinant techniques, or substantially free of chemical precursors or other chemicals when chemically synthesized.

A biomarker nucleic acid molecule of the present invention can be isolated using standard molecular biology techniques and the sequence information in the database records described herein. Using all or a portion of such nucleic acid sequences, nucleic acid molecules of the invention can be isolated using standard hybridization and cloning

techniques (e.g., as described in Sambrook *et al.*, ed., *Molecular Cloning: A Laboratory Manual*, 2nd ed., Cold Spring Harbor Laboratory Press, Cold Spring Harbor, NY, 1989).

A nucleic acid molecule of the invention can be amplified using cDNA, mRNA, or genomic DNA as a template and appropriate oligonucleotide primers according to standard PCR amplification techniques. The nucleic acid molecules so amplified can be cloned into an appropriate vector and characterized by DNA sequence analysis. Furthermore, oligonucleotides corresponding to all or a portion of a nucleic acid molecule of the invention can be prepared by standard synthetic techniques, e.g., using an automated DNA synthesizer.

Moreover, a nucleic acid molecule of the invention can comprise only a portion of a nucleic acid sequence, wherein the full length nucleic acid sequence comprises a marker of the invention or which encodes a polypeptide corresponding to a marker of the invention. Such nucleic acid molecules can be used, for example, as a probe or primer. The probe/primer typically is used as one or more substantially purified oligonucleotides. The oligonucleotide typically comprises a region of nucleotide sequence that hybridizes under stringent conditions to at least about 7, preferably about 15, more preferably about 25, 50, 75, 100, 125, 150, 175, 200, 250, 300, 350, or 400 or more consecutive nucleotides of a biomarker nucleic acid sequence. Probes based on the sequence of a biomarker nucleic acid molecule can be used to detect transcripts or genomic sequences corresponding to one or more markers of the invention. The probe comprises a label group attached thereto, e.g., a radioisotope, a fluorescent compound, an enzyme, or an enzyme co-factor.

A biomarker nucleic acid molecules that differ, due to degeneracy of the genetic code, from the nucleotide sequence of nucleic acid molecules encoding a protein which corresponds to the biomarker, and thus encode the same protein, are also contemplated.

In addition, it will be appreciated by those skilled in the art that DNA sequence polymorphisms that lead to changes in the amino acid sequence can exist within a population (e.g., the human population). Such genetic polymorphisms can exist among individuals within a population due to natural allelic variation. An allele is one of a group of genes which occur alternatively at a given genetic locus. In addition, it will be appreciated that DNA polymorphisms that affect RNA expression levels can also exist that may affect the overall expression level of that gene (e.g., by affecting regulation or degradation).

The term “allele,” which is used interchangeably herein with “allelic variant,” refers to alternative forms of a gene or portions thereof. Alleles occupy the same locus or position on homologous chromosomes. When a subject has two identical alleles of a gene, the subject is said to be homozygous for the gene or allele. When a subject has two different alleles of a gene, the subject is said to be heterozygous for the gene or allele. For example, biomarker alleles can differ from each other in a single nucleotide, or several nucleotides, and can include substitutions, deletions, and insertions of nucleotides. An allele of a gene can also be a form of a gene containing one or more mutations.

The term “allelic variant of a polymorphic region of gene” or “allelic variant”, used interchangeably herein, refers to an alternative form of a gene having one of several possible nucleotide sequences found in that region of the gene in the population. As used herein, allelic variant is meant to encompass functional allelic variants, non-functional allelic variants, SNPs, mutations and polymorphisms.

The term “single nucleotide polymorphism” (SNP) refers to a polymorphic site occupied by a single nucleotide, which is the site of variation between allelic sequences. The site is usually preceded by and followed by highly conserved sequences of the allele (*e.g.*, sequences that vary in less than 1/100 or 1/1000 members of a population). A SNP usually arises due to substitution of one nucleotide for another at the polymorphic site. SNPs can also arise from a deletion of a nucleotide or an insertion of a nucleotide relative to a reference allele. Typically the polymorphic site is occupied by a base other than the reference base. For example, where the reference allele contains the base “T” (thymidine) at the polymorphic site, the altered allele can contain a “C” (cytidine), “G” (guanine), or “A” (adenine) at the polymorphic site. SNP’s may occur in protein-coding nucleic acid sequences, in which case they may give rise to a defective or otherwise variant protein, or genetic disease. Such a SNP may alter the coding sequence of the gene and therefore specify another amino acid (a “missense” SNP) or a SNP may introduce a stop codon (a “nonsense” SNP). When a SNP does not alter the amino acid sequence of a protein, the SNP is called “silent.” SNP’s may also occur in noncoding regions of the nucleotide sequence. This may result in defective protein expression, *e.g.*, as a result of alternative splicing, or it may have no effect on the function of the protein.

As used herein, the terms “gene” and “recombinant gene” refer to nucleic acid molecules comprising an open reading frame encoding a polypeptide corresponding to a marker of the invention. Such natural allelic variations can typically result in 1-5%

variance in the nucleotide sequence of a given gene. Alternative alleles can be identified by sequencing the gene of interest in a number of different individuals. This can be readily carried out by using hybridization probes to identify the same genetic locus in a variety of individuals. Any and all such nucleotide variations and resulting amino acid polymorphisms or variations that are the result of natural allelic variation and that do not alter the functional activity are intended to be within the scope of the invention.

In another embodiment, a biomarker nucleic acid molecule is at least 7, 15, 20, 25, 30, 40, 60, 80, 100, 150, 200, 250, 300, 350, 400, 450, 550, 650, 700, 800, 900, 1000, 1100, 1200, 1300, 1400, 1500, 1600, 1700, 1800, 1900, 2000, 2200, 2400, 2600, 2800, 3000, 3500, 4000, 4500, or more nucleotides in length and hybridizes under stringent conditions to a nucleic acid molecule corresponding to a marker of the invention or to a nucleic acid molecule encoding a protein corresponding to a marker of the invention. As used herein, the term "hybridizes under stringent conditions" is intended to describe conditions for hybridization and washing under which nucleotide sequences at least 60% (65%, 70%, 75%, 80%, preferably 85%) identical to each other typically remain hybridized to each other. Such stringent conditions are known to those skilled in the art and can be found in sections 6.3.1-6.3.6 of *Current Protocols in Molecular Biology*, John Wiley & Sons, N.Y. (1989). A preferred, non-limiting example of stringent hybridization conditions are hybridization in 6X sodium chloride/sodium citrate (SSC) at about 45°C, followed by one or more washes in 0.2X SSC, 0.1% SDS at 50-65°C.

In addition to naturally-occurring allelic variants of a nucleic acid molecule of the invention that can exist in the population, the skilled artisan will further appreciate that sequence changes can be introduced by mutation thereby leading to changes in the amino acid sequence of the encoded protein, without altering the biological activity of the protein encoded thereby. For example, one can make nucleotide substitutions leading to amino acid substitutions at "non-essential" amino acid residues. A "non-essential" amino acid residue is a residue that can be altered from the wild-type sequence without altering the biological activity, whereas an "essential" amino acid residue is required for biological activity. For example, amino acid residues that are not conserved or only semi-conserved among homologs of various species may be non-essential for activity and thus would be likely targets for alteration. Alternatively, amino acid residues that are conserved among the homologs of various species (*e.g.*, murine and human) may be essential for activity and thus would not be likely targets for alteration.

Accordingly, another aspect of the invention pertains to nucleic acid molecules encoding a polypeptide of the invention that contain changes in amino acid residues that are not essential for activity. Such polypeptides differ in amino acid sequence from the naturally-occurring proteins which correspond to the markers of the invention, yet retain biological activity. In one embodiment, a biomarker protein has an amino acid sequence that is at least about 40% identical, 50%, 60%, 70%, 75%, 80%, 83%, 85%, 87.5%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99% or identical to the amino acid sequence of a biomarker protein described herein.

An isolated nucleic acid molecule encoding a variant protein can be created by introducing one or more nucleotide substitutions, additions or deletions into the nucleotide sequence of nucleic acids of the invention, such that one or more amino acid residue substitutions, additions, or deletions are introduced into the encoded protein. Mutations can be introduced by standard techniques, such as site-directed mutagenesis and PCR-mediated mutagenesis. Preferably, conservative amino acid substitutions are made at one or more predicted non-essential amino acid residues. A "conservative amino acid substitution" is one in which the amino acid residue is replaced with an amino acid residue having a similar side chain. Families of amino acid residues having similar side chains have been defined in the art. These families include amino acids with basic side chains (e.g., lysine, arginine, histidine), acidic side chains (e.g., aspartic acid, glutamic acid), uncharged polar side chains (e.g., glycine, asparagine, glutamine, serine, threonine, tyrosine, cysteine), non-polar side chains (e.g., alanine, valine, leucine, isoleucine, proline, phenylalanine, methionine, tryptophan), beta-branched side chains (e.g., threonine, valine, isoleucine) and aromatic side chains (e.g., tyrosine, phenylalanine, tryptophan, histidine). Alternatively, mutations can be introduced randomly along all or part of the coding sequence, such as by saturation mutagenesis, and the resultant mutants can be screened for biological activity to identify mutants that retain activity. Following mutagenesis, the encoded protein can be expressed recombinantly and the activity of the protein can be determined.

The present invention also contemplates the use of nucleic acids for modulating the expression and/or activity of target biomolecules. Generally, such nucleic acids may be nucleic acids themselves or encode a polypeptide, a naturally-occurring binding partner of a target of interest, an antibody against a target of interest, a combination of antibodies against a target of interest and antibodies against other immune-related targets, an agonist or antagonist of a target of interest, a peptidomimetic of a target of interest, a

peptidomimetic of a target of interest, a small RNA directed against or a mimic of a target of interest, and the like. Such modulators are well known in the art and include, for example, an antisense nucleic acid molecule, RNAi molecule, shRNA, mature miRNA, pre-miRNA, pri-miRNA, miRNA*, anti-miRNA, or a miRNA binding site, or a variant thereof, or other small RNA molecule such as a Piwi RNA, triplex oligonucleotide, ribozyme, coding sequence for a target of interest. Such agents modulate the expression and/or activity of target biomolecules, which includes any decrease in expression or activity of the target biomolecule of at least about 30%, 35%, 40%, 45%, 50%, 55%, 60%, 65%, 70%, 75%, 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99% or more as compared to the expression or activity of the target biomolecule which has not been targeted by a modulating agent.

In one embodiment, nucleic acids are useful for overexpressing and/or enhancing the activity of a nucleic acid or protein of interest. For example, the nucleic acid may encode a protein or other molecule the expression of which is desired in the host cell. Such protein-encoding nucleic acid sequences are not particularly limited and are selected based on the desired exogenous perturbation desired. Thus, the nucleic acid includes any gene that the skilled practitioner desires to have integrated and/or expressed. For example, exogenous expression of proteins related to autoimmune, allergic, vaccination, immunotolerance, cancer immunotherapy, immune exhaustion, immunological memory, or immunological epitope responses may be used. The nucleic acid can encode a protein or be a nucleic acid that serves as a marker to identify cells of interest or transduced cells. The nucleic acid may encode a protein that modifies a physical characteristic of the transduced cell, such as a protein that modifies size, growth, or eventual tissue composition. In another example, the nucleic acid may encode a protein of commercial value that may be harvested. Generally, the nucleic acid is operatively linked to other sequences that are useful for obtaining the desired expression of the nucleic acid, such as transcriptional regulatory sequences like inducible promoters, as described further below.

In one embodiment, the nucleic acid is engineered to express the CRISPR-Cas system for precise editing of genomic nucleic acids (e.g., for creating null mutations). In such embodiments, the CRISPR guide RNA and/or the Cas enzyme may be expressed. For example, a vector containing only the guide RNA can be administered to an animal or cells transgenic for the Cas9 enzyme. Similar strategies may be used (e.g., designer zinc finger, transcription activator-like effectors (TALEs) or homing meganucleases). Such systems are

well known in the art (see, for example, U.S. Pat. No. 8,697,359; Sander and Joung (2014) *Nat. Biotech.* 32:347-355; Hale *et al.* (2009) *Cell* 139:945-956; Karginov and Hannon (2010) *Mol. Cell* 37:7; U.S. Pat. Publ. 2014/0087426 and 2012/0178169; Boch *et al.* (2011) *Nat. Biotech.* 29:135-136; Boch *et al.* (2009) *Science* 326:1509-1512; Moscou and Bogdanove (2009) *Science* 326:1501; Weber *et al.* (2011) *PLoS One* 6:e19722; Li *et al.* (2011) *Nucl. Acids Res.* 39:6315-6325; Zhang *et al.* (2011) *Nat. Biotech.* 29:149-153; Miller *et al.* (2011) *Nat. Biotech.* 29:143-148; Lin *et al.* (2014) *Nucl. Acids Res.* 42:e47).

In another embodiment, the nucleic acid is useful for inhibiting the expression and/or activity of a nucleic acid or protein of interest. For example, target biomolecule expression and/or activity, such as an RNA coding region, may be reduced or inhibited using inhibitory RNAs. An "RNA coding region" is a nucleic acid that may serve as a template for the synthesis of an RNA molecule, such as an siRNA. "RNA interference (RNAi)" is an evolutionally conserved process whereby the expression or introduction of RNA of a sequence that is identical or highly similar to a target biomarker nucleic acid results in the sequence specific degradation or specific post-transcriptional gene silencing (PTGS) of messenger RNA (mRNA) transcribed from that targeted gene (see, for example, Coburn and Cullen (2002) *J. Virol.* 76:9225), thereby inhibiting expression of the target biomarker nucleic acid. In one embodiment, the RNA coding region is a DNA sequence. The ability to down-regulate a target gene has many therapeutic and research applications, including identifying the biological functions of particular genes. Moreover, such inhibition may be achieved in screening assays that take advantage of pooling techniques, whereby groups of 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100, or more, or any number or range in between, of RNA inhibitory agents, either co-expressed from the same vector or more than one vector, are transduced into cells of interest. Suitable inhibitory RNAs include, but are not limited to siRNAs, shRNAs, miRNAs, Piwis, dicer-substrate 27-mer duplexes, single-stranded interfering RNA, and the like. In particular, the combination of RNA inhibitory technology and lentiviruses as a tool for a gene specific knock-down in animal models is well known in the art (see, for example, U.S. Pat. Publ. 2005/0251872; EP Pat. Publ. 2166107; PCT Publs. WO 2004/022722 and 2007/109131; Tiscornia *et al.* (2003) *Proc. Natl. Acad. Sci. U.S.A.* 100:1844-1848; Robinson *et al.* (2003) *Nat. Genet.* 33:401-406; and Dann *et al.* (2006) *Proc. Natl. Acad. Sci. U.S.A.* 103:11246-11251).

siRNAs typically refer to a double-stranded interfering RNA unless otherwise noted. In various embodiments, suitable siRNA molecules include double-stranded ribonucleic acid molecules comprising two nucleotide strands, each strand having about 19 to about 28 nucleotides (*i.e.* about 19, 20, 21, 22, 23, 24, 25, 26, 27, or 28 nucleotides). Thus, the phrase "interfering RNA having a length of 19 to 49 nucleotides" when referring to a double-stranded interfering RNA means that the antisense and sense strands independently have a length of about 19 to about 49 nucleotides, including interfering RNA molecules where the sense and antisense strands are connected by a linker molecule.

In addition to siRNA molecules, other interfering RNA molecules and RNA-like molecules may be used. Examples of other interfering RNA molecules that may inhibit target biomolecules include, but are not limited to, short hairpin RNAs (shRNAs), single-stranded siRNAs, microRNAs (miRNAs), piwiRNA, dicer-substrate 27-mer duplexes, and variants thereof containing one or more chemically modified nucleotides, one or more non-nucleotides, one or more deoxyribonucleotides, and/or one or more non-phosphodiester linkages. Typically, all RNA or RNA-like molecules that may interact with transcripts RISC complexes and participate in RISC-related changes in gene expression may be referred to as "interfering RNAs" or "interfering RNA molecules."

Suitable interfering RNAs may readily be produced based on the well-known nucleotide sequences of target biomolecules. In various embodiments interfering RNAs that inhibit target biomolecules may comprise partially purified RNA, substantially pure RNA, synthetic RNA, recombinantly produced RNA, as well as altered RNA that differs from naturally-occurring RNA by the addition, deletion, substitution, and/or alteration of one or more nucleotides. Such alterations may include, for example, addition of non-nucleotide material, such as to the end(s) of the interfering RNAs or to one or more internal nucleotides of the interfering RNAs, including modifications that make the interfering RNAs resistant to nuclease digestion. Such alterations result in sequences that are generally at least about 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, 99.5%, or more, or 100% identical to the sequence of the target biomolecule. When the gene to be down regulated is in a family of highly conserved genes, the sequence of the duplex region may be chosen with the aid of sequence comparison to target only the desired gene. On the other hand, if there is sufficient identity among a family of homologous genes within an organism, a duplex region may be designed that would down regulate a plurality of genes simultaneously.

In various embodiments one or both strands of the interfering RNAs may comprise a 3' overhang. As used herein, a "3' overhang" refers to at least one unpaired nucleotide extending from the 3'-end of an RNA strand. Thus in one embodiment, the interfering RNAs comprises at least one 3' overhang of from 1 to about 6 nucleotides (which includes ribonucleotides or deoxynucleotides) in length, from 1 to about 5 nucleotides in length, from 1 to about 4 nucleotides in length, or about 2 to about 4 nucleotides in length. In an illustrative embodiment in which both strands of the interfering RNAs molecule comprise a 3' overhang, wherein the length of the overhangs may be the same or different for each strand. In certain embodiments the 3' overhang is present on both strands of the interfering RNAs and is one, two, or three nucleotides in length. For example, each strand of the interfering RNAs may comprise 3' overhangs of dithymidylic acid ("TT") or diuridylic acid ("uu").

In order to enhance the stability of the interfering RNAs, the 3' overhangs may be also stabilized against degradation. In one embodiment, the overhangs are stabilized by including purine nucleotides, such as adenosine or guanosine nucleotides. In certain embodiments, substitution of pyrimidine nucleotides by modified analogues, *e.g.*, substitution of uridine nucleotides in the 3' overhangs with 2'-deoxythymidine, is tolerated and does not affect the efficiency of RNA interference degradation. In particular, it is believed the absence of a 2' hydroxyl in the 2'-deoxythymidine may significantly enhance the nuclease resistance of the 3' overhang.

Interfering RNAs may be expressed from a vector described herein either as two separate, complementary RNA molecules, or as a single RNA molecule with two complementary regions. Selection of vectors suitable for expressing interfering RNAs, methods for inserting nucleic acid sequences for expressing the interfering RNAs into the vector, and methods of delivering the recombinant plasmid to the cells of interest are well known in the art (Tuschl (2002) *Nat. Biotechnol.* 20: 446-448; Brummelkamp *et al.* (2002) *Science* 296:550-553; Miyagishi *et al.* (2002) *Nat. Biotechnol.* 20:497-500; Paddison *et al.* (2002) *Genes Dev.* 16:948-958; Lee *et al.* (2002) *Nat. Biotechnol.* 20:500-505; and Paul *et al.* (2002) *Nat. Biotechnol.* 20:505-508).

In certain embodiments, the interfering RNAs may be delivered as a small hairpin RNA or short hairpin RNA (shRNA) (see, for example, U.S. Pats. 8,697,359 and 8,642,569). shRNA is a sequence of RNA that makes a tight hairpin turn that may be used to silence gene expression via RNA interference. In typical embodiments, shRNA uses a

vector introduced into cells and utilizes the U6 promoter to ensure that the shRNA is always expressed. This vector is usually passed on to daughter cells, allowing the gene silencing to be inherited. The shRNA hairpin structure is cleaved by the cellular machinery into siRNA, which is then bound to the RNA-induced silencing complex (RISC). This complex binds to and cleaves mRNAs that match the siRNA that is bound to it.

In certain embodiments, the sense sequence of the shRNA will be from about 19 to about 30, more nucleotides (e.g. about 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, or 30 nucleotides) in length, more typically from about 19 to about 22 nucleotides in length, the antisense sequence will be from about 19 to about 30, more typically from 19 to about 22 nucleotides (e.g. about 19, 20, 21 or 22 nucleotides), in length, and the loop region will be from about 3 to about 19 nucleotides (e.g., about 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, and 19 nucleotides) in length. In some embodiments, the sense and antisense sequences are the same length, i.e. the shRNA will form a symmetrical hairpin, but this is not necessarily the case. In some cases, the sense or antisense strand may be shorter than its complementary strand, and an asymmetric hairpin is formed. Further, while in some instances the base pairing between the sense and antisense sequences is exact, this also need not be the case. Thus, some mismatch between the sequences may be tolerated, or even desired, e.g. to decrease the strength of the hydrogen bonding between the two strands. However, in one illustrative embodiment, the sense and antisense sequences are the same length, and the base pairing between the two is exact and does not contain any mismatches. The shRNA molecule may also comprise a 5'-terminal phosphate group that may be chemically modified. In addition, the loop portion of the shRNA molecule may comprise, for example, nucleotides, non- nucleotides, linker molecules, conjugate molecules, etc.

In certain embodiments, the PIWI RNA pathway is used to provide inhibition of target biomolecules. Piwi-interacting RNAs (piRNAs) were identified through association with Piwi proteins in mammalian testes (Aravin *et al.* (2006); Girard *et al.* (2006); Grivna *et al.* (2006); Lau *et al.* (2006). piRNAs and methods of making and using same to target and degrade nucleic acids are well known in the art (see, for example, U.S. Pat. Publ. 2011-0207625). These RNAs range from 26-30 nucleotides in length and are produced from discrete loci. Generally, genomic regions spanning 50-100 kB in length give rise to abundant piRNAs with profound strand asymmetry. Although the piRNAs themselves are not conserved, even between closely related species, the positions of piRNA loci in related genomes are conserved, with virtually all major piRNA-producing loci having syntenic

counterparts in mice, rats and humans (Girard *et al.* (2006)). The loci and consequently the piRNAs themselves are relatively depleted of repeat and transposon sequences, with only 17% of human piRNAs corresponding to known repetitive elements as compared to a nearly 50% repeat content for the genome as a whole. In certain embodiments, methods are provided for inhibiting such targets in a cell, comprising administering an effective amount of a siRNA/shRNA/piwiRNA to the cell, such that target mRNA is degraded.

In some embodiments, the present invention further contemplates the use of anti-biomarker antisense nucleic acid molecules, *i.e.*, molecules which are complementary to a sense nucleic acid of the invention, *e.g.*, complementary to the coding strand of a double-stranded cDNA molecule corresponding to a marker of the invention or complementary to an mRNA sequence corresponding to a marker of the invention. Accordingly, an antisense nucleic acid molecule of the invention can hydrogen bond to (*i.e.* anneal with) a sense nucleic acid of the invention. The antisense nucleic acid can be complementary to an entire coding strand, or to only a portion thereof, *e.g.*, all or part of the protein coding region (or open reading frame). An antisense nucleic acid molecule can also be antisense to all or part of a non-coding region of the coding strand of a nucleotide sequence encoding a polypeptide of the invention. The non-coding regions ("5' and 3' untranslated regions") are the 5' and 3' sequences which flank the coding region and are not translated into amino acids.

An antisense oligonucleotide can be, for example, about 5, 10, 15, 20, 25, 30, 35, 40, 45, or 50 or more nucleotides in length. An antisense nucleic acid can be constructed using chemical synthesis and enzymatic ligation reactions using procedures known in the art. For example, an antisense nucleic acid (*e.g.*, an antisense oligonucleotide) can be chemically synthesized using naturally occurring nucleotides or variously modified nucleotides designed to increase the biological stability of the molecules or to increase the physical stability of the duplex formed between the antisense and sense nucleic acids, *e.g.*, phosphorothioate derivatives and acridine substituted nucleotides can be used. Examples of modified nucleotides which can be used to generate the antisense nucleic acid include 5-fluorouracil, 5-bromouracil, 5-chlorouracil, 5-iodouracil, hypoxanthine, xanthine, 4-acetylcytosine, 5-(carboxyhydroxymethyl) uracil, 5-carboxymethylaminomethyl-2-thiouridine, 5-carboxymethylaminomethyluracil, dihydrouracil, beta-D-galactosylqueosine, inosine, N6-isopentenyladenine, 1-methylguanine, 1-methylinosine, 2,2-dimethylguanine, 2-methyladenine, 2-methylguanine, 3-methylcytosine, 5-methylcytosine, N6-adenine, 7-

methylguanine, 5-methylaminomethyluracil, 5-methoxyaminomethyl-2-thiouracil, beta-D-mannosylqueosine, 5'-methoxycarboxymethyluracil, 5-methoxyuracil, 2-methylthio-N6-isopentenyladenine, uracil-5-oxyacetic acid (v), wybutoxosine, pseudouracil, queosine, 2-thiocytosine, 5-methyl-2-thiouracil, 2-thiouracil, 4-thiouracil, 5-methyluracil, uracil-5-oxyacetic acid methylester, uracil-5-oxyacetic acid (v), 5-methyl-2-thiouracil, 3-(3-amino-3-N-2-carboxypropyl) uracil, (acp3)w, and 2,6-diaminopurine. Alternatively, the antisense nucleic acid can be produced biologically using an expression vector into which a nucleic acid has been sub-cloned in an antisense orientation (*i.e.*, RNA transcribed from the inserted nucleic acid will be of an antisense orientation to a target nucleic acid of interest, described further in the following subsection).

The antisense nucleic acid molecules of the invention are typically administered to a subject or generated *in situ* such that they hybridize with or bind to cellular mRNA and/or genomic DNA encoding a polypeptide corresponding to a selected marker of the invention to thereby inhibit expression of the marker, *e.g.*, by inhibiting transcription and/or translation. The hybridization can be by conventional nucleotide complementarity to form a stable duplex, or, for example, in the case of an antisense nucleic acid molecule which binds to DNA duplexes, through specific interactions in the major groove of the double helix. Examples of a route of administration of antisense nucleic acid molecules of the invention includes direct injection at a tissue site or infusion of the antisense nucleic acid into a blood- or bone marrow-associated body fluid. Alternatively, antisense nucleic acid molecules can be modified to target selected cells and then administered systemically. For example, for systemic administration, antisense molecules can be modified such that they specifically bind to receptors or antigens expressed on a selected cell surface, *e.g.*, by linking the antisense nucleic acid molecules to peptides or antibodies which bind to cell surface receptors or antigens. The antisense nucleic acid molecules can also be delivered to cells using the vectors described herein. To achieve sufficient intracellular concentrations of the antisense molecules, vector constructs in which the antisense nucleic acid molecule is placed under the control of a strong pol II or pol III promoter are preferred.

An antisense nucleic acid molecule of the invention can be an α -anomeric nucleic acid molecule. An α -anomeric nucleic acid molecule forms specific double-stranded hybrids with complementary RNA in which, contrary to the usual α -units, the strands run parallel to each other (Gaultier *et al.*, 1987, *Nucleic Acids Res.* 15:6625-6641). The antisense nucleic acid molecule can also comprise a 2'-o-methylribonucleotide (Inoue *et al.*,

1987, *Nucleic Acids Res.* 15:6131-6148) or a chimeric RNA-DNA analogue (Inoue *et al.*, 1987, *FEBS Lett.* 215:327-330).

The present invention also encompasses ribozymes. Ribozymes are catalytic RNA molecules with ribonuclease activity which are capable of cleaving a single-stranded nucleic acid, such as an mRNA, to which they have a complementary region. Thus, ribozymes (*e.g.*, hammerhead ribozymes as described in Haselhoff and Gerlach, 1988, *Nature* 334:585-591) can be used to catalytically cleave mRNA transcripts to thereby inhibit translation of the protein encoded by the mRNA. A ribozyme having specificity for a nucleic acid molecule encoding a polypeptide corresponding to a marker of the invention can be designed based upon the nucleotide sequence of a cDNA corresponding to the marker. For example, a derivative of a *Tetrahymena* L-19 IVS RNA can be constructed in which the nucleotide sequence of the active site is complementary to the nucleotide sequence to be cleaved (see Cech *et al.* U.S. Patent No. 4,987,071; and Cech *et al.* U.S. Patent No. 5,116,742). Alternatively, an mRNA encoding a polypeptide of the invention can be used to select a catalytic RNA having a specific ribonuclease activity from a pool of RNA molecules (see, *e.g.*, Bartel and Szostak, 1993, *Science* 261:1411-1418).

The present invention also encompasses nucleic acid molecules which form triple helical structures. For example, expression of a biomarker protein can be inhibited by targeting nucleotide sequences complementary to the regulatory region of the gene encoding the polypeptide (*e.g.*, the promoter and/or enhancer) to form triple helical structures that prevent transcription of the gene in target cells. See generally Helene (1991) *Anticancer Drug Des.* 6(6):569-84; Helene (1992) *Ann. N.Y. Acad. Sci.* 660:27-36; and Maher (1992) *Bioassays* 14(12):807-15.

In various embodiments, the nucleic acid molecules of the present invention can be modified at the base moiety, sugar moiety or phosphate backbone to improve, *e.g.*, the stability, hybridization, or solubility of the molecule. For example, the deoxyribose phosphate backbone of the nucleic acid molecules can be modified to generate peptide nucleic acid molecules (see Hyrup *et al.*, 1996, *Bioorganic & Medicinal Chemistry* 4(1): 5-23). As used herein, the terms "peptide nucleic acids" or "PNAs" refer to nucleic acid mimics, *e.g.*, DNA mimics, in which the deoxyribose phosphate backbone is replaced by a pseudopeptide backbone and only the four natural nucleobases are retained. The neutral backbone of PNAs has been shown to allow for specific hybridization to DNA and RNA under conditions of low ionic strength. The synthesis of PNA oligomers can be performed

using standard solid phase peptide synthesis protocols as described in Hyrup *et al.* (1996), *supra*; Perry-O'Keefe *et al.* (1996) *Proc. Natl. Acad. Sci. USA* 93:14670-675.

PNAs can be used in therapeutic and diagnostic applications. For example, PNAs can be used as antisense or antigen agents for sequence-specific modulation of gene expression by, *e.g.*, inducing transcription or translation arrest or inhibiting replication. PNAs can also be used, *e.g.*, in the analysis of single base pair mutations in a gene by, *e.g.*, PNA directed PCR clamping; as artificial restriction enzymes when used in combination with other enzymes, *e.g.*, S1 nucleases (Hyrup (1996), *supra*; or as probes or primers for DNA sequence and hybridization (Hyrup, 1996, *supra*; Perry-O'Keefe *et al.*, 1996, *Proc. Natl. Acad. Sci. USA* 93:14670-675).

In another embodiment, PNAs can be modified, *e.g.*, to enhance their stability or cellular uptake, by attaching lipophilic or other helper groups to PNA, by the formation of PNA-DNA chimeras, or by the use of liposomes or other techniques of drug delivery known in the art. For example, PNA-DNA chimeras can be generated which can combine the advantageous properties of PNA and DNA. Such chimeras allow DNA recognition enzymes, *e.g.*, RNASE H and DNA polymerases, to interact with the DNA portion while the PNA portion would provide high binding affinity and specificity. PNA-DNA chimeras can be linked using linkers of appropriate lengths selected in terms of base stacking, number of bonds between the nucleobases, and orientation (Hyrup, 1996, *supra*). The synthesis of PNA-DNA chimeras can be performed as described in Hyrup (1996), *supra*, and Finn *et al.* (1996) *Nucleic Acids Res.* 24(17):3357-63. For example, a DNA chain can be synthesized on a solid support using standard phosphoramidite coupling chemistry and modified nucleoside analogs. Compounds such as 5'-(4-methoxytrityl)amino-5'-deoxy-thymidine phosphoramidite can be used as a link between the PNA and the 5' end of DNA (Mag *et al.*, 1989, *Nucleic Acids Res.* 17:5973-88). PNA monomers are then coupled in a step-wise manner to produce a chimeric molecule with a 5' PNA segment and a 3' DNA segment (Finn *et al.*, 1996, *Nucleic Acids Res.* 24(17):3357-63). Alternatively, chimeric molecules can be synthesized with a 5' DNA segment and a 3' PNA segment (Peterser *et al.*, 1975, *Bioorganic Med. Chem. Lett.* 5:1119-1124).

In other embodiments, the oligonucleotide can include other appended groups such as peptides (*e.g.*, for targeting host cell receptors *in vivo*), or agents facilitating transport across the cell membrane (see, *e.g.*, Letsinger *et al.*, 1989, *Proc. Natl. Acad. Sci. USA* 86:6553-6556; Lemaitre *et al.*, 1987, *Proc. Natl. Acad. Sci. USA* 84:648-652; PCT

Publication No. WO 88/09810) or the blood-brain barrier (see, *e.g.*, PCT Publication No. WO 89/10134). In addition, oligonucleotides can be modified with hybridization-triggered cleavage agents (see, *e.g.*, Krol *et al.*, 1988, *Bio/Techniques* 6:958-976) or intercalating agents (see, *e.g.*, Zon, 1988, *Pharm. Res.* 5:539-549). To this end, the oligonucleotide can be conjugated to another molecule, *e.g.*, a peptide, hybridization triggered cross-linking agent, transport agent, hybridization-triggered cleavage agent, *etc.*

Another aspect of the invention pertains to the use of biomarker proteins and biologically active portions thereof. In one embodiment, the native polypeptide corresponding to a marker can be isolated from cells or tissue sources by an appropriate purification scheme using standard protein purification techniques. In another embodiment, polypeptides corresponding to a marker of the invention are produced by recombinant DNA techniques. Alternative to recombinant expression, a polypeptide corresponding to a marker of the invention can be synthesized chemically using standard peptide synthesis techniques.

An "isolated" or "purified" protein or biologically active portion thereof is substantially free of cellular material or other contaminating proteins from the cell or tissue source from which the protein is derived, or substantially free of chemical precursors or other chemicals when chemically synthesized. The language "substantially free of cellular material" includes preparations of protein in which the protein is separated from cellular components of the cells from which it is isolated or recombinantly produced. Thus, protein that is substantially free of cellular material includes preparations of protein having less than about 30%, 20%, 10%, or 5% (by dry weight) of heterologous protein (also referred to herein as a "contaminating protein"). When the protein or biologically active portion thereof is recombinantly produced, it is also preferably substantially free of culture medium, *i.e.*, culture medium represents less than about 20%, 10%, or 5% of the volume of the protein preparation. When the protein is produced by chemical synthesis, it is preferably substantially free of chemical precursors or other chemicals, *i.e.*, it is separated from chemical precursors or other chemicals which are involved in the synthesis of the protein. Accordingly such preparations of the protein have less than about 30%, 20%, 10%, 5% (by dry weight) of chemical precursors or compounds other than the polypeptide of interest.

Biologically active portions of a biomarker polypeptide include polypeptides comprising amino acid sequences sufficiently identical to or derived from a biomarker

protein amino acid sequence described herein, but which includes fewer amino acids than the full length protein, and exhibit at least one activity of the corresponding full-length protein. Typically, biologically active portions comprise a domain or motif with at least one activity of the corresponding protein. A biologically active portion of a protein of the invention can be a polypeptide which is, for example, 10, 25, 50, 100 or more amino acids in length. Moreover, other biologically active portions, in which other regions of the protein are deleted, can be prepared by recombinant techniques and evaluated for one or more of the functional activities of the native form of a polypeptide of the invention.

Preferred polypeptides have an amino acid sequence of a biomarker protein encoded by a nucleic acid molecule described herein. Other useful proteins are substantially identical (*e.g.*, at least about 40%, preferably 50%, 60%, 70%, 75%, 80%, 83%, 85%, 88%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99%) to one of these sequences and retain the functional activity of the protein of the corresponding naturally-occurring protein yet differ in amino acid sequence due to natural allelic variation or mutagenesis.

To determine the percent identity of two amino acid sequences or of two nucleic acids, the sequences are aligned for optimal comparison purposes (*e.g.*, gaps can be introduced in the sequence of a first amino acid or nucleic acid sequence for optimal alignment with a second amino or nucleic acid sequence). The amino acid residues or nucleotides at corresponding amino acid positions or nucleotide positions are then compared. When a position in the first sequence is occupied by the same amino acid residue or nucleotide as the corresponding position in the second sequence, then the molecules are identical at that position. The percent identity between the two sequences is a function of the number of identical positions shared by the sequences (*i.e.*, % identity = # of identical positions/total # of positions (*e.g.*, overlapping positions) x100). In one embodiment the two sequences are the same length.

The determination of percent identity between two sequences can be accomplished using a mathematical algorithm. A preferred, non-limiting example of a mathematical algorithm utilized for the comparison of two sequences is the algorithm of Karlin and Altschul (1990) *Proc. Natl. Acad. Sci. USA* 87:2264-2268, modified as in Karlin and Altschul (1993) *Proc. Natl. Acad. Sci. USA* 90:5873-5877. Such an algorithm is incorporated into the NBLAST and XBLAST programs of Altschul, *et al.* (1990) *J. Mol. Biol.* 215:403-410. BLAST nucleotide searches can be performed with the NBLAST program, score = 100, wordlength = 12 to obtain nucleotide sequences homologous to a

nucleic acid molecules of the invention. BLAST protein searches can be performed with the XBLAST program, score = 50, wordlength = 3 to obtain amino acid sequences homologous to a protein molecules of the invention. To obtain gapped alignments for comparison purposes, Gapped BLAST can be utilized as described in Altschul *et al.* (1997) *Nucleic Acids Res.* 25:3389-3402. Alternatively, PSI-Blast can be used to perform an iterated search which detects distant relationships between molecules. When utilizing BLAST, Gapped BLAST, and PSI-Blast programs, the default parameters of the respective programs (*e.g.*, XBLAST and NBLAST) can be used. See <http://www.ncbi.nlm.nih.gov>. Another preferred, non-limiting example of a mathematical algorithm utilized for the comparison of sequences is the algorithm of Myers and Miller, (1988) *Comput Appl Biosci*, 4:11-7. Such an algorithm is incorporated into the ALIGN program (version 2.0) which is part of the GCG sequence alignment software package. When utilizing the ALIGN program for comparing amino acid sequences, a PAM120 weight residue table, a gap length penalty of 12, and a gap penalty of 4 can be used. Yet another useful algorithm for identifying regions of local sequence similarity and alignment is the FASTA algorithm as described in Pearson and Lipman (1988) *Proc. Natl. Acad. Sci. USA* 85:2444-2448. When using the FASTA algorithm for comparing nucleotide or amino acid sequences, a PAM120 weight residue table can, for example, be used with a *k*-tuple value of 2.

The percent identity between two sequences can be determined using techniques similar to those described above, with or without allowing gaps. In calculating percent identity, only exact matches are counted.

The invention also provides chimeric or fusion proteins corresponding to a biomarker protein. As used herein, a "chimeric protein" or "fusion protein" comprises all or part (preferably a biologically active part) of a polypeptide corresponding to a marker of the invention operably linked to a heterologous polypeptide (*i.e.*, a polypeptide other than the polypeptide corresponding to the marker). Within the fusion protein, the term "operably linked" is intended to indicate that the polypeptide of the invention and the heterologous polypeptide are fused in-frame to each other. The heterologous polypeptide can be fused to the amino-terminus or the carboxyl-terminus of the polypeptide of the invention.

One useful fusion protein is a GST fusion protein in which a polypeptide corresponding to a marker of the invention is fused to the carboxyl terminus of GST

sequences. Such fusion proteins can facilitate the purification of a recombinant polypeptide of the invention.

In another embodiment, the fusion protein contains a heterologous signal sequence, immunoglobulin fusion protein, toxin, or other useful protein sequence. Chimeric and fusion proteins of the invention can be produced by standard recombinant DNA techniques. In another embodiment, the fusion gene can be synthesized by conventional techniques including automated DNA synthesizers. Alternatively, PCR amplification of gene fragments can be carried out using anchor primers which give rise to complementary overhangs between two consecutive gene fragments which can subsequently be annealed and re-amplified to generate a chimeric gene sequence (see, *e.g.*, Ausubel *et al.*, *supra*). Moreover, many expression vectors are commercially available that already encode a fusion moiety (*e.g.*, a GST polypeptide). A nucleic acid encoding a polypeptide of the invention can be cloned into such an expression vector such that the fusion moiety is linked in-frame to the polypeptide of the invention.

A signal sequence can be used to facilitate secretion and isolation of the secreted protein or other proteins of interest. Signal sequences are typically characterized by a core of hydrophobic amino acids which are generally cleaved from the mature protein during secretion in one or more cleavage events. Such signal peptides contain processing sites that allow cleavage of the signal sequence from the mature proteins as they pass through the secretory pathway. Thus, the invention pertains to the described polypeptides having a signal sequence, as well as to polypeptides from which the signal sequence has been proteolytically cleaved (*i.e.*, the cleavage products). In one embodiment, a nucleic acid sequence encoding a signal sequence can be operably linked in an expression vector to a protein of interest, such as a protein which is ordinarily not secreted or is otherwise difficult to isolate. The signal sequence directs secretion of the protein, such as from a eukaryotic host into which the expression vector is transformed, and the signal sequence is subsequently or concurrently cleaved. The protein can then be readily purified from the extracellular medium by art recognized methods. Alternatively, the signal sequence can be linked to the protein of interest using a sequence which facilitates purification, such as with a GST domain.

The present invention also pertains to variants of the biomarker polypeptides described herein. Such variants have an altered amino acid sequence which can function as either agonists (mimetics) or as antagonists. Variants can be generated by mutagenesis,

e.g., discrete point mutation or truncation. An agonist can retain substantially the same, or a subset, of the biological activities of the naturally occurring form of the protein. An antagonist of a protein can inhibit one or more of the activities of the naturally occurring form of the protein by, for example, competitively binding to a downstream or upstream member of a cellular signaling cascade which includes the protein of interest. Thus, specific biological effects can be elicited by treatment with a variant of limited function. Treatment of a subject with a variant having a subset of the biological activities of the naturally occurring form of the protein can have fewer side effects in a subject relative to treatment with the naturally occurring form of the protein.

Variants of a biomarker protein which function as either agonists (mimetics) or as antagonists can be identified by screening combinatorial libraries of mutants, *e.g.*, truncation mutants, of the protein of the invention for agonist or antagonist activity. In one embodiment, a variegated library of variants is generated by combinatorial mutagenesis at the nucleic acid level and is encoded by a variegated gene library. A variegated library of variants can be produced by, for example, enzymatically ligating a mixture of synthetic oligonucleotides into gene sequences such that a degenerate set of potential protein sequences is expressible as individual polypeptides, or alternatively, as a set of larger fusion proteins (*e.g.*, for phage display). There are a variety of methods which can be used to produce libraries of potential variants of the polypeptides of the invention from a degenerate oligonucleotide sequence. Methods for synthesizing degenerate oligonucleotides are known in the art (see, *e.g.*, Narang, 1983, *Tetrahedron* 39:3; Itakura *et al.*, 1984, *Annu. Rev. Biochem.* 53:323; Itakura *et al.*, 1984, *Science* 198:1056; Ike *et al.*, 1983 *Nucleic Acid Res.* 11:477).

In addition, libraries of fragments of the coding sequence of a polypeptide corresponding to a marker of the invention can be used to generate a variegated population of polypeptides for screening and subsequent selection of variants. For example, a library of coding sequence fragments can be generated by treating a double stranded PCR fragment of the coding sequence of interest with a nuclease under conditions wherein nicking occurs only about once per molecule, denaturing the double stranded DNA, renaturing the DNA to form double stranded DNA which can include sense/antisense pairs from different nicked products, removing single stranded portions from reformed duplexes by treatment with S1 nuclease, and ligating the resulting fragment library into an expression vector. By this

method, an expression library can be derived which encodes amino terminal and internal fragments of various sizes of the protein of interest.

Several techniques are known in the art for screening gene products of combinatorial libraries made by point mutations or truncation, and for screening cDNA libraries for gene products having a selected property. The most widely used techniques, which are amenable to high throughput analysis, for screening large gene libraries typically include cloning the gene library into replicable expression vectors, transforming appropriate cells with the resulting library of vectors, and expressing the combinatorial genes under conditions in which detection of a desired activity facilitates isolation of the vector encoding the gene whose product was detected. Recursive ensemble mutagenesis (REM), a technique which enhances the frequency of functional mutants in the libraries, can be used in combination with the screening assays to identify variants of a protein of the invention (Arkin and Yourvan, 1992, *Proc. Natl. Acad. Sci. USA* 89:7811-7815; Delgrave *et al.*, 1993, *Protein Engineering* 6(3):327- 331).

The production and use of biomarker nucleic acid and/or biomarker polypeptide molecules described herein can be facilitated by using standard recombinant techniques. In some embodiments, such techniques use vectors, preferably expression vectors, containing a nucleic acid encoding a biomarker polypeptide or a portion of such a polypeptide. As used herein, the term "vector" refers to a nucleic acid molecule capable of transporting another nucleic acid to which it has been linked. One type of vector is a "plasmid", which refers to a circular double stranded DNA loop into which additional DNA segments can be ligated. Another type of vector is a viral vector, wherein additional DNA segments can be ligated into the viral genome. Certain vectors are capable of autonomous replication in a host cell into which they are introduced (*e.g.*, bacterial vectors having a bacterial origin of replication and episomal mammalian vectors). Other vectors (*e.g.*, non-episomal mammalian vectors) are integrated into the genome of a host cell upon introduction into the host cell, and thereby are replicated along with the host genome. Moreover, certain vectors, namely expression vectors, are capable of directing the expression of genes to which they are operably linked. In general, expression vectors of utility in recombinant DNA techniques are often in the form of plasmids (vectors). However, the present invention is intended to include such other forms of expression vectors, such as viral vectors (*e.g.*, replication defective retroviruses, adenoviruses and adeno-associated viruses), which serve equivalent functions.

The recombinant expression vectors of the invention comprise a nucleic acid of the invention in a form suitable for expression of the nucleic acid in a host cell. This means that the recombinant expression vectors include one or more regulatory sequences, selected on the basis of the host cells to be used for expression, which is operably linked to the nucleic acid sequence to be expressed. Within a recombinant expression vector, "operably linked" is intended to mean that the nucleotide sequence of interest is linked to the regulatory sequence(s) in a manner which allows for expression of the nucleotide sequence (e.g., in an *in vitro* transcription/translation system or in a host cell when the vector is introduced into the host cell). The term "regulatory sequence" is intended to include promoters, enhancers and other expression control elements (e.g., polyadenylation signals). Such regulatory sequences are described, for example, in Goeddel, *Methods in Enzymology: Gene Expression Technology* vol.185, Academic Press, San Diego, CA (1991). Regulatory sequences include those which direct constitutive expression of a nucleotide sequence in many types of host cell and those which direct expression of the nucleotide sequence only in certain host cells (e.g., tissue-specific regulatory sequences). It will be appreciated by those skilled in the art that the design of the expression vector can depend on such factors as the choice of the host cell to be transformed, the level of expression of protein desired, and the like. The expression vectors of the invention can be introduced into host cells to thereby produce proteins or peptides, including fusion proteins or peptides, encoded by nucleic acids as described herein.

The recombinant expression vectors for use in the invention can be designed for expression of a polypeptide corresponding to a marker of the invention in prokaryotic (e.g., *E. coli*) or eukaryotic cells (e.g., insect cells {using baculovirus expression vectors}, yeast cells or mammalian cells). Suitable host cells are discussed further in Goeddel, *supra*. Alternatively, the recombinant expression vector can be transcribed and translated *in vitro*, for example using T7 promoter regulatory sequences and T7 polymerase.

Expression of proteins in prokaryotes is most often carried out in *E. coli* with vectors containing constitutive or inducible promoters directing the expression of either fusion or non-fusion proteins. Fusion vectors add a number of amino acids to a protein encoded therein, usually to the amino terminus of the recombinant protein. Such fusion vectors typically serve three purposes: 1) to increase expression of recombinant protein; 2) to increase the solubility of the recombinant protein; and 3) to aid in the purification of the recombinant protein by acting as a ligand in affinity purification. Often, in fusion

expression vectors, a proteolytic cleavage site is introduced at the junction of the fusion moiety and the recombinant protein to enable separation of the recombinant protein from the fusion moiety subsequent to purification of the fusion protein. Such enzymes, and their cognate recognition sequences, include Factor Xa, thrombin and enterokinase. Typical fusion expression vectors include pGEX (Pharmacia Biotech Inc; Smith and Johnson, 1988, *Gene* 67:31-40), pMAL (New England Biolabs, Beverly, MA) and pRIT5 (Pharmacia, Piscataway, NJ) which fuse glutathione S-transferase (GST), maltose E binding protein, or protein A, respectively, to the target recombinant protein.

Examples of suitable inducible non-fusion *E. coli* expression vectors include pTrec (Amann *et al.*, 1988, *Gene* 69:301-315) and pET 11d (Studier *et al.*, p. 60-89, In *Gene Expression Technology: Methods in Enzymology* vol.185, Academic Press, San Diego, CA, 1991). Target biomarker nucleic acid expression from the pTrec vector relies on host RNA polymerase transcription from a hybrid trp-lac fusion promoter. Target biomarker nucleic acid expression from the pET 11d vector relies on transcription from a T7 gn10-lac fusion promoter mediated by a co-expressed viral RNA polymerase (T7 gn1). This viral polymerase is supplied by host strains BL21 (DE3) or HMS174(DE3) from a resident prophage harboring a T7 gn1 gene under the transcriptional control of the lacUV 5 promoter.

One strategy to maximize recombinant protein expression in *E. coli* is to express the protein in a host bacterium with an impaired capacity to proteolytically cleave the recombinant protein (Gottesman, p. 119-128, In *Gene Expression Technology: Methods in Enzymology* vol. 185, Academic Press, San Diego, CA, 1990. Another strategy is to alter the nucleic acid sequence of the nucleic acid to be inserted into an expression vector so that the individual codons for each amino acid are those preferentially utilized in *E. coli* (Wada *et al.*, 1992, *Nucleic Acids Res.* 20:2111-2118). Such alteration of nucleic acid sequences of the invention can be carried out by standard DNA synthesis techniques.

In another embodiment, the expression vector is a yeast expression vector. Examples of vectors for expression in yeast *S. cerevisiae* include pYepSec1 (Baldari *et al.*, 1987, *EMBO J.* 6:229-234), pMFa (Kurjan and Herskowitz, 1982, *Cell* 30:933-943), pJRY88 (Schultz *et al.*, 1987, *Gene* 54:113-123), pYES2 (Invitrogen Corporation, San Diego, CA), and pPicZ (Invitrogen Corp, San Diego, CA).

Alternatively, the expression vector is a baculovirus expression vector. Baculovirus vectors available for expression of proteins in cultured insect cells (*e.g.*, Sf9 cells) include

the pAc series (Smith *et al.*, 1983, *Mol. Cell Biol.* 3:2156-2165) and the pVL series (Lucklow and Summers, 1989, *Virology* 170:31-39).

In yet another embodiment, a nucleic acid of the invention is expressed in mammalian cells using a mammalian expression vector. Examples of mammalian expression vectors include pCDM8 (Seed, 1987, *Nature* 329:840) and pMT2PC (Kaufman *et al.*, 1987, *EMBO J.* 6:187-195). When used in mammalian cells, the expression vector's control functions are often provided by viral regulatory elements. For example, commonly used promoters are derived from polyoma, adenovirus 2, cytomegalovirus and Simian Virus 40. For other suitable expression systems for both prokaryotic and eukaryotic cells see chapters 16 and 17 of Sambrook *et al.*, *supra*.

In another embodiment, the recombinant mammalian expression vector is capable of directing expression of the nucleic acid preferentially in a particular cell type (*e.g.*, tissue-specific regulatory elements are used to express the nucleic acid). Tissue-specific regulatory elements are known in the art. Non-limiting examples of suitable tissue-specific promoters include the albumin promoter (liver-specific; Pinkert *et al.*, 1987, *Genes Dev.* 1:268-277), lymphoid-specific promoters (Calame and Eaton, 1988, *Adv. Immunol.* 43:235-275), in particular promoters of T cell receptors (Winoto and Baltimore, 1989, *EMBO J.* 8:729-733) and immunoglobulins (Banerji *et al.*, 1983, *Cell* 33:729-740; Queen and Baltimore, 1983, *Cell* 33:741-748), neuron-specific promoters (*e.g.*, the neurofilament promoter; Byrne and Ruddle, 1989, *Proc. Natl. Acad. Sci. USA* 86:5473-5477), pancreas-specific promoters (Edlund *et al.*, 1985, *Science* 230:912-916), and mammary gland-specific promoters (*e.g.*, milk whey promoter; U.S. Patent No. 4,873,316 and European Application Publication No. 264,166). Developmentally-regulated promoters are also encompassed, for example the murine hox promoters (Kessel and Gruss, 1990, *Science* 249:374-379) and the α -fetoprotein promoter (Camper and Tilghman, 1989, *Genes Dev.* 3:537-546).

The invention further provides a recombinant expression vector comprising a DNA molecule cloned into the expression vector in an antisense orientation. That is, the DNA molecule is operably linked to a regulatory sequence in a manner which allows for expression (by transcription of the DNA molecule) of an RNA molecule which is antisense to the mRNA encoding a polypeptide of the invention. Regulatory sequences operably linked to a nucleic acid cloned in the antisense orientation can be chosen which direct the continuous expression of the antisense RNA molecule in a variety of cell types, for instance

viral promoters and/or enhancers, or regulatory sequences can be chosen which direct constitutive, tissue-specific or cell type specific expression of antisense RNA. The antisense expression vector can be in the form of a recombinant plasmid, phagemid, or attenuated virus in which antisense nucleic acids are produced under the control of a high efficiency regulatory region, the activity of which can be determined by the cell type into which the vector is introduced. For a discussion of the regulation of gene expression using antisense genes (see Weintraub *et al.*, 1986, *Trends in Genetics*, Vol. 1(1)).

Another aspect of the invention pertains to host cells into which a recombinant expression vector of the invention has been introduced. The terms "host cell" and "recombinant host cell" are used interchangeably herein. It is understood that such terms refer not only to the particular subject cell but to the progeny or potential progeny of such a cell. Because certain modifications may occur in succeeding generations due to either mutation or environmental influences, such progeny may not, in fact, be identical to the parent cell, but are still included within the scope of the term as used herein.

A host cell can be any prokaryotic (e.g., *E. coli*) or eukaryotic cell (e.g., insect cells, yeast or mammalian cells).

Vector DNA can be introduced into prokaryotic or eukaryotic cells via conventional transformation or transfection techniques. As used herein, the terms "transformation" and "transfection" are intended to refer to a variety of art-recognized techniques for introducing foreign nucleic acid into a host cell, including calcium phosphate or calcium chloride co-precipitation, DEAE-dextran-mediated transfection, lipofection, or electroporation. Suitable methods for transforming or transfecting host cells can be found in Sambrook, *et al.* (*supra*), and other laboratory manuals.

For stable transfection of mammalian cells, it is known that, depending upon the expression vector and transfection technique used, only a small fraction of cells may integrate the foreign DNA into their genome. In order to identify and select these integrants, a gene that encodes a selectable marker (e.g., for resistance to antibiotics) is generally introduced into the host cells along with the gene of interest. Preferred selectable markers include those which confer resistance to drugs, such as G418, hygromycin and methotrexate. Cells stably transfected with the introduced nucleic acid can be identified by drug selection (e.g., cells that have incorporated the selectable marker gene will survive, while the other cells die).

V. Analyzing Biomarker Nucleic Acids and Polypeptides

Biomarker nucleic acids and/or biomarker polypeptides can be analyzed according to the methods described herein and techniques known to the skilled artisan to identify such genetic or expression alterations useful for the present invention including, but not limited to, 1) an alteration in the level of a biomarker transcript or polypeptide, 2) a deletion or addition of one or more nucleotides from a biomarker gene, 4) a substitution of one or more nucleotides of a biomarker gene, 5) aberrant modification of a biomarker gene, such as an expression regulatory region, and the like. In addition, analysis of biomarker activity can be performed according to a determination of metabolites resulting from biomarker enzymatic function.

a. Methods for Detection of Copy Number

Methods of evaluating the copy number of a biomarker nucleic acid are well known to those of skill in the art. The presence or absence of chromosomal gain or loss can be evaluated simply by a determination of copy number of the regions or markers identified herein.

In one embodiment, a biological sample is tested for the presence of copy number changes in genomic loci containing the genomic marker. A copy number of at least 3, 4, 5, 6, 7, 8, 9, or 10 is predictive of poorer outcome of anti-immune checkpoint inhibitor treatment.

Methods of evaluating the copy number of a biomarker locus include, but are not limited to, hybridization-based assays. Hybridization-based assays include, but are not limited to, traditional "direct probe" methods, such as Southern blots, *in situ* hybridization (*e.g.*, FISH and FISH plus SKY) methods, and "comparative probe" methods, such as comparative genomic hybridization (CGH), *e.g.*, cDNA-based or oligonucleotide-based CGH. The methods can be used in a wide variety of formats including, but not limited to, substrate (*e.g.*, membrane or glass) bound methods or array-based approaches.

In one embodiment, evaluating the biomarker gene copy number in a sample involves a Southern Blot. In a Southern Blot, the genomic DNA (typically fragmented and separated on an electrophoretic gel) is hybridized to a probe specific for the target region. Comparison of the intensity of the hybridization signal from the probe for the target region with control probe signal from analysis of normal genomic DNA (*e.g.*, a non-amplified portion of the same or related cell, tissue, organ, *etc.*) provides an estimate of the relative copy number of the target nucleic acid. Alternatively, a Northern blot may be utilized for

evaluating the copy number of encoding nucleic acid in a sample. In a Northern blot, mRNA is hybridized to a probe specific for the target region. Comparison of the intensity of the hybridization signal from the probe for the target region with control probe signal from analysis of normal RNA (e.g., a non-amplified portion of the same or related cell, tissue, organ, etc.) provides an estimate of the relative copy number of the target nucleic acid. Alternatively, other methods well known in the art to detect RNA can be used, such that higher or lower expression relative to an appropriate control (e.g., a non-amplified portion of the same or related cell tissue, organ, etc.) provides an estimate of the relative copy number of the target nucleic acid.

An alternative means for determining genomic copy number is *in situ* hybridization (e.g., Angerer (1987) *Meth. Enzymol* 152: 649). Generally, *in situ* hybridization comprises the following steps: (1) fixation of tissue or biological structure to be analyzed; (2) prehybridization treatment of the biological structure to increase accessibility of target DNA, and to reduce nonspecific binding; (3) hybridization of the mixture of nucleic acids to the nucleic acid in the biological structure or tissue; (4) post-hybridization washes to remove nucleic acid fragments not bound in the hybridization and (5) detection of the hybridized nucleic acid fragments. The reagent used in each of these steps and the conditions for use vary depending on the particular application. In a typical *in situ* hybridization assay, cells are fixed to a solid support, typically a glass slide. If a nucleic acid is to be probed, the cells are typically denatured with heat or alkali. The cells are then contacted with a hybridization solution at a moderate temperature to permit annealing of labeled probes specific to the nucleic acid sequence encoding the protein. The targets (e.g., cells) are then typically washed at a predetermined stringency or at an increasing stringency until an appropriate signal to noise ratio is obtained. The probes are typically labeled, e.g., with radioisotopes or fluorescent reporters. In one embodiment, probes are sufficiently long so as to specifically hybridize with the target nucleic acid(s) under stringent conditions. Probes generally range in length from about 200 bases to about 1000 bases. In some applications it is necessary to block the hybridization capacity of repetitive sequences. Thus, in some embodiments, tRNA, human genomic DNA, or Cot-I DNA is used to block non-specific hybridization.

An alternative means for determining genomic copy number is comparative genomic hybridization. In general, genomic DNA is isolated from normal reference cells, as well as from test cells (e.g., tumor cells) and amplified, if necessary. The two nucleic

acids are differentially labeled and then hybridized *in situ* to metaphase chromosomes of a reference cell. The repetitive sequences in both the reference and test DNAs are either removed or their hybridization capacity is reduced by some means, for example by prehybridization with appropriate blocking nucleic acids and/or including such blocking nucleic acid sequences for said repetitive sequences during said hybridization. The bound, labeled DNA sequences are then rendered in a visualizable form, if necessary.

Chromosomal regions in the test cells which are at increased or decreased copy number can be identified by detecting regions where the ratio of signal from the two DNAs is altered. For example, those regions that have decreased in copy number in the test cells will show relatively lower signal from the test DNA than the reference compared to other regions of the genome. Regions that have been increased in copy number in the test cells will show relatively higher signal from the test DNA. Where there are chromosomal deletions or multiplications, differences in the ratio of the signals from the two labels will be detected and the ratio will provide a measure of the copy number. In another embodiment of CGH, array CGH (aCGH), the immobilized chromosome element is replaced with a collection of solid support bound target nucleic acids on an array, allowing for a large or complete percentage of the genome to be represented in the collection of solid support bound targets. Target nucleic acids may comprise cDNAs, genomic DNAs, oligonucleotides (*e.g.*, to detect single nucleotide polymorphisms) and the like. Array-based CGH may also be performed with single-color labeling (as opposed to labeling the control and the possible tumor sample with two different dyes and mixing them prior to hybridization, which will yield a ratio due to competitive hybridization of probes on the arrays). In single color CGH, the control is labeled and hybridized to one array and absolute signals are read, and the possible tumor sample is labeled and hybridized to a second array (with identical content) and absolute signals are read. Copy number difference is calculated based on absolute signals from the two arrays. Methods of preparing immobilized chromosomes or arrays and performing comparative genomic hybridization are well known in the art (see, *e.g.*, U.S. Pat. Nos: 6,335,167; 6,197,501; 5,830,645; and 5,665,549 and Albertson (1984) *EMBO J.* 3: 1227-1234; Pinkel (1988) *Proc. Natl. Acad. Sci. USA* 85: 9138-9142; EPO Pub. No. 430,402; *Methods in Molecular Biology*, Vol. 33: *In situ* Hybridization Protocols, Choo, ed., Humana Press, Totowa, N.J. (1994), *etc.*) In another embodiment, the hybridization protocol of Pinkel, *et al.* (1998) *Nature Genetics* 20: 207-211, or of Kallioniemi (1992) *Proc. Natl Acad Sci USA* 89:5321-5325 (1992) is used.

In still another embodiment, amplification-based assays can be used to measure copy number. In such amplification-based assays, the nucleic acid sequences act as a template in an amplification reaction (e.g., Polymerase Chain Reaction (PCR)). In a quantitative amplification, the amount of amplification product will be proportional to the amount of template in the original sample. Comparison to appropriate controls, e.g. healthy tissue, provides a measure of the copy number.

Methods of "quantitative" amplification are well known to those of skill in the art. For example, quantitative PCR involves simultaneously co-amplifying a known quantity of a control sequence using the same primers. This provides an internal standard that may be used to calibrate the PCR reaction. Detailed protocols for quantitative PCR are provided in Innis, *et al.* (1990) *PCR Protocols, A Guide to Methods and Applications*, Academic Press, Inc. N.Y.). Measurement of DNA copy number at microsatellite loci using quantitative PCR analysis is described in Ginzinger, *et al.* (2000) *Cancer Research* 60:5405-5409. The known nucleic acid sequence for the genes is sufficient to enable one of skill in the art to routinely select primers to amplify any portion of the gene. Fluorogenic quantitative PCR may also be used in the methods of the invention. In fluorogenic quantitative PCR, quantitation is based on amount of fluorescence signals, e.g., TaqMan and SYBR green.

Other suitable amplification methods include, but are not limited to, ligase chain reaction (LCR) (see Wu and Wallace (1989) *Genomics* 4: 560, Landegren, *et al.* (1988) *Science* 241:1077, and Barringer *et al.* (1990) *Gene* 89: 117), transcription amplification (Kwoh, *et al.* (1989) *Proc. Natl. Acad. Sci. USA* 86: 1173), self-sustained sequence replication (Guatelli, *et al.* (1990) *Proc. Nat. Acad. Sci. USA* 87: 1874), dot PCR, and linker adapter PCR, *etc.*

Loss of heterozygosity (LOH) and major copy proportion (MCP) mapping (Wang, Z.C., *et al.* (2004) *Cancer Res* 64(1):64-71; Seymour, A. B., *et al.* (1994) *Cancer Res* 54, 2761-4; Hahn, S. A., *et al.* (1995) *Cancer Res* 55, 4670-5; Kimura, M., *et al.* (1996) *Genes Chromosomes Cancer* 17, 88-93; Li *et al.*, (2008) *MBC Bioinform.* 9, 204-219) may also be used to identify regions of amplification or deletion.

b. Methods for Detection of Biomarker Nucleic Acid Expression

Biomarker expression may be assessed by any of a wide variety of well known methods for detecting expression of a transcribed molecule or protein. Non-limiting examples of such methods include immunological methods for detection of secreted, cell-surface, cytoplasmic, or nuclear proteins, protein purification methods, protein function or

activity assays, nucleic acid hybridization methods, nucleic acid reverse transcription methods, and nucleic acid amplification methods.

In preferred embodiments, activity of a particular gene is characterized by a measure of gene transcript (*e.g.* mRNA), by a measure of the quantity of translated protein, or by a measure of gene product activity. Marker expression can be monitored in a variety of ways, including by detecting mRNA levels, protein levels, or protein activity, any of which can be measured using standard techniques. Detection can involve quantification of the level of gene expression (*e.g.*, genomic DNA, cDNA, mRNA, protein, or enzyme activity), or, alternatively, can be a qualitative assessment of the level of gene expression, in particular in comparison with a control level. The type of level being detected will be clear from the context.

In another embodiment, detecting or determining expression levels of a biomarker and functionally similar homologs thereof, including a fragment or genetic alteration thereof (*e.g.*, in regulatory or promoter regions thereof) comprises detecting or determining RNA levels for the marker of interest. In one embodiment, one or more cells from the subject to be tested are obtained and RNA is isolated from the cells. In a preferred embodiment, a sample of breast tissue cells is obtained from the subject.

In one embodiment, RNA is obtained from a single cell. For example, a cell can be isolated from a tissue sample by laser capture microdissection (LCM). Using this technique, a cell can be isolated from a tissue section, including a stained tissue section, thereby assuring that the desired cell is isolated (*see, e.g.*, Bonner *et al.* (1997) *Science* 278: 1481; Emmert-Buck *et al.* (1996) *Science* 274:998; Fend *et al.* (1999) *Am. J. Path.* 154: 61 and Murakami *et al.* (2000) *Kidney Int.* 58:1346). For example, Murakami *et al., supra*, describe isolation of a cell from a previously immunostained tissue section.

It is also possible to obtain cells from a subject and culture the cells *in vitro*, such as to obtain a larger population of cells from which RNA can be extracted. Methods for establishing cultures of non-transformed cells, *i.e.*, primary cell cultures, are known in the art.

When isolating RNA from tissue samples or cells from individuals, it may be important to prevent any further changes in gene expression after the tissue or cells has been removed from the subject. Changes in expression levels are known to change rapidly following perturbations, *e.g.*, heat shock or activation with lipopolysaccharide (LPS) or other reagents. In addition, the RNA in the tissue and cells may quickly become degraded.

Accordingly, in a preferred embodiment, the tissue or cells obtained from a subject is snap frozen as soon as possible.

RNA can be extracted from the tissue sample by a variety of methods, *e.g.*, the guanidium thiocyanate lysis followed by CsCl centrifugation (Chirgwin *et al.*, 1979, *Biochemistry* 18:5294-5299). RNA from single cells can be obtained as described in methods for preparing cDNA libraries from single cells, such as those described in Dulac, C. (1998) *Curr. Top. Dev. Biol.* 36, 245 and Jena *et al.* (1996) *J. Immunol. Methods* 190:199. Care to avoid RNA degradation must be taken, *e.g.*, by inclusion of RNasin.

The RNA sample can then be enriched in particular species. In one embodiment, poly(A)⁺ RNA is isolated from the RNA sample. In general, such purification takes advantage of the poly-A tails on mRNA. In particular and as noted above, poly-T oligonucleotides may be immobilized within on a solid support to serve as affinity ligands for mRNA. Kits for this purpose are commercially available, *e.g.*, the MessageMaker kit (Life Technologies, Grand Island, NY).

In a preferred embodiment, the RNA population is enriched in marker sequences. Enrichment can be undertaken, *e.g.*, by primer-specific cDNA synthesis, or multiple rounds of linear amplification based on cDNA synthesis and template-directed *in vitro* transcription (*see, e.g.*, Wang *et al.* (1989) *PNAS* 86, 9717; Dulac *et al.*, *supra*, and Jena *et al.*, *supra*).

The population of RNA, enriched or not in particular species or sequences, can further be amplified. As defined herein, an "amplification process" is designed to strengthen, increase, or augment a molecule within the RNA. For example, where RNA is mRNA, an amplification process such as RT-PCR can be utilized to amplify the mRNA, such that a signal is detectable or detection is enhanced. Such an amplification process is beneficial particularly when the biological, tissue, or tumor sample is of a small size or volume.

Various amplification and detection methods can be used. For example, it is within the scope of the present invention to reverse transcribe mRNA into cDNA followed by polymerase chain reaction (RT-PCR); or, to use a single enzyme for both steps as described in U.S. Pat. No. 5,322,770, or reverse transcribe mRNA into cDNA followed by symmetric gap ligase chain reaction (RT-AGLCR) as described by R. L. Marshall, *et al.*, *PCR Methods and Applications* 4: 80-84 (1994). Real time PCR may also be used.

Other known amplification methods which can be utilized herein include but are not limited to the so-called "NASBA" or "3SR" technique described in PNAS USA 87: 1874-1878 (1990) and also described in Nature 350 (No. 6313): 91-92 (1991); Q-beta amplification as described in published European Patent Application (EPA) No. 4544610; strand displacement amplification (as described in G. T. Walker *et al.*, Clin. Chem. 42: 9-13 (1996) and European Patent Application No. 684315; target mediated amplification, as described by PCT Publication WO9322461; PCR; ligase chain reaction (LCR) (*see, e.g.*, Wu and Wallace, Genomics 4, 560 (1989), Landegren *et al.*, Science 241, 1077 (1988)); self-sustained sequence replication (SSR) (*see, e.g.*, Guatelli *et al.*, Proc. Nat. Acad. Sci. USA, 87, 1874 (1990)); and transcription amplification (*see, e.g.*, Kwoh *et al.*, Proc. Natl. Acad. Sci. USA 86, 1173 (1989)).

Many techniques are known in the state of the art for determining absolute and relative levels of gene expression, commonly used techniques suitable for use in the present invention include Northern analysis, RNase protection assays (RPA), microarrays and PCR-based techniques, such as quantitative PCR and differential display PCR. For example, Northern blotting involves running a preparation of RNA on a denaturing agarose gel, and transferring it to a suitable support, such as activated cellulose, nitrocellulose or glass or nylon membranes. Radiolabeled cDNA or RNA is then hybridized to the preparation, washed and analyzed by autoradiography.

In situ hybridization visualization may also be employed, wherein a radioactively labeled antisense RNA probe is hybridized with a thin section of a biopsy sample, washed, cleaved with RNase and exposed to a sensitive emulsion for autoradiography. The samples may be stained with hematoxylin to demonstrate the histological composition of the sample, and dark field imaging with a suitable light filter shows the developed emulsion. Non-radioactive labels such as digoxigenin may also be used.

Alternatively, mRNA expression can be detected on a DNA array, chip or a microarray. Labeled nucleic acids of a test sample obtained from a subject may be hybridized to a solid surface comprising biomarker DNA. Positive hybridization signal is obtained with the sample containing biomarker transcripts. Methods of preparing DNA arrays and their use are well known in the art (*see, e.g.*, U.S. Pat. Nos: 6,618,6796; 6,379,897; 6,664,377; 6,451,536; 548,257; U.S. 20030157485 and Schena *et al.* (1995) *Science* 20, 467-470; Gerhold *et al.* (1999) *Trends In Biochem. Sci.* 24, 168-173; and Lennon *et al.* (2000) *Drug Discovery Today* 5, 59-65, which are herein incorporated by

reference in their entirety). Serial Analysis of Gene Expression (SAGE) can also be performed (See for example U.S. Patent Application 20030215858).

To monitor mRNA levels, for example, mRNA is extracted from the biological sample to be tested, reverse transcribed, and fluorescently-labeled cDNA probes are generated. The microarrays capable of hybridizing to marker cDNA are then probed with the labeled cDNA probes, the slides scanned and fluorescence intensity measured. This intensity correlates with the hybridization intensity and expression levels.

Types of probes that can be used in the methods described herein include cDNA, riboprobes, synthetic oligonucleotides and genomic probes. The type of probe used will generally be dictated by the particular situation, such as riboprobes for *in situ* hybridization, and cDNA for Northern blotting, for example. In one embodiment, the probe is directed to nucleotide regions unique to the RNA. The probes may be as short as is required to differentially recognize marker mRNA transcripts, and may be as short as, for example, 15 bases; however, probes of at least 17, 18, 19 or 20 or more bases can be used. In one embodiment, the primers and probes hybridize specifically under stringent conditions to a DNA fragment having the nucleotide sequence corresponding to the marker. As herein used, the term "stringent conditions" means hybridization will occur only if there is at least 95% identity in nucleotide sequences. In another embodiment, hybridization under "stringent conditions" occurs when there is at least 97% identity between the sequences.

The form of labeling of the probes may be any that is appropriate, such as the use of radioisotopes, for example, ^{32}P and ^{35}S . Labeling with radioisotopes may be achieved, whether the probe is synthesized chemically or biologically, by the use of suitably labeled bases.

In one embodiment, the biological sample contains polypeptide molecules from the test subject. Alternatively, the biological sample can contain mRNA molecules from the test subject or genomic DNA molecules from the test subject.

In another embodiment, the methods further involve obtaining a control biological sample from a control subject, contacting the control sample with a compound or agent capable of detecting marker polypeptide, mRNA, genomic DNA, or fragments thereof, such that the presence of the marker polypeptide, mRNA, genomic DNA, or fragments thereof, is detected in the biological sample, and comparing the presence of the marker polypeptide, mRNA, genomic DNA, or fragments thereof, in the control sample with the presence of the marker polypeptide, mRNA, genomic DNA, or fragments thereof in the test sample.

c. Methods for Detection of Biomarker Protein Expression

The activity or level of a biomarker protein can be detected and/or quantified by detecting or quantifying the expressed polypeptide. The polypeptide can be detected and quantified by any of a number of means well known to those of skill in the art. Aberrant levels of polypeptide expression of the polypeptides encoded by a biomarker nucleic acid and functionally similar homologs thereof, including a fragment or genetic alteration thereof (e.g., in regulatory or promoter regions thereof) are associated with the likelihood of response of a cancer to an anti-immune checkpoint inhibitor therapy. Any method known in the art for detecting polypeptides can be used. Such methods include, but are not limited to, immunodiffusion, immunoelectrophoresis, radioimmunoassay (RIA), enzyme-linked immunosorbent assays (ELISAs), immunofluorescent assays, Western blotting, binder-ligand assays, immunohistochemical techniques, agglutination, complement assays, high performance liquid chromatography (HPLC), thin layer chromatography (TLC), hyperdiffusion chromatography, and the like (e.g., Basic and Clinical Immunology, Sites and Terr, eds., Appleton and Lange, Norwalk, Conn. pp 217-262, 1991 which is incorporated by reference). Preferred are binder-ligand immunoassay methods including reacting antibodies with an epitope or epitopes and competitively displacing a labeled polypeptide or derivative thereof.

For example, ELISA and RIA procedures may be conducted such that a desired biomarker protein standard is labeled (with a radioisotope such as ^{125}I or ^{35}S , or an assayable enzyme, such as horseradish peroxidase or alkaline phosphatase), and, together with the unlabelled sample, brought into contact with the corresponding antibody, whereon a second antibody is used to bind the first, and radioactivity or the immobilized enzyme assayed (competitive assay). Alternatively, the biomarker protein in the sample is allowed to react with the corresponding immobilized antibody, radioisotope- or enzyme-labeled anti-biomarker proteinantibody is allowed to react with the system, and radioactivity or the enzyme assayed (ELISA-sandwich assay). Other conventional methods may also be employed as suitable.

The above techniques may be conducted essentially as a "one-step" or "two-step" assay. A "one-step" assay involves contacting antigen with immobilized antibody and, without washing, contacting the mixture with labeled antibody. A "two-step" assay involves washing before contacting, the mixture with labeled antibody. Other conventional methods may also be employed as suitable.

In one embodiment, a method for measuring biomarker protein levels comprises the steps of: contacting a biological specimen with an antibody or variant (e.g., fragment) thereof which selectively binds the biomarker protein, and detecting whether said antibody or variant thereof is bound to said sample and thereby measuring the levels of the biomarker protein.

Enzymatic and radiolabeling of biomarker protein and/or the antibodies may be effected by conventional means. Such means will generally include covalent linking of the enzyme to the antigen or the antibody in question, such as by glutaraldehyde, specifically so as not to adversely affect the activity of the enzyme, by which is meant that the enzyme must still be capable of interacting with its substrate, although it is not necessary for all of the enzyme to be active, provided that enough remains active to permit the assay to be effected. Indeed, some techniques for binding enzyme are non-specific (such as using formaldehyde), and will only yield a proportion of active enzyme.

It is usually desirable to immobilize one component of the assay system on a support, thereby allowing other components of the system to be brought into contact with the component and readily removed without laborious and time-consuming labor. It is possible for a second phase to be immobilized away from the first, but one phase is usually sufficient.

It is possible to immobilize the enzyme itself on a support, but if solid-phase enzyme is required, then this is generally best achieved by binding to antibody and affixing the antibody to a support, models and systems for which are well-known in the art. Simple polyethylene may provide a suitable support.

Enzymes employable for labeling are not particularly limited, but may be selected from the members of the oxidase group, for example. These catalyze production of hydrogen peroxide by reaction with their substrates, and glucose oxidase is often used for its good stability, ease of availability and cheapness, as well as the ready availability of its substrate (glucose). Activity of the oxidase may be assayed by measuring the concentration of hydrogen peroxide formed after reaction of the enzyme-labeled antibody with the substrate under controlled conditions well-known in the art.

Other techniques may be used to detect biomarker protein according to a practitioner's preference based upon the present disclosure. One such technique is Western blotting (Towbin et al., Proc. Nat. Acad. Sci. 76:4350 (1979)), wherein a suitably treated sample is run on an SDS-PAGE gel before being transferred to a solid support, such as a

nitrocellulose filter. Anti-biomarker protein antibodies (unlabeled) are then brought into contact with the support and assayed by a secondary immunological reagent, such as labeled protein A or anti-immunoglobulin (suitable labels including ^{125}I , horseradish peroxidase and alkaline phosphatase). Chromatographic detection may also be used.

Immunohistochemistry may be used to detect expression of biomarker protein, e.g., in a biopsy sample. A suitable antibody is brought into contact with, for example, a thin layer of cells, washed, and then contacted with a second, labeled antibody. Labeling may be by fluorescent markers, enzymes, such as peroxidase, avidin, or radiolabelling. The assay is scored visually, using microscopy.

Anti- biomarker protein antibodies, such as intrabodies, may also be used for imaging purposes, for example, to detect the presence of biomarker protein in cells and tissues of a subject. Suitable labels include radioisotopes, iodine (^{125}I , ^{121}I), carbon (^{14}C), sulphur (^{35}S), tritium (^3H), indium (^{112}In), and technetium (^{99}mTc), fluorescent labels, such as fluorescein and rhodamine, and biotin.

For *in vivo* imaging purposes, antibodies are not detectable, as such, from outside the body, and so must be labeled, or otherwise modified, to permit detection. Markers for this purpose may be any that do not substantially interfere with the antibody binding, but which allow external detection. Suitable markers may include those that may be detected by X-radiography, NMR or MRI. For X-radiographic techniques, suitable markers include any radioisotope that emits detectable radiation but that is not overtly harmful to the subject, such as barium or cesium, for example. Suitable markers for NMR and MRI generally include those with a detectable characteristic spin, such as deuterium, which may be incorporated into the antibody by suitable labeling of nutrients for the relevant hybridoma, for example.

The size of the subject, and the imaging system used, will determine the quantity of imaging moiety needed to produce diagnostic images. In the case of a radioisotope moiety, for a human subject, the quantity of radioactivity injected will normally range from about 5 to 20 millicuries of technetium-99. The labeled antibody or antibody fragment will then preferentially accumulate at the location of cells which contain biomarker protein. The labeled antibody or antibody fragment can then be detected using known techniques.

Antibodies that may be used to detect biomarker protein include any antibody, whether natural or synthetic, full length or a fragment thereof, monoclonal or polyclonal, that binds sufficiently strongly and specifically to the biomarker protein to be detected. An

antibody may have a K_d of at most about $10^{-6}M$, $10^{-7}M$, $10^{-8}M$, $10^{-9}M$, $10^{-10}M$, $10^{-11}M$, $10^{-12}M$. The phrase "specifically binds" refers to binding of, for example, an antibody to an epitope or antigen or antigenic determinant in such a manner that binding can be displaced or competed with a second preparation of identical or similar epitope, antigen or antigenic determinant. An antibody may bind preferentially to the biomarker protein relative to other proteins, such as related proteins.

Antibodies are commercially available or may be prepared according to methods known in the art.

Antibodies and derivatives thereof that may be used encompass polyclonal or monoclonal antibodies, chimeric, human, humanized, primatized (CDR-grafted), veneered or single-chain antibodies as well as functional fragments, *i.e.*, biomarker protein binding fragments, of antibodies. For example, antibody fragments capable of binding to a biomarker protein or portions thereof, including, but not limited to, Fv, Fab, Fab' and F(ab')₂ fragments can be used. Such fragments can be produced by enzymatic cleavage or by recombinant techniques. For example, papain or pepsin cleavage can generate Fab or F(ab')₂ fragments, respectively. Other proteases with the requisite substrate specificity can also be used to generate Fab or F(ab')₂ fragments. Antibodies can also be produced in a variety of truncated forms using antibody genes in which one or more stop codons have been introduced upstream of the natural stop site. For example, a chimeric gene encoding a F(ab')₂ heavy chain portion can be designed to include DNA sequences encoding the CH₁ domain and hinge region of the heavy chain.

Synthetic and engineered antibodies are described in, *e.g.*, Cabilly *et al.*, U.S. Pat. No. 4,816,567 Cabilly *et al.*, European Patent No. 0,125,023 B1; Boss *et al.*, U.S. Pat. No. 4,816,397; Boss *et al.*, European Patent No. 0,120,694 B1; Neuberger, M. S. *et al.*, WO 86/01533; Neuberger, M. S. *et al.*, European Patent No. 0,194,276 B1; Winter, U.S. Pat. No. 5,225,539; Winter, European Patent No. 0,239,400 B1; Queen *et al.*, European Patent No. 0451216 B1; and Padlan, E. A. *et al.*, EP 0519596 A1. See also, Newman, R. *et al.*, *BioTechnology*, 10: 1455-1460 (1992), regarding primatized antibody, and Ladner *et al.*, U.S. Pat. No. 4,946,778 and Bird, R. E. *et al.*, *Science*, 242: 423-426 (1988)) regarding single-chain antibodies. Antibodies produced from a library, *e.g.*, phage display library, may also be used.

In some embodiments, agents that specifically bind to a biomarker protein other than antibodies are used, such as peptides. Peptides that specifically bind to a biomarker

protein can be identified by any means known in the art. For example, specific peptide binders of a biomarker protein can be screened for using peptide phage display libraries.

d. Methods for Detection of Biomarker Structural Alterations

The following illustrative methods can be used to identify the presence of a structural alteration in a biomarker nucleic acid and/or biomarker polypeptide molecule in order to, for example, identify biomarkers.

In certain embodiments, detection of the alteration involves the use of a probe/primer in a polymerase chain reaction (PCR) (see, e.g., U.S. Pat. Nos. 4,683,195 and 4,683,202), such as anchor PCR or RACE PCR, or, alternatively, in a ligation chain reaction (LCR) (see, e.g., Landegran *et al.* (1988) *Science* 241:1077-1080; and Nakazawa *et al.* (1994) *Proc. Natl. Acad. Sci. USA* 91:360-364), the latter of which can be particularly useful for detecting point mutations in a biomarker nucleic acid such as a biomarker gene (see Abravaya *et al.* (1995) *Nucleic Acids Res.* 23:675-682). This method can include the steps of collecting a sample of cells from a subject, isolating nucleic acid (e.g., genomic, mRNA or both) from the cells of the sample, contacting the nucleic acid sample with one or more primers which specifically hybridize to a biomarker gene under conditions such that hybridization and amplification of the biomarker gene (if present) occurs, and detecting the presence or absence of an amplification product, or detecting the size of the amplification product and comparing the length to a control sample. It is anticipated that PCR and/or LCR may be desirable to use as a preliminary amplification step in conjunction with any of the techniques used for detecting mutations described herein.

Alternative amplification methods include: self sustained sequence replication (Guatelli, J. C. *et al.* (1990) *Proc. Natl. Acad. Sci. USA* 87:1874-1878), transcriptional amplification system (Kwoh, D. Y. *et al.* (1989) *Proc. Natl. Acad. Sci. USA* 86:1173-1177), Q-Beta Replicase (Lizardi, P. M. *et al.* (1988) *Bio-Technology* 6:1197), or any other nucleic acid amplification method, followed by the detection of the amplified molecules using techniques well known to those of skill in the art. These detection schemes are especially useful for the detection of nucleic acid molecules if such molecules are present in very low numbers.

In an alternative embodiment, mutations in a biomarker nucleic acid from a sample cell can be identified by alterations in restriction enzyme cleavage patterns. For example, sample and control DNA is isolated, amplified (optionally), digested with one or more restriction endonucleases, and fragment length sizes are determined by gel electrophoresis

and compared. Differences in fragment length sizes between sample and control DNA indicates mutations in the sample DNA. Moreover, the use of sequence specific ribozymes (see, for example, U.S. Pat. No. 5,498,531) can be used to score for the presence of specific mutations by development or loss of a ribozyme cleavage site.

5 In other embodiments, genetic mutations in biomarker nucleic acid can be identified by hybridizing a sample and control nucleic acids, *e.g.*, DNA or RNA, to high density arrays containing hundreds or thousands of oligonucleotide probes (Cronin, M. T. *et al.* (1996) *Hum. Mutat.* 7:244-255; Kozal, M. J. *et al.* (1996) *Nat. Med.* 2:753-759). For example, biomarker genetic mutations can be identified in two dimensional arrays
10 containing light-generated DNA probes as described in Cronin *et al.* (1996) *supra*. Briefly, a first hybridization array of probes can be used to scan through long stretches of DNA in a sample and control to identify base changes between the sequences by making linear arrays of sequential, overlapping probes. This step allows the identification of point mutations. This step is followed by a second hybridization array that allows the characterization of
15 specific mutations by using smaller, specialized probe arrays complementary to all variants or mutations detected. Each mutation array is composed of parallel probe sets, one complementary to the wild-type gene and the other complementary to the mutant gene. Such biomarker genetic mutations can be identified in a variety of contexts, including, for example, germline and somatic mutations.

20 In yet another embodiment, any of a variety of sequencing reactions known in the art can be used to directly sequence a biomarker gene and detect mutations by comparing the sequence of the sample biomarker with the corresponding wild-type (control) sequence. Examples of sequencing reactions include those based on techniques developed by Maxam and Gilbert (1977) *Proc. Natl. Acad. Sci. USA* 74:560 or Sanger (1977) *Proc. Natl. Acad. Sci. USA* 74:5463. It is also contemplated that any of a variety of automated sequencing
25 procedures can be utilized when performing the diagnostic assays (Naeve (1995) *Biotechniques* 19:448-53), including sequencing by mass spectrometry (see, *e.g.*, PCT International Publication No. WO 94/16101; Cohen *et al.* (1996) *Adv. Chromatogr.* 36:127-162; and Griffin *et al.* (1993) *Appl. Biochem. Biotechnol.* 38:147-159).

30 Other methods for detecting mutations in a biomarker gene include methods in which protection from cleavage agents is used to detect mismatched bases in RNA/RNA or RNA/DNA heteroduplexes (Myers *et al.* (1985) *Science* 230:1242). In general, the art technique of "mismatch cleavage" starts by providing heteroduplexes formed by

hybridizing (labeled) RNA or DNA containing the wild-type biomarker sequence with potentially mutant RNA or DNA obtained from a tissue sample. The double-stranded duplexes are treated with an agent which cleaves single-stranded regions of the duplex such as which will exist due to base pair mismatches between the control and sample strands.

5 For instance, RNA/DNA duplexes can be treated with RNase and DNA/DNA hybrids treated with SI nuclease to enzymatically digest the mismatched regions. In other embodiments, either DNA/DNA or RNA/DNA duplexes can be treated with hydroxylamine or osmium tetroxide and with piperidine in order to digest mismatched regions. After digestion of the mismatched regions, the resulting material is then separated by size on

10 denaturing polyacrylamide gels to determine the site of mutation. See, for example, Cotton *et al.* (1988) *Proc. Natl. Acad. Sci. USA* 85:4397 and Saleeba *et al.* (1992) *Methods Enzymol.* 217:286-295. In a preferred embodiment, the control DNA or RNA can be labeled for detection.

In still another embodiment, the mismatch cleavage reaction employs one or more

15 proteins that recognize mismatched base pairs in double-stranded DNA (so called "DNA mismatch repair" enzymes) in defined systems for detecting and mapping point mutations in biomarker cDNAs obtained from samples of cells. For example, the mutY enzyme of *E. coli* cleaves A at G/A mismatches and the thymidine DNA glycosylase from HeLa cells cleaves T at G/T mismatches (Hsu *et al.* (1994) *Carcinogenesis* 15:1657-1662). According

20 to an exemplary embodiment, a probe based on a biomarker sequence, *e.g.*, a wild-type biomarker treated with a DNA mismatch repair enzyme, and the cleavage products, if any, can be detected from electrophoresis protocols or the like (*e.g.*, U.S. Pat. No. 5,459,039.)

In other embodiments, alterations in electrophoretic mobility can be used to identify mutations in biomarker genes. For example, single strand conformation polymorphism

25 (SSCP) may be used to detect differences in electrophoretic mobility between mutant and wild type nucleic acids (Orita *et al.* (1989) *Proc Natl. Acad. Sci USA* 86:2766; see also Cotton (1993) *Mutat. Res.* 285:125-144 and Hayashi (1992) *Genet. Anal. Tech. Appl.* 9:73-79). Single-stranded DNA fragments of sample and control biomarker nucleic acids will be denatured and allowed to renature. The secondary structure of single-stranded nucleic acids

30 varies according to sequence, the resulting alteration in electrophoretic mobility enables the detection of even a single base change. The DNA fragments may be labeled or detected with labeled probes. The sensitivity of the assay may be enhanced by using RNA (rather than DNA), in which the secondary structure is more sensitive to a change in sequence. In

a preferred embodiment, the subject method utilizes heteroduplex analysis to separate double stranded heteroduplex molecules on the basis of changes in electrophoretic mobility (Keen *et al.* (1991) *Trends Genet.* 7:5).

In yet another embodiment the movement of mutant or wild-type fragments in polyacrylamide gels containing a gradient of denaturant is assayed using denaturing
5 gradient gel electrophoresis (DGGE) (Myers *et al.* (1985) *Nature* 313:495). When DGGE is used as the method of analysis, DNA will be modified to ensure that it does not completely denature, for example by adding a GC clamp of approximately 40 bp of high-melting GC-rich DNA by PCR. In a further embodiment, a temperature gradient is used in
10 place of a denaturing gradient to identify differences in the mobility of control and sample DNA (Rosenbaum and Reissner (1987) *Biophys. Chem.* 265:12753).

Examples of other techniques for detecting point mutations include, but are not limited to, selective oligonucleotide hybridization, selective amplification, or selective primer extension. For example, oligonucleotide primers may be prepared in which the
15 known mutation is placed centrally and then hybridized to target DNA under conditions which permit hybridization only if a perfect match is found (Saiki *et al.* (1986) *Nature* 324:163; Saiki *et al.* (1989) *Proc. Natl. Acad. Sci. USA* 86:6230). Such allele specific oligonucleotides are hybridized to PCR amplified target DNA or a number of different mutations when the oligonucleotides are attached to the hybridizing membrane and
20 hybridized with labeled target DNA.

Alternatively, allele specific amplification technology which depends on selective PCR amplification may be used in conjunction with the instant invention. Oligonucleotides used as primers for specific amplification may carry the mutation of interest in the center of the molecule (so that amplification depends on differential hybridization) (Gibbs *et al.*
25 (1989) *Nucleic Acids Res.* 17:2437-2448) or at the extreme 3' end of one primer where, under appropriate conditions, mismatch can prevent, or reduce polymerase extension (Prossner (1993) *Tibtech* 11:238). In addition it may be desirable to introduce a novel restriction site in the region of the mutation to create cleavage-based detection (Gasparini *et al.* (1992) *Mol. Cell Probes* 6:1). It is anticipated that in certain embodiments amplification
30 may also be performed using Taq ligase for amplification (Barany (1991) *Proc. Natl. Acad. Sci USA* 88:189). In such cases, ligation will occur only if there is a perfect match at the 3' end of the 5' sequence making it possible to detect the presence of a known mutation at a specific site by looking for the presence or absence of amplification.

e. Methods for Detection of Biomarker Metabolite Expression

Biomarker metabolites, such as those shown in Table 1 or the Examples, can be detected in numerous ways according to well-known techniques. For example, such metabolites, as well as biomarker proteins, can be detected using mass spectrometry methods, such as MALDI/TOF (time-of-flight), SELDI/TOF, liquid chromatography-mass spectrometry (LC-MS), gas chromatography-mass spectrometry (GC-MS), high performance liquid chromatography-mass spectrometry (HPLC-MS), reverse phase high performance liquid chromatography (rpHPLC), capillary electrophoresis-mass spectrometry, nuclear magnetic resonance spectrometry, or tandem mass spectrometry (e.g., MS/MS, MS/MS/MS, ESI-MS/MS, etc.). See for example, U.S. Patent Application Nos: 20030199001, 20030134304, 20030077616, which are herein incorporated by reference.

Mass spectrometry methods are well known in the art and have been used to quantify and/or identify biomolecules, such as chemical metabolites and proteins (see, e.g., Li et al. (2000) *Tibtech* 18, 151-160; Rowley et al. (2000) *Methods* 20, 383-397; Kuster and Mann (1998) *Curr. Opin. Structural Biol.* 8, 393-400). Further, mass spectrometric techniques have been developed that permit at least partial *de novo* sequencing of isolated proteins (see, e.g., Chait et al. (1993) *Science* 262, 89-92; Keough et al. (1999) *Proc. Natl. Acad. Sci. USA.* 96, 7131-7136; reviewed in Bergman (2000) *EXS* 88, 133-44).

In certain embodiments, a gas phase ion spectrophotometer is used. In other embodiments, laser-desorption/ionization mass spectrometry is used to analyze the sample. Modern laser desorption/ionization mass spectrometry ("LDI-MS") can be practiced in two main variations: matrix assisted laser desorption/ionization ("MALDI") mass spectrometry and surface-enhanced laser desorption/ionization ("SELDI"). In MALDI, the analyte is mixed with a solution containing a matrix, and a drop of the liquid is placed on the surface of a substrate. The matrix solution then co-crystallizes with the biological molecules. The substrate is inserted into the mass spectrometer. Laser energy is directed to the substrate surface where it desorbs and ionizes the biological molecules without significantly fragmenting them. However, MALDI has limitations as an analytical tool. It does not provide means for fractionating the sample, and the matrix material can interfere with detection, especially for low molecular weight analytes (see, e.g., Hellenkamp et al., U.S. Pat. No. 5,118,937 and Beavis and Chait, U.S. Pat. No. 5,045,694).

In SELDI, the substrate surface is modified so that it is an active participant in the desorption process. In one variant, the surface is derivatized with adsorbent and/or capture

reagents that selectively bind the protein of interest. In another variant, the surface is derivatized with energy absorbing molecules that are not desorbed when struck with the laser. In another variant, the surface is derivatized with molecules that bind the protein of interest and that contain a photolytic bond that is broken upon application of the laser. In each of these methods, the derivatizing agent generally is localized to a specific location on the substrate surface where the sample is applied (see, e.g., Hutchens and Yip, U.S. Pat. No. 5,719,060 and Hutchens and Yip, WO 98/59361). The two methods can be combined by, for example, using a SELDI affinity surface to capture an analyte and adding matrix-containing liquid to the captured analyte to provide the energy absorbing material.

For additional information regarding mass spectrometers, see, e.g., Principles of Instrumental Analysis, 3rd edition., Skoog, Saunders College Publishing, Philadelphia, 1985; and Kirk-Othmer Encyclopedia of Chemical Technology, 4.sup.th ed. Vol. 15 (John Wiley & Sons, New York 1995), pp. 1071-1094.

Detection of the presence of a marker or other substances will typically involve detection of signal intensity. For example, in certain embodiments, the signal strength of peak values from spectra of a first sample and a second sample can be compared (e.g., visually or by computer analysis) to determine the relative amounts of particular biomolecules. Software programs such as the Biomarker Wizard program (CIPHERGEN Biosystems, Inc., Fremont, Calif.) can be used to aid in analyzing mass spectra. The mass spectrometers and their techniques are well known to those of skill in the art.

Any person skilled in the art understands, any of the components of a mass spectrometer (e.g., desorption source, mass analyzer, detect, etc.) and varied sample preparations can be combined with other suitable components or preparations described herein, or to those known in the art. For example, in some embodiments a control sample may contain heavy atoms (e.g. ^{13}C) thereby permitting the test sample to be mixed with the known control sample in the same mass spectrometry run. In some embodiments, internal controls, such as phenylalanine-d8 and/or valine-d8 can be run with the samples.

In one embodiment, a laser desorption time-of-flight (TOF) mass spectrometer is used. In laser desorption mass spectrometry, a substrate with a bound marker is introduced into an inlet system. The marker is desorbed and ionized into the gas phase by laser from the ionization source. The ions generated are collected by an ion optic assembly, and then in a time-of-flight mass analyzer, ions are accelerated through a short high voltage field and let drift into a high vacuum chamber. At the far end of the high vacuum chamber, the

accelerated ions strike a sensitive detector surface at a different time. Since the time-of-flight is a function of the mass of the ions, the elapsed time between ion formation and ion detector impact can be used to identify the presence or absence of molecules of specific mass to charge ratio.

5 In some embodiments the relative amounts of one or more biomolecules present in a first or second sample is determined, in part, by executing an algorithm with a programmable digital computer. The algorithm identifies at least one peak value in the first mass spectrum and the second mass spectrum. The algorithm then compares the signal strength of the peak value of the first mass spectrum to the signal strength of the peak value
10 of the second mass spectrum of the mass spectrum. The relative signal strengths are an indication of the amount of the biomolecule that is present in the first and second samples. A standard containing a known amount of a biomolecule can be analyzed as the second sample to provide better quantification of the amount of the biomolecule present in the first sample. In certain embodiments, the identity of the biomolecules in the first and second
15 sample can also be determined.

Biomarker expression and activity can also be assessed according to functional assays described further below.

3. Anti-Chronic Immune Disorder Therapies and Combination Therapies

20 Anti-chronic immune disorder therapy according to the present invention is based on the use of anti-CD39 therapy with or without anti-immune checkpoint inhibitor therapy (e.g., anti-PD-1, anti-PD-L1, anti-PD-L2, and anti-CTLA4 therapies). In addition, other additional therapy can be combined, such as anti-infection therapy or anti-cancer therapy. Other combination therapies are also contemplated and can comprise, for example, one or
25 more chemotherapeutic agents and radiation, one or more chemotherapeutic agents and immunotherapy, or one or more chemotherapeutic agents, radiation and chemotherapy, each combination of which can be with an anti-CD39 therapy with or without anti-immune checkpoint inhibitor therapy. In another embodiment, such therapies can be avoided once a subject is indicated as not being a likely responder (e.g., not having exhausted CD8+ T
30 cells) and an alternative treatment regimen, such as targeted and/or untargeted anti-viral or anti-cancer therapies can be administered.

Useful agents for use in treating chronic immune disorders arising from infections are well known in the art. For example, antiviral agents (e.g., vidarabine, acyclovir,

gancyclovir, valgancyclovir, nucleoside-analog reverse transcriptase inhibitor (NRTI) such as AZT (Zidovudine), ddl (Didanosine), ddC (Zalcitabine), d4T (Stavudine), or 3TC (Lainivudine), non-nucleoside reverse transcriptase inhibitor (NNRTI) such as nevirapine or delavirdine, protease inhibitors, such as saquinavir, ritonavir, indinavir, or nelfinavir, 5 ribavirin, and interferon), an antibacterial compound, an antifungal compound, an antiparasitic compound, an anti-inflammatory compound, anti-neoplastic compounds or an analgesic, are contemplated.

The term "targeted therapy" refers to administration of agents that selectively interact with a chosen biomolecule to thereby treat cancer.

10 Immunotherapy is one form of targeted therapy that may comprise, for example, the use of cancer vaccines and/or sensitized antigen presenting cells. For example, an oncolytic virus is a virus that is able to infect and lyse cancer cells, while leaving normal cells unharmed, making them potentially useful in cancer therapy. Replication of oncolytic viruses both facilitates tumor cell destruction and also produces dose amplification at the 15 tumor site. They may also act as vectors for anticancer genes, allowing them to be specifically delivered to the tumor site. The immunotherapy can involve passive immunity for short-term protection of a host, achieved by the administration of pre-formed antibody directed against a cancer antigen or disease antigen (e.g., administration of a monoclonal antibody, optionally linked to a chemotherapeutic agent or toxin, to a tumor antigen).

20 Immunotherapy can also focus on using the cytotoxic lymphocyte-recognized epitopes of cancer cell lines. Alternatively, antisense polynucleotides, ribozymes, RNA interference molecules, triple helix polynucleotides and the like, can be used to selectively modulate biomolecules that are linked to the initiation, progression, and/or pathology of a tumor or cancer.

25 The term "untargeted therapy" refers to administration of agents that do not selectively interact with a chosen biomolecule yet treat cancer. Representative examples of untargeted therapies include, without limitation, chemotherapy, gene therapy, and radiation therapy.

In one embodiment, chemotherapy is used. Chemotherapy includes the 30 administration of a chemotherapeutic agent. Such a chemotherapeutic agent may be, but is not limited to, those selected from among the following groups of compounds: platinum compounds, cytotoxic antibiotics, antimetabolites, anti-mitotic agents, alkylating agents, arsenic compounds, DNA topoisomerase inhibitors, taxanes, nucleoside analogues, plant

alkaloids, and toxins; and synthetic derivatives thereof. Exemplary compounds include, but are not limited to, alkylating agents: cisplatin, carboplatin, treosulfan, and trofosfamide; plant alkaloids: vinblastine, paclitaxel, docetaxol; DNA topoisomerase inhibitors: teniposide, crisnatol, and mitomycin; anti-folates: methotrexate, mycophenolic acid, and hydroxyurea; pyrimidine analogs: 5-fluorouracil, doxifluridine, and cytosine arabinoside; purine analogs: mercaptopurine and thioguanine; DNA antimetabolites: 2'-deoxy-5-fluorouridine, aphidicolin glycinate, pemetrexed, and pyrazoloimidazole; and antimetabolic agents: halichondrin, colchicine, and rhizoxin. Compositions comprising one or more chemotherapeutic agents (*e.g.*, FLAG, CHOP) may also be used. FLAG comprises fludarabine, cytosine arabinoside (Ara-C) and G-CSF. CHOP comprises cyclophosphamide, vincristine, doxorubicin, and prednisone. In another embodiment, PARP (*e.g.*, PARP-1 and/or PARP-2) inhibitors are used and such inhibitors are well known in the art (*e.g.*, Olaparib, ABT-888, BSI-201, BGP-15 (N-Gene Research Laboratories, Inc.); INO-1001 (Inotek Pharmaceuticals Inc.); PJ34 (Soriano *et al.*, 2001; Pacher *et al.*, 2002b); 3-aminobenzamide (Trevigen); 4-amino-1,8-naphthalimide; (Trevigen); 6(5H)-phenanthridinone (Trevigen); benzamide (U.S. Pat. Re. 36,397); and NU1025 (Bowman *et al.*). The mechanism of action is generally related to the ability of PARP inhibitors to bind PARP and decrease its activity. PARP catalyzes the conversion of .beta.-nicotinamide adenine dinucleotide (NAD⁺) into nicotinamide and poly-ADP-ribose (PAR). Both poly (ADP-ribose) and PARP have been linked to regulation of transcription, cell proliferation, genomic stability, and carcinogenesis (Bouchard V. J. *et al.* Experimental Hematology, Volume 31, Number 6, June 2003, pp. 446-454(9); Hereeg Z.; Wang Z.-Q. Mutation Research/Fundamental and Molecular Mechanisms of Mutagenesis, Volume 477, Number 1, 2 Jun. 2001, pp. 97-110(14)). Poly(ADP-ribose) polymerase 1 (PARP1) is a key molecule in the repair of DNA single-strand breaks (SSBs) (de Murcia J. *et al.* 1997. Proc Natl Acad Sci USA 94:7303-7307; Schreiber V, Dantzer F, Ame J C, de Murcia G (2006) Nat Rev Mol Cell Biol 7:517-528; Wang Z Q, *et al.* (1997) Genes Dev 11:2347-2358). Knockout of SSB repair by inhibition of PARP1 function induces DNA double-strand breaks (DSBs) that can trigger synthetic lethality in cancer cells with defective homology-directed DSB repair (Bryant H E, *et al.* (2005) Nature 434:913-917; Farmer H, *et al.* (2005) Nature 434:917-921). The foregoing examples of chemotherapeutic agents are illustrative, and are not intended to be limiting.

In another embodiment, radiation therapy is used. The radiation used in radiation therapy can be ionizing radiation. Radiation therapy can also be gamma rays, X-rays, or proton beams. Examples of radiation therapy include, but are not limited to, external-beam radiation therapy, interstitial implantation of radioisotopes (I-125, palladium, iridium),
 5 radioisotopes such as strontium-89, thoracic radiation therapy, intraperitoneal P-32 radiation therapy, and/or total abdominal and pelvic radiation therapy. For a general overview of radiation therapy, see Hellman, Chapter 16: Principles of Cancer Management: Radiation Therapy, 6th edition, 2001, DeVita *et al.*, eds., J. B. Lippencott Company, Philadelphia. The radiation therapy can be administered as external beam radiation or
 10 teletherapy wherein the radiation is directed from a remote source. The radiation treatment can also be administered as internal therapy or brachytherapy wherein a radioactive source is placed inside the body close to cancer cells or a tumor mass. Also encompassed is the use of photodynamic therapy comprising the administration of photosensitizers, such as hematoporphyrin and its derivatives, Vertoporphin (BPD-MA), phthalocyanine,
 15 photosensitizer Pc4, demethoxy-hypocrellin A; and 2BA-2-DMHA.

In another embodiment, hormone therapy is used. Hormonal therapeutic treatments can comprise, for example, hormonal agonists, hormonal antagonists (*e.g.*, flutamide, bicalutamide, tamoxifen, raloxifene, leuprolide acetate (LUPRON), LH-RH antagonists),
 20 inhibitors of hormone biosynthesis and processing, and steroids (*e.g.*, dexamethasone, retinoids, deltoids, betamethasone, cortisol, cortisone, prednisone, dehydrotestosterone, glucocorticoids, mineralocorticoids, estrogen, testosterone, progestins), vitamin A derivatives (*e.g.*, all-trans retinoic acid (ATRA)); vitamin D3 analogs; antigestagens (*e.g.*, mifepristone, onapristone), or antiandrogens (*e.g.*, cyproterone acetate).

In another embodiment, hyperthermia, a procedure in which body tissue is exposed
 25 to high temperatures (up to 106°F.) is used. Heat may help shrink tumors by damaging cells or depriving them of substances they need to live. Hyperthermia therapy can be local, regional, and whole-body hyperthermia, using external and internal heating devices. Hyperthermia is almost always used with other forms of therapy (*e.g.*, radiation therapy, chemotherapy, and biological therapy) to try to increase their effectiveness. Local
 30 hyperthermia refers to heat that is applied to a very small area, such as a tumor. The area may be heated externally with high-frequency waves aimed at a tumor from a device outside the body. To achieve internal heating, one of several types of sterile probes may be used, including thin, heated wires or hollow tubes filled with warm water; implanted

microwave antennae; and radiofrequency electrodes. In regional hyperthermia, an organ or a limb is heated. Magnets and devices that produce high energy are placed over the region to be heated. In another approach, called perfusion, some of the patient's blood is removed, heated, and then pumped (perfused) into the region that is to be heated internally. Whole-body heating is used to treat metastatic cancer that has spread throughout the body. It can be accomplished using warm-water blankets, hot wax, inductive coils (like those in electric blankets), or thermal chambers (similar to large incubators). Hyperthermia does not cause any marked increase in radiation side effects or complications. Heat applied directly to the skin, however, can cause discomfort or even significant local pain in about half the patients treated. It can also cause blisters, which generally heal rapidly.

In still another embodiment, photodynamic therapy (also called PDT, photoradiation therapy, phototherapy, or photochemotherapy) is used for the treatment of some types of cancer. It is based on the discovery that certain chemicals known as photosensitizing agents can kill one-celled organisms when the organisms are exposed to a particular type of light. PDT destroys cancer cells through the use of a fixed-frequency laser light in combination with a photosensitizing agent. In PDT, the photosensitizing agent is injected into the bloodstream and absorbed by cells all over the body. The agent remains in cancer cells for a longer time than it does in normal cells. When the treated cancer cells are exposed to laser light, the photosensitizing agent absorbs the light and produces an active form of oxygen that destroys the treated cancer cells. Light exposure must be timed carefully so that it occurs when most of the photosensitizing agent has left healthy cells but is still present in the cancer cells. The laser light used in PDT can be directed through a fiber-optic (a very thin glass strand). The fiber-optic is placed close to the cancer to deliver the proper amount of light. The fiber-optic can be directed through a bronchoscope into the lungs for the treatment of lung cancer or through an endoscope into the esophagus for the treatment of esophageal cancer. An advantage of PDT is that it causes minimal damage to healthy tissue. However, because the laser light currently in use cannot pass through more than about 3 centimeters of tissue (a little more than one and an eighth inch), PDT is mainly used to treat tumors on or just under the skin or on the lining of internal organs. Photodynamic therapy makes the skin and eyes sensitive to light for 6 weeks or more after treatment. Patients are advised to avoid direct sunlight and bright indoor light for at least 6 weeks. If patients must go outdoors, they need to wear protective clothing, including sunglasses. Other temporary side effects of PDT are related to the treatment of specific

areas and can include coughing, trouble swallowing, abdominal pain, and painful breathing or shortness of breath. In December 1995, the U.S. Food and Drug Administration (FDA) approved a photosensitizing agent called porfimer sodium, or Photofrin®, to relieve symptoms of esophageal cancer that is causing an obstruction and for esophageal cancer
5 that cannot be satisfactorily treated with lasers alone. In January 1998, the FDA approved porfimer sodium for the treatment of early nonsmall cell lung cancer in patients for whom the usual treatments for lung cancer are not appropriate. The National Cancer Institute and other institutions are supporting clinical trials (research studies) to evaluate the use of photodynamic therapy for several types of cancer, including cancers of the bladder, brain,
10 larynx, and oral cavity.

In yet another embodiment, laser therapy is used to harness high-intensity light to destroy cancer cells. This technique is often used to relieve symptoms of cancer such as bleeding or obstruction, especially when the cancer cannot be cured by other treatments. It may also be used to treat cancer by shrinking or destroying tumors. The term “laser” stands
15 for light amplification by stimulated emission of radiation. Ordinary light, such as that from a light bulb, has many wavelengths and spreads in all directions. Laser light, on the other hand, has a specific wavelength and is focused in a narrow beam. This type of high-intensity light contains a lot of energy. Lasers are very powerful and may be used to cut through steel or to shape diamonds. Lasers also can be used for very precise surgical work,
20 such as repairing a damaged retina in the eye or cutting through tissue (in place of a scalpel). Although there are several different kinds of lasers, only three kinds have gained wide use in medicine: Carbon dioxide (CO₂) laser--This type of laser can remove thin layers from the skin's surface without penetrating the deeper layers. This technique is particularly useful in treating tumors that have not spread deep into the skin and certain
25 precancerous conditions. As an alternative to traditional scalpel surgery, the CO₂ laser is also able to cut the skin. The laser is used in this way to remove skin cancers. Neodymium:yttrium-aluminum-garnet (Nd:YAG) laser-- Light from this laser can penetrate deeper into tissue than light from the other types of lasers, and it can cause blood to clot quickly. It can be carried through optical fibers to less accessible parts of the body. This
30 type of laser is sometimes used to treat throat cancers. Argon laser--This laser can pass through only superficial layers of tissue and is therefore useful in dermatology and in eye surgery. It also is used with light-sensitive dyes to treat tumors in a procedure known as photodynamic therapy (PDT). Lasers have several advantages over standard surgical tools,

including: Lasers are more precise than scalpels. Tissue near an incision is protected, since there is little contact with surrounding skin or other tissue. The heat produced by lasers sterilizes the surgery site, thus reducing the risk of infection. Less operating time may be needed because the precision of the laser allows for a smaller incision. Healing time is often shortened; since laser heat seals blood vessels, there is less bleeding, swelling, or scarring. Laser surgery may be less complicated. For example, with fiber optics, laser light can be directed to parts of the body without making a large incision. More procedures may be done on an outpatient basis. Lasers can be used in two ways to treat cancer: by shrinking or destroying a tumor with heat, or by activating a chemical--known as a photosensitizing agent--that destroys cancer cells. In PDT, a photosensitizing agent is retained in cancer cells and can be stimulated by light to cause a reaction that kills cancer cells. CO₂ and Nd:YAG lasers are used to shrink or destroy tumors. They may be used with endoscopes, tubes that allow physicians to see into certain areas of the body, such as the bladder. The light from some lasers can be transmitted through a flexible endoscope fitted with fiber optics. This allows physicians to see and work in parts of the body that could not otherwise be reached except by surgery and therefore allows very precise aiming of the laser beam. Lasers also may be used with low-power microscopes, giving the doctor a clear view of the site being treated. Used with other instruments, laser systems can produce a cutting area as small as 200 microns in diameter--less than the width of a very fine thread. Lasers are used to treat many types of cancer. Laser surgery is a standard treatment for certain stages of glottis (vocal cord), cervical, skin, lung, vaginal, vulvar, and penile cancers. In addition to its use to destroy the cancer, laser surgery is also used to help relieve symptoms caused by cancer (palliative care). For example, lasers may be used to shrink or destroy a tumor that is blocking a patient's trachea (windpipe), making it easier to breathe. It is also sometimes used for palliation in colorectal and anal cancer. Laser-induced interstitial thermotherapy (LITT) is one of the most recent developments in laser therapy. LITT uses the same idea as a cancer treatment called hyperthermia; that heat may help shrink tumors by damaging cells or depriving them of substances they need to live. In this treatment, lasers are directed to interstitial areas (areas between organs) in the body. The laser light then raises the temperature of the tumor, which damages or destroys cancer cells.

The duration and/or dose of treatment with anti-immune checkpoint inhibitor therapies may vary according to the particular anti-immune checkpoint inhibitor agent or

combination thereof (e.g., Jak kinase stimulating agents in combination with inhibitors of PD-1, PD-L1, PD-L2, CTLA-4, and the like). An appropriate treatment time for a particular cancer therapeutic agent will be appreciated by the skilled artisan. The invention contemplates the continued assessment of optimal treatment schedules for each cancer
5 therapeutic agent, where the phenotype of the cancer of the subject as determined by the methods of the invention is a factor in determining optimal treatment doses and schedules.

Any means for the introduction of a polynucleotide into mammals, human or non-human, or cells thereof may be adapted to the practice of this invention for the delivery of the various constructs of the invention into the intended recipient. In one embodiment of
10 the invention, the DNA constructs are delivered to cells by transfection, *i.e.*, by delivery of "naked" DNA or in a complex with a colloidal dispersion system. A colloidal system includes macromolecule complexes, nanocapsules, microspheres, beads, and lipid-based systems including oil-in-water emulsions, micelles, mixed micelles, and liposomes. The preferred colloidal system of this invention is a lipid-complexed or liposome-formulated
15 DNA. In the former approach, prior to formulation of DNA, *e.g.*, with lipid, a plasmid containing a transgene bearing the desired DNA constructs may first be experimentally optimized for expression (*e.g.*, inclusion of an intron in the 5' untranslated region and elimination of unnecessary sequences (Felgner, *et al.*, Ann NY Acad Sci 126-139, 1995). Formulation of DNA, *e.g.* with various lipid or liposome materials, may then be effected
20 using known methods and materials and delivered to the recipient mammal. See, *e.g.*, Canonico *et al.*, Am J Respir Cell Mol Biol 10:24-29, 1994; Tsan *et al.*, Am J Physiol 268; Alton *et al.*, Nat Genet. 5:135-142, 1993 and U.S. patent No. 5,679,647 by Carson *et al.*

The targeting of liposomes can be classified based on anatomical and mechanistic factors. Anatomical classification is based on the level of selectivity, for example, organ-
25 specific, cell-specific, and organelle-specific. Mechanistic targeting can be distinguished based upon whether it is passive or active. Passive targeting utilizes the natural tendency of liposomes to distribute to cells of the reticulo-endothelial system (RES) in organs, which contain sinusoidal capillaries. Active targeting, on the other hand, involves alteration of the liposome by coupling the liposome to a specific ligand such as a monoclonal antibody,
30 sugar, glycolipid, or protein, or by changing the composition or size of the liposome in order to achieve targeting to organs and cell types other than the naturally occurring sites of localization.

The surface of the targeted delivery system may be modified in a variety of ways. In the case of a liposomal targeted delivery system, lipid groups can be incorporated into the lipid bilayer of the liposome in order to maintain the targeting ligand in stable association with the liposomal bilayer. Various linking groups can be used for joining the lipid chains to the targeting ligand. Naked DNA or DNA associated with a delivery vehicle, *e.g.*, liposomes, can be administered to several sites in a subject (see below).

Nucleic acids can be delivered in any desired vector. These include viral or non-viral vectors, including adenovirus vectors, adeno-associated virus vectors, retrovirus vectors, lentivirus vectors, and plasmid vectors. Exemplary types of viruses include HSV (herpes simplex virus), AAV (adeno associated virus), HIV (human immunodeficiency virus), BIV (bovine immunodeficiency virus), and MLV (murine leukemia virus). Nucleic acids can be administered in any desired format that provides sufficiently efficient delivery levels, including in virus particles, in liposomes, in nanoparticles, and complexed to polymers.

The nucleic acids encoding a protein or nucleic acid of interest may be in a plasmid or viral vector, or other vector as is known in the art. Such vectors are well known and any can be selected for a particular application. In one embodiment of the invention, the gene delivery vehicle comprises a promoter and a demethylase coding sequence. Preferred promoters are tissue-specific promoters and promoters which are activated by cellular proliferation, such as the thymidine kinase and thymidylate synthase promoters. Other preferred promoters include promoters which are activatable by infection with a virus, such as the α - and β -interferon promoters, and promoters which are activatable by a hormone, such as estrogen. Other promoters which can be used include the Moloney virus LTR, the CMV promoter, and the mouse albumin promoter. A promoter may be constitutive or inducible.

In another embodiment, naked polynucleotide molecules are used as gene delivery vehicles, as described in WO 90/11092 and U.S. Patent 5,580,859. Such gene delivery vehicles can be either growth factor DNA or RNA and, in certain embodiments, are linked to killed adenovirus. Curiel *et al.*, Hum. Gene. Ther. 3:147-154, 1992. Other vehicles which can optionally be used include DNA-ligand (Wu *et al.*, J. Biol. Chem. 264:16985-16987, 1989), lipid-DNA combinations (Felgner *et al.*, Proc. Natl. Acad. Sci. USA 84:7413-7417, 1989), liposomes (Wang *et al.*, Proc. Natl. Acad. Sci. 84:7851-7855, 1987) and microprojectiles (Williams *et al.*, Proc. Natl. Acad. Sci. 88:2726-2730, 1991).

A gene delivery vehicle can optionally comprise viral sequences such as a viral origin of replication or packaging signal. These viral sequences can be selected from viruses such as astrovirus, coronavirus, orthomyxovirus, papovavirus, paramyxovirus, parvovirus, picornavirus, poxvirus, retrovirus, togavirus or adenovirus. In a preferred embodiment, the growth factor gene delivery vehicle is a recombinant retroviral vector. Recombinant retroviruses and various uses thereof have been described in numerous references including, for example, Mann *et al.*, Cell 33:153, 1983, Cane and Mulligan, Proc. Nat'l. Acad. Sci. USA 81:6349, 1984, Miller *et al.*, Human Gene Therapy 1:5-14, 1990, U.S. Patent Nos. 4,405,712, 4,861,719, and 4,980,289, and PCT Application Nos. WO 89/02,468, WO 89/05,349, and WO 90/02,806. Numerous retroviral gene delivery vehicles can be utilized in the present invention, including for example those described in EP 0,415,731; WO 90/07936; WO 94/03622; WO 93/25698; WO 93/25234; U.S. Patent No. 5,219,740; WO 93/11230; WO 93/10218; Vile and Hart, Cancer Res. 53:3860-3864, 1993; Vile and Hart, Cancer Res. 53:962-967, 1993; Ram *et al.*, Cancer Res. 53:83-88, 1993; Takamiya *et al.*, J. Neurosci. Res. 33:493-503, 1992; Baba *et al.*, J. Neurosurg. 79:729-735, 1993 (U.S. Patent No. 4,777,127, GB 2,200,651, EP 0,345,242 and WO91/02805).

Other viral vector systems that can be used to deliver a polynucleotide of the invention have been derived from herpes virus, *e.g.*, Herpes Simplex Virus (U.S. Patent No. 5,631,236 by Woo *et al.*, issued May 20, 1997 and WO 00/08191 by Neurovex), vaccinia virus (Ridgeway (1988) Ridgeway, "Mammalian expression vectors," In: Rodriguez R L, Denhardt D T, ed. Vectors: A survey of molecular cloning vectors and their uses. Stoneham: Butterworth,; Baichwal and Sugden (1986) "Vectors for gene transfer derived from animal DNA viruses: Transient and stable expression of transferred genes," In: Kucherlapati R, ed. Gene transfer. New York: Plenum Press; Coupar *et al.* (1988) Gene, 68:1-10), and several RNA viruses. Preferred viruses include an alphavirus, a poxvirus, an arena virus, a vaccinia virus, a polio virus, and the like. They offer several attractive features for various mammalian cells (Friedmann (1989) Science, 244:1275-1281; Ridgeway, 1988, *supra*; Baichwal and Sugden, 1986, *supra*; Coupar *et al.*, 1988; Horwich *et al.* (1990) J. Virol., 64:642-650).

In other embodiments, target DNA in the genome can be manipulated using well-known methods in the art. For example, the target DNA in the genome can be manipulated by deletion, insertion, and/or mutation are retroviral insertion, artificial chromosome

techniques, gene insertion, random insertion with tissue specific promoters, gene targeting, transposable elements and/or any other method for introducing foreign DNA or producing modified DNA/modified nuclear DNA. Other modification techniques include deleting DNA sequences from a genome and/or altering nuclear DNA sequences. Nuclear DNA sequences, for example, may be altered by site-directed mutagenesis.

In other embodiments, recombinant biomarker polypeptides, and fragments thereof, can be administered to subjects. In some embodiments, fusion proteins can be constructed and administered which have enhanced biological properties. In addition, the biomarker polypeptides, and fragment thereof, can be modified according to well-known pharmacological methods in the art (*e.g.*, pegylation, glycosylation, oligomerization, *etc.*) in order to further enhance desirable biological activities, such as increased bioavailability and decreased proteolytic degradation.

4. Clinical Efficacy

Clinical efficacy can be measured by any method known in the art. For example, the response to a therapy, such as anti-CD39 therapy with or without anti-immune checkpoint inhibitor therapies, relates to any response of the chronic immune disorder, *e.g.*, a tumor, to the therapy, preferably to a change in tumor mass and/or volume after initiation of neoadjuvant or adjuvant chemotherapy.

For example, clinical efficacy for treating chronic immune disorders caused by infectious agents can involve determining reductions in the infectious microbial (*e.g.*, viral, bacterial, fungal, mycoplasma, or parasitic) load in the subject relative to such load in an untreated control. As compared with an equivalent untreated control, such reduction or degree of prevention is at least 5%, 10%, 20%, 40%, 50%, 60%, 80%, 90%, 95%, or 100% as measured by any standard technique. The infectious agent can be completely cleared as detected by any standard method known in the art. Diagnosis and monitoring may involve, for example, detecting the level of microbial load in a biological sample (*e.g.*, tissue biopsy, blood test, or urine test), detecting the level of a biomarker surrogate marker of the infectious agent in a biological sample, detecting symptoms associated with the chronic immune disorder, or detecting immune cells involved in the immune response typical of the chronic immune disorder (*e.g.*, detection of antigen-specific, exhausted CD8⁺ T cells).

Chronic immune disorders associated with cancers can also be assessed. Tumor response may be assessed in a neoadjuvant or adjuvant situation where the size of a tumor

after systemic intervention can be compared to the initial size and dimensions as measured by CT, PET, mammogram, ultrasound or palpation and the cellularity of a tumor can be estimated histologically and compared to the cellularity of a tumor biopsy taken before initiation of treatment. Response may also be assessed by caliper measurement or

5 pathological examination of the tumor after biopsy or surgical resection. Response may be recorded in a quantitative fashion like percentage change in tumor volume or cellularity or using a semi-quantitative scoring system such as residual cancer burden (Symmans *et al.*, *J. Clin. Oncol.* (2007) 25:4414-4422) or Miller-Payne score (Ogston *et al.*, (2003) *Breast* (Edinburgh, Scotland) 12:320-327) in a qualitative fashion like “pathological complete

10 response” (pCR), “clinical complete remission” (cCR), “clinical partial remission” (cPR), “clinical stable disease” (cSD), “clinical progressive disease” (cPD) or other qualitative criteria. Assessment of tumor response may be performed early after the onset of neoadjuvant or adjuvant therapy, *e.g.*, after a few hours, days, weeks or preferably after a few months. A typical endpoint for response assessment is upon termination of

15 neoadjuvant chemotherapy or upon surgical removal of residual tumor cells and/or the tumor bed.

In some embodiments, clinical efficacy of the therapeutic treatments described herein may be determined by measuring the clinical benefit rate (CBR). The clinical benefit rate is measured by determining the sum of the percentage of patients who are in

20 complete remission (CR), the number of patients who are in partial remission (PR) and the number of patients having stable disease (SD) at a time point at least 6 months out from the end of therapy. The shorthand for this formula is $CBR = CR + PR + SD$ over 6 months. In some embodiments, the CBR for a particular anti-immune checkpoint inhibitor therapeutic regimen is at least 25%, 30%, 35%, 40%, 45%, 50%, 55%, 60%, 65%, 70%, 75%, 80%,

25 85%, or more.

Additional criteria for evaluating the response to anti-CD39 therapy with or without anti-immune checkpoint inhibitor therapies are related to “survival,” which includes all of the following: survival until mortality, also known as overall survival (wherein said mortality may be either irrespective of cause or tumor related); “recurrence-free survival”

30 (wherein the term recurrence shall include both localized and distant recurrence); metastasis free survival; disease free survival (wherein the term disease shall include cancer and diseases associated therewith). The length of said survival may be calculated by reference to a defined start point (*e.g.*, time of diagnosis or start of treatment) and end point (*e.g.*,

death, recurrence or metastasis). In addition, criteria for efficacy of treatment can be expanded to include response to chemotherapy, probability of survival, probability of metastasis within a given time period, and probability of tumor recurrence.

For example, in order to determine appropriate threshold values, a particular anti-CD39 therapy with or without anti-immune checkpoint inhibitor therapeutic regimen can be administered to a population of subjects and the outcome can be correlated to biomarker measurements that were determined prior to administration of the therapy or any therapy. The outcome measurement may be pathologic response to therapy given in the neoadjuvant setting. Alternatively, outcome measures, such as overall survival and disease-free survival can be monitored over a period of time for subjects following anti-immune checkpoint inhibitor therapy for whom biomarker measurement values are known. In certain embodiments, the same doses of therapeutic agents are administered to each subject. In related embodiments, the doses administered are standard doses known in the art for such agents. The period of time for which subjects are monitored can vary. For example, subjects may be monitored for at least 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 25, 30, 35, 40, 45, 50, 55, or 60 months. Biomarker measurement threshold values that correlate to outcome of an CD39 therapy with or without anti-immune checkpoint inhibitor therapy can be determined using methods such as those described in the Examples section.

5. Further Uses and Methods of the Present Invention

The compositions described herein can be used in a variety of diagnostic, prognostic, and therapeutic applications.

a. Screening Methods

One aspect of the present invention relates to screening assays, including non-cell based assays. In one embodiment, the assays provide a method for identifying exhausted CD8+ T cells. In another embodiment, the assays provide a method for determining whether a chronic immune disorder is likely to respond to anti-CD39 therapy with or without anti-immune checkpoint inhibitor therapy. In still another embodiment, the assays provide a method for determining whether an agent can reduce exhaustion in exhausted CD8+ T cells with or without anti-immune checkpoint inhibitor therapy. For any method described herein, the presence, copy number, level of expression, and/or level of activity of CD39 or other biomarker described herein can be assessed. In addition, the presence, copy

number, level of expression, and/or level of activity of one or more biomarkers of exhausted T cells can be analyzed (*e.g.*, an immune checkpoint inhibitor).

In one embodiment, the invention relates to assays for screening test agents which bind to, or modulate the biological activity of, at least one biomarker listed in Table 1. In one embodiment, a method for identifying such an agent entails determining the ability of the agent to modulate, *e.g.* inhibit, the at least one biomarker listed in Table 1.

In one embodiment, an assay is a cell-free or cell-based assay, comprising contacting at least one biomarker listed in Table 1, with a test agent, and determining the ability of the test agent to modulate (*e.g.* inhibit) the enzymatic activity of the biomarker, such as by measuring direct binding of substrates or by measuring indirect parameters as described below.

For example, in a direct binding assay, biomarker protein (or their respective target polypeptides or molecules) can be coupled with a radioisotope or enzymatic label such that binding can be determined by detecting the labeled protein or molecule in a complex. For example, the targets can be labeled with ^{125}I , ^{35}S , ^{14}C , or ^3H , either directly or indirectly, and the radioisotope detected by direct counting of radioemission or by scintillation counting. Alternatively, the targets can be enzymatically labeled with, for example, horseradish peroxidase, alkaline phosphatase, or luciferase, and the enzymatic label detected by determination of conversion of an appropriate substrate to product.

Determining the interaction between biomarker and substrate can also be accomplished using standard binding or enzymatic analysis assays. In one or more embodiments of the above described assay methods, it may be desirable to immobilize polypeptides or molecules to facilitate separation of complexed from uncomplexed forms of one or both of the proteins or molecules, as well as to accommodate automation of the assay.

Binding of a test agent to a target can be accomplished in any vessel suitable for containing the reactants. Non-limiting examples of such vessels include microtiter plates, test tubes, and micro-centrifuge tubes. Immobilized forms of the antibodies of the present invention can also include antibodies bound to a solid phase like a porous, microporous (with an average pore diameter less than about one micron) or macroporous (with an average pore diameter of more than about 10 microns) material, such as a membrane, cellulose, nitrocellulose, or glass fibers; a bead, such as that made of agarose or polyacrylamide or latex; or a surface of a dish, plate, or well, such as one made of polystyrene.

In an alternative embodiment, determining the ability of the agent to modulate the interaction between the biomarker and a substrate or a biomarker metabolite and its natural binding partner can be accomplished by determining the ability of the test agent to modulate the activity of a polypeptide or other product that functions downstream or upstream of its position within the pathway (*e.g.*, feedback loops).

The present invention further pertains to novel agents identified by the above-described screening assays. Accordingly, it is within the scope of this invention to further use an agent identified as described herein in an appropriate animal model. For example, an agent identified as described herein can be used in an animal model to determine the efficacy, toxicity, or side effects of treatment with such an agent. Alternatively, an antibody identified as described herein can be used in an animal model to determine the mechanism of action of such an agent.

In some embodiments, the assay is based on the capability of a test agent to modulate the ability of CD39 to bind a substrate or hydrolyzes the substrate. The term "substrate" refers to adenosine triphosphate (ATP) or an analog that can be bound by CD39 and hydrolyzed by CD39. A test agent is contacted or reacted with a suitable reaction mixture comprising CD39 polypeptide and a substrate. The reaction is carried out under conditions and for a time sufficient to allow any substrate hydrolysis to be detected. Subsequently, the presence or absence of hydrolyzed substrate in the substrate may be determined by standard methods known in the art as described above for autophosphorylation assays. Further, the assay may comprise a step, wherein the level of substrate hydrolysis in the presence of a test substance is compared to that in the absence of said test substance. If the level of substrate hydrolysis is decreased as compared to the control (no test substance present), the test substance is an inhibitor of CD39 enzymatic activity. Performing the assay using CD39 expressed on a biological membrane, such as on a cell, can be used to confirm that the CD39 enzymatic activity is also ectonucleotidase activity.

CD39 modulators can also be screened, identified, and characterized by employing calorimetric methods such as differential scanning calorimetry or fluorimetry, or isothermal titration calorimetry or fluorimetry, where the binding of the modulator is analysed with respect to a change in the kinetic properties of CD39. Such methods are known to a person skilled in the art and include measurement of surface plasmon resonance or spectroscopical

methods including fluorescence, UV/visible light, CD, NMR based methods and microscopy methods including atom force microscopy, as well as crystallography.

In cell-based assays, cells can be used that express the specified biomarker of interest on the cell surface. Furthermore, infectious agent load, replication, cytokine
 5 production, colony formation, cellular mobility, proliferation, or other cellular functions can be used as a readout for the assays. In one embodiment, the expression of at least one immune checkpoint inhibitor is analyzed (e.g., PD-1 and/or LAG-3 expression).

b. Predictive Medicine

The present invention also pertains to the field of predictive medicine in which
 10 diagnostic assays, prognostic assays, and monitoring clinical trials are used for prognostic (predictive) purposes to thereby treat an individual prophylactically. Accordingly, one aspect of the present invention relates to diagnostic assays for determining the amount and/or activity level of a biomarker listed in Table 1 in the context of a biological sample (e.g., blood, serum, cells, or tissue) to thereby identify the presence of exhausted CD8+ T
 15 cells and/or the status of an individual afflicted with a chronic immune disorder. Such assays can be used for prognostic or predictive purpose to thereby prophylactically treat an individual prior to the onset or after recurrence of a disorder characterized by or associated with biomarker polypeptide, nucleic acid expression or activity. The skilled artisan will appreciate that any method can use one or more (e.g., combinations) of biomarkers listed in
 20 Table 1.

Another aspect of the present invention pertains to monitoring the influence of agents (e.g., drugs, compounds, and small nucleic acid-based molecules) on the expression or activity of a biomarker listed in Table 1. These and other agents are described in further detail in the following sections.

25 The skilled artisan will also appreciate that, in certain embodiments, the methods of the present invention implement a computer program and computer system. For example, a computer program can be used to perform the algorithms described herein. A computer system can also store and manipulate data generated by the methods of the present invention which comprises a plurality of biomarker signal changes/profiles which
 30 can be used by a computer system in implementing the methods of this invention. In certain embodiments, a computer system receives biomarker expression data; (ii) stores the data; and (iii) compares the data in any number of ways described herein (e.g., analysis relative to appropriate controls) to determine the state of informative biomarkers from

cancerous or pre-cancerous tissue. In other embodiments, a computer system (i) compares the determined expression biomarker level to a threshold value; and (ii) outputs an indication of whether said biomarker level is significantly modulated (e.g., above or below) the threshold value, or a phenotype based on said indication.

5 In certain embodiments, such computer systems are also considered part of the present invention. Numerous types of computer systems can be used to implement the analytic methods of this invention according to knowledge possessed by a skilled artisan in the bioinformatics and/or computer arts. Several software components can be loaded into memory during operation of such a computer system. The software components can
10 comprise both software components that are standard in the art and components that are special to the present invention (e.g., dCHIP software described in Lin *et al.* (2004) *Bioinformatics* 20, 1233-1240; radial basis machine learning algorithms (RBM) known in the art).

The methods of the present invention can also be programmed or modeled in
15 mathematical software packages that allow symbolic entry of equations and high-level specification of processing, including specific algorithms to be used, thereby freeing a user of the need to procedurally program individual equations and algorithms. Such packages include, e.g., Matlab from Mathworks (Natick, Mass.), Mathematica from Wolfram Research (Champaign, Ill.) or S-Plus from MathSoft (Seattle, Wash.).

20 In certain embodiments, the computer comprises a database for storage of biomarker data. Such stored profiles can be accessed and used to perform comparisons of interest at a later point in time. For example, biomarker expression profiles of a sample derived from the non-cancerous tissue of a subject and/or profiles generated from population-based distributions of informative loci of interest in relevant populations of the same species can
25 be stored and later compared to that of a sample derived from the cancerous tissue of the subject or tissue suspected of being cancerous of the subject.

In addition to the exemplary program structures and computer systems described herein, other, alternative program structures and computer systems will be readily apparent to the skilled artisan. Such alternative systems, which do not depart from the above
30 described computer system and programs structures either in spirit or in scope, are therefore intended to be comprehended within the accompanying claims.

c. Diagnostic Assays

The present invention provides, in part, methods, systems, and code for accurately classifying whether a biological sample contains exhausted CD8⁺ T cells and/or is associated with a chronic immune disorder. In some embodiments, the present invention is useful for classifying such a sample using a statistical algorithm and/or empirical data (e.g., the amount or activity of a biomarker listed in Table 1).

An exemplary method involves obtaining a biological sample from a test subject and contacting the biological sample with an agent, such as a protein-binding agent like an antibody or antigen-binding fragment thereof, or a nucleic acid-binding agent like an oligonucleotide, capable of detecting the amount or activity of the biomarker in the biological sample. In some embodiments, at least one antibody or antigen-binding fragment thereof is used, wherein two, three, four, five, six, seven, eight, nine, ten, or more such antibodies or antibody fragments can be used in combination (e.g., in sandwich ELISAs) or in serial. In certain instances, the statistical algorithm is a single learning statistical classifier system. For example, a single learning statistical classifier system can be used to classify a sample as a based upon a prediction or probability value and the presence or level of the biomarker. The use of a single learning statistical classifier system typically classifies the sample as, for example, a likely anti-immune checkpoint inhibitor therapy responder or progressor sample with a sensitivity, specificity, positive predictive value, negative predictive value, and/or overall accuracy of at least about 75%, 76%, 77%, 78%, 79%, 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99%.

Other suitable statistical algorithms are well known to those of skill in the art. For example, learning statistical classifier systems include a machine learning algorithmic technique capable of adapting to complex data sets (e.g., panel of markers of interest) and making decisions based upon such data sets. In some embodiments, a single learning statistical classifier system such as a classification tree (e.g., random forest) is used. In other embodiments, a combination of 2, 3, 4, 5, 6, 7, 8, 9, 10, or more learning statistical classifier systems are used, preferably in tandem. Examples of learning statistical classifier systems include, but are not limited to, those using inductive learning (e.g., decision/classification trees such as random forests, classification and regression trees (C&RT), boosted trees, etc.), Probably Approximately Correct (PAC) learning, connectionist learning (e.g., neural networks (NN), artificial neural networks (ANN), neuro fuzzy networks (NFN), network structures, perceptrons such as multi-layer perceptrons,

multi-layer feed-forward networks, applications of neural networks, Bayesian learning in belief networks, etc.), reinforcement learning (e.g., passive learning in a known environment such as naive learning, adaptive dynamic learning, and temporal difference learning, passive learning in an unknown environment, active learning in an unknown environment, learning action-value functions, applications of reinforcement learning, etc.), and genetic algorithms and evolutionary programming. Other learning statistical classifier systems include support vector machines (e.g., Kernel methods), multivariate adaptive regression splines (MARS), Levenberg-Marquardt algorithms, Gauss-Newton algorithms, mixtures of Gaussians, gradient descent algorithms, and learning vector quantization (LVQ). In certain embodiments, the method of the present invention further comprises sending the sample classification results to a clinician, e.g., an oncologist.

In another embodiment, the diagnosis of a subject is followed by administering to the individual a therapeutically effective amount of a defined treatment based upon the diagnosis.

In one embodiment, the methods further involve obtaining a control biological sample (e.g., biological sample from a subject who does not have a chronic immune disorder or exhausted T CD8⁺ T cells), a biological sample from the subject during remission, or a biological sample from the subject during treatment for the chronic immune disorder.

d. Prognostic Assays

The diagnostic methods described herein can furthermore be utilized to identify subjects having or at risk of developing a chronic immune disorder or for identifying the subjects having a chronic immune disorder who will benefit from anti-CD39 therapy with or without anti-immune checkpoint inhibitor therapy. The assays described herein, such as the preceding diagnostic assays or the following assays, can be utilized to identify a subject having or at risk of developing a disorder associated with a misregulation of the amount or activity of at least one biomarker described in Table 1, such as in cancer. Furthermore, the prognostic assays described herein can be used to determine whether a subject can be administered an agent (e.g., an agonist, antagonist, peptidomimetic, polypeptide, peptide, nucleic acid, small molecule, or other drug candidate) to treat a disease or disorder associated with the aberrant biomarker expression or activity.

e. Treatment Methods

The compositions described herein (including dual binding antibodies and derivatives and conjugates thereof) can be used in a variety of *in vitro* and *in vivo* therapeutic applications using the formulations and/or combinations described herein. In one embodiment, anti-CD39 inhibitor is used. In another embodiment, the anti-CD39 inhibitor is used in combination with one or more additional anti-immune disorder agents. In still another embodiment, at least one of the one or more additional anti-immune disorder agents is an anti-immune checkpoint inhibitor. For example, antibodies that block the interaction between PD-L1, PD-L2, and/or CTLA-4 and their receptors (e.g., PD-L1 binding to PD-1, PD-L2 binding to PD-1, and the like) can be used as anti-immune checkpoint inhibitors.

6. Pharmaceutical Compositions

In another aspect, the present invention provides pharmaceutically acceptable compositions which comprise a therapeutically-effective amount of an agent that modulates biomarker expression and/or activity (e.g., decreases CD39 activity and/or decreases the activity of CD39 activators), one or more anti-immune checkpoint inhibitors, or a combination thereof, formulated together with one or more pharmaceutically acceptable carriers (additives) and/or diluents. As described in detail below, the pharmaceutical compositions of the present invention may be specially formulated for administration in solid or liquid form, including those adapted for the following: (1) oral administration, for example, drenches (aqueous or non-aqueous solutions or suspensions), tablets, boluses, powders, granules, pastes; (2) parenteral administration, for example, by subcutaneous, intramuscular or intravenous injection as, for example, a sterile solution or suspension; (3) topical application, for example, as a cream, ointment or spray applied to the skin; (4) intravaginally or intrarectally, for example, as a pessary, cream or foam; or (5) aerosol, for example, as an aqueous aerosol, liposomal preparation or solid particles containing the compound.

The phrase "therapeutically-effective amount" as used herein means that amount of an agent that modulates biomarker expression and/or activity, or expression and/or activity of the complex, or composition comprising an agent that modulates biomarker expression and/or activity, or expression and/or activity of the complex, which is effective for

producing some desired therapeutic effect, e.g., cancer treatment, at a reasonable benefit/risk ratio.

The phrase “pharmaceutically acceptable” is employed herein to refer to those agents, materials, compositions, and/or dosage forms which are, within the scope of sound
5 medical judgment, suitable for use in contact with the tissues of human beings and animals without excessive toxicity, irritation, allergic response, or other problem or complication, commensurate with a reasonable benefit/risk ratio.

The phrase “pharmaceutically-acceptable carrier” as used herein means a pharmaceutically-acceptable material, composition or vehicle, such as a liquid or solid
10 filler, diluent, excipient, solvent or encapsulating material, involved in carrying or transporting the subject chemical from one organ, or portion of the body, to another organ, or portion of the body. Each carrier must be “acceptable” in the sense of being compatible with the other ingredients of the formulation and not injurious to the subject. Some examples of materials which can serve as pharmaceutically-acceptable carriers include: (1)
15 sugars, such as lactose, glucose and sucrose; (2) starches, such as corn starch and potato starch; (3) cellulose, and its derivatives, such as sodium carboxymethyl cellulose, ethyl cellulose and cellulose acetate; (4) powdered tragacanth; (5) malt; (6) gelatin; (7) talc; (8) excipients, such as cocoa butter and suppository waxes; (9) oils, such as peanut oil, cottonseed oil, safflower oil, sesame oil, olive oil, corn oil and soybean oil; (10) glycols,
20 such as propylene glycol; (11) polyols, such as glycerin, sorbitol, mannitol and polyethylene glycol; (12) esters, such as ethyl oleate and ethyl laurate; (13) agar; (14) buffering agents, such as magnesium hydroxide and aluminum hydroxide; (15) alginic acid; (16) pyrogen-free water; (17) isotonic saline; (18) Ringer's solution; (19) ethyl alcohol; (20) phosphate buffer solutions; and (21) other non-toxic compatible substances employed in
25 pharmaceutical formulations.

The term “pharmaceutically-acceptable salts” refers to the relatively non-toxic, inorganic and organic acid addition salts of the agents that modulates biomarker expression and/or activity, or expression and/or activity of the complex encompassed by the invention. These salts can be prepared *in situ* during the final isolation and purification of the agents,
30 or by separately reacting a purified agent in its free base form with a suitable organic or inorganic acid, and isolating the salt thus formed. Representative salts include the hydrobromide, hydrochloride, sulfate, bisulfate, phosphate, nitrate, acetate, valerate, oleate, palmitate, stearate, laurate, benzoate, lactate, phosphate, tosylate, citrate, maleate, fumarate,

succinate, tartrate, naphylate, mesylate, glucoheptonate, lactobionate, and laurylsulphonate salts and the like (See, for example, Berge *et al.* (1977) "Pharmaceutical Salts", *J. Pharm. Sci.* 66:1-19).

In other cases, the agents useful in the methods of the present invention may contain one or more acidic functional groups and, thus, are capable of forming pharmaceutically-acceptable salts with pharmaceutically-acceptable bases. The term "pharmaceutically-acceptable salts" in these instances refers to the relatively non-toxic, inorganic and organic base addition salts of agents that modulates biomarker expression and/or activity, or expression and/or activity of the complex. These salts can likewise be prepared in situ during the final isolation and purification of the agents, or by separately reacting the purified agent in its free acid form with a suitable base, such as the hydroxide, carbonate or bicarbonate of a pharmaceutically-acceptable metal cation, with ammonia, or with a pharmaceutically-acceptable organic primary, secondary or tertiary amine. Representative alkali or alkaline earth salts include the lithium, sodium, potassium, calcium, magnesium, and aluminum salts and the like. Representative organic amines useful for the formation of base addition salts include ethylamine, diethylamine, ethylenediamine, ethanolamine, diethanolamine, piperazine and the like (see, for example, Berge *et al.*, *supra*).

Wetting agents, emulsifiers and lubricants, such as sodium lauryl sulfate and magnesium stearate, as well as coloring agents, release agents, coating agents, sweetening, flavoring and perfuming agents, preservatives and antioxidants can also be present in the compositions.

Examples of pharmaceutically-acceptable antioxidants include: (1) water soluble antioxidants, such as ascorbic acid, cysteine hydrochloride, sodium bisulfate, sodium metabisulfite, sodium sulfite and the like; (2) oil-soluble antioxidants, such as ascorbyl palmitate, butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), lecithin, propyl gallate, alpha-tocopherol, and the like; and (3) metal chelating agents, such as citric acid, ethylenediamine tetraacetic acid (EDTA), sorbitol, tartaric acid, phosphoric acid, and the like.

Formulations useful in the methods of the present invention include those suitable for oral, nasal, topical (including buccal and sublingual), rectal, vaginal, aerosol and/or parenteral administration. The formulations may conveniently be presented in unit dosage form and may be prepared by any methods well known in the art of pharmacy. The amount of active ingredient which can be combined with a carrier material to produce a single

dosage form will vary depending upon the host being treated, the particular mode of administration. The amount of active ingredient, which can be combined with a carrier material to produce a single dosage form will generally be that amount of the compound which produces a therapeutic effect. Generally, out of one hundred per cent, this amount
 5 will range from about 1 per cent to about ninety-nine percent of active ingredient, preferably from about 5 per cent to about 70 per cent, most preferably from about 10 per cent to about 30 per cent.

Methods of preparing these formulations or compositions include the step of bringing into association an agent that modulates biomarker expression and/or activity, with
 10 the carrier and, optionally, one or more accessory ingredients. In general, the formulations are prepared by uniformly and intimately bringing into association a agent with liquid carriers, or finely divided solid carriers, or both, and then, if necessary, shaping the product.

Formulations suitable for oral administration may be in the form of capsules, cachets, pills, tablets, lozenges (using a flavored basis, usually sucrose and acacia or tragacanth), powders, granules, or as a solution or a suspension in an aqueous or non-
 15 aqueous liquid, or as an oil-in-water or water-in-oil liquid emulsion, or as an elixir or syrup, or as pastilles (using an inert base, such as gelatin and glycerin, or sucrose and acacia) and/or as mouth washes and the like, each containing a predetermined amount of a agent as an active ingredient. A compound may also be administered as a bolus, electuary or paste.

20 In solid dosage forms for oral administration (capsules, tablets, pills, dragees, powders, granules and the like), the active ingredient is mixed with one or more pharmaceutically-acceptable carriers, such as sodium citrate or dicalcium phosphate, and/or any of the following: (1) fillers or extenders, such as starches, lactose, sucrose, glucose, mannitol, and/or silicic acid; (2) binders, such as, for example, carboxymethylcellulose,
 25 alginates, gelatin, polyvinyl pyrrolidone, sucrose and/or acacia; (3) humectants, such as glycerol; (4) disintegrating agents, such as agar-agar, calcium carbonate, potato or tapioca starch, alginic acid, certain silicates, and sodium carbonate; (5) solution retarding agents, such as paraffin; (6) absorption accelerators, such as quaternary ammonium compounds; (7) wetting agents, such as, for example, acetyl alcohol and glycerol monostearate; (8)
 30 absorbents, such as kaolin and bentonite clay; (9) lubricants, such a talc, calcium stearate, magnesium stearate, solid polyethylene glycols, sodium lauryl sulfate, and mixtures thereof; and (10) coloring agents. In the case of capsules, tablets and pills, the pharmaceutical compositions may also comprise buffering agents. Solid compositions of a

similar type may also be employed as fillers in soft and hard-filled gelatin capsules using such excipients as lactose or milk sugars, as well as high molecular weight polyethylene glycols and the like.

A tablet may be made by compression or molding, optionally with one or more
5 accessory ingredients. Compressed tablets may be prepared using binder (for example, gelatin or hydroxypropylmethyl cellulose), lubricant, inert diluent, preservative, disintegrant (for example, sodium starch glycolate or cross-linked sodium carboxymethyl cellulose), surface-active or dispersing agent. Molded tablets may be made by molding in a suitable machine a mixture of the powdered peptide or peptidomimetic moistened with an
10 inert liquid diluent.

Tablets, and other solid dosage forms, such as dragees, capsules, pills and granules, may optionally be scored or prepared with coatings and shells, such as enteric coatings and other coatings well known in the pharmaceutical-formulating art. They may also be formulated so as to provide slow or controlled release of the active ingredient therein using,
15 for example, hydroxypropylmethyl cellulose in varying proportions to provide the desired release profile, other polymer matrices, liposomes and/or microspheres. They may be sterilized by, for example, filtration through a bacteria-retaining filter, or by incorporating sterilizing agents in the form of sterile solid compositions, which can be dissolved in sterile water, or some other sterile injectable medium immediately before use. These compositions
20 may also optionally contain opacifying agents and may be of a composition that they release the active ingredient(s) only, or preferentially, in a certain portion of the gastrointestinal tract, optionally, in a delayed manner. Examples of embedding compositions, which can be used include polymeric substances and waxes. The active ingredient can also be in micro-encapsulated form, if appropriate, with one or more of the
25 above-described excipients.

Liquid dosage forms for oral administration include pharmaceutically acceptable emulsions, microemulsions, solutions, suspensions, syrups and elixirs. In addition to the active ingredient, the liquid dosage forms may contain inert diluents commonly used in the art, such as, for example, water or other solvents, solubilizing agents and emulsifiers, such
30 as ethyl alcohol, isopropyl alcohol, ethyl carbonate, ethyl acetate, benzyl alcohol, benzyl benzoate, propylene glycol, 1,3-butylene glycol, oils (in particular, cottonseed, groundnut, corn, germ, olive, castor and sesame oils), glycerol, tetrahydrofuryl alcohol, polyethylene glycols and fatty acid esters of sorbitan, and mixtures thereof.

Besides inert diluents, the oral compositions can also include adjuvants such as wetting agents, emulsifying and suspending agents, sweetening, flavoring, coloring, perfuming and preservative agents.

Suspensions, in addition to the active agent may contain suspending agents as, for example, ethoxylated isostearyl alcohols, polyoxyethylene sorbitol and sorbitan esters, microcrystalline cellulose, aluminum metahydroxide, bentonite, agar-agar and tragacanth, and mixtures thereof.

Formulations for rectal or vaginal administration may be presented as a suppository, which may be prepared by mixing one or more agents with one or more suitable nonirritating excipients or carriers comprising, for example, cocoa butter, polyethylene glycol, a suppository wax or a salicylate, and which is solid at room temperature, but liquid at body temperature and, therefore, will melt in the rectum or vaginal cavity and release the active agent.

Formulations which are suitable for vaginal administration also include pessaries, tampons, creams, gels, pastes, foams or spray formulations containing such carriers as are known in the art to be appropriate.

Dosage forms for the topical or transdermal administration of an agent that modulates (*e.g.*, inhibits) biomarker expression and/or activity include powders, sprays, ointments, pastes, creams, lotions, gels, solutions, patches and inhalants. The active component may be mixed under sterile conditions with a pharmaceutically-acceptable carrier, and with any preservatives, buffers, or propellants which may be required.

The ointments, pastes, creams and gels may contain, in addition to a agent, excipients, such as animal and vegetable fats, oils, waxes, paraffins, starch, tragacanth, cellulose derivatives, polyethylene glycols, silicones, bentonites, silicic acid, talc and zinc oxide, or mixtures thereof.

Powders and sprays can contain, in addition to an agent that modulates (*e.g.*, inhibits) biomarker expression and/or activity, excipients such as lactose, talc, silicic acid, aluminum hydroxide, calcium silicates and polyamide powder, or mixtures of these substances. Sprays can additionally contain customary propellants, such as chlorofluorohydrocarbons and volatile unsubstituted hydrocarbons, such as butane and propane.

The agent that modulates (*e.g.*, inhibits) biomarker expression and/or activity, can be alternatively administered by aerosol. This is accomplished by preparing an aqueous

aerosol, liposomal preparation or solid particles containing the compound. A nonaqueous (*e.g.*, fluorocarbon propellant) suspension could be used. Sonic nebulizers are preferred because they minimize exposing the agent to shear, which can result in degradation of the compound.

5 Ordinarily, an aqueous aerosol is made by formulating an aqueous solution or suspension of the agent together with conventional pharmaceutically acceptable carriers and stabilizers. The carriers and stabilizers vary with the requirements of the particular compound, but typically include nonionic surfactants (Tweens, Pluronic, or polyethylene glycol), innocuous proteins like serum albumin, sorbitan esters, oleic acid, lecithin, amino
10 acids such as glycine, buffers, salts, sugars or sugar alcohols. Aerosols generally are prepared from isotonic solutions.

Transdermal patches have the added advantage of providing controlled delivery of a agent to the body. Such dosage forms can be made by dissolving or dispersing the agent in the proper medium. Absorption enhancers can also be used to increase the flux of the
15 peptidomimetic across the skin. The rate of such flux can be controlled by either providing a rate controlling membrane or dispersing the peptidomimetic in a polymer matrix or gel.

Ophthalmic formulations, eye ointments, powders, solutions and the like, are also contemplated as being within the scope of this invention.

Pharmaceutical compositions of this invention suitable for parenteral administration
20 comprise one or more agents in combination with one or more pharmaceutically-acceptable sterile isotonic aqueous or nonaqueous solutions, dispersions, suspensions or emulsions, or sterile powders which may be reconstituted into sterile injectable solutions or dispersions just prior to use, which may contain antioxidants, buffers, bacteriostats, solutes which render the formulation isotonic with the blood of the intended recipient or suspending or
25 thickening agents.

Examples of suitable aqueous and nonaqueous carriers which may be employed in the pharmaceutical compositions of the invention include water, ethanol, polyols (such as glycerol, propylene glycol, polyethylene glycol, and the like), and suitable mixtures thereof, vegetable oils, such as olive oil, and injectable organic esters, such as ethyl oleate. Proper
30 fluidity can be maintained, for example, by the use of coating materials, such as lecithin, by the maintenance of the required particle size in the case of dispersions, and by the use of surfactants.

These compositions may also contain adjuvants such as preservatives, wetting agents, emulsifying agents and dispersing agents. Prevention of the action of microorganisms may be ensured by the inclusion of various antibacterial and antifungal agents, for example, paraben, chlorobutanol, phenol sorbic acid, and the like. It may also be
5 desirable to include isotonic agents, such as sugars, sodium chloride, and the like into the compositions. In addition, prolonged absorption of the injectable pharmaceutical form may be brought about by the inclusion of agents which delay absorption such as aluminum monostearate and gelatin.

In some cases, in order to prolong the effect of a drug, it is desirable to slow the
10 absorption of the drug from subcutaneous or intramuscular injection. This may be accomplished by the use of a liquid suspension of crystalline or amorphous material having poor water solubility. The rate of absorption of the drug then depends upon its rate of dissolution, which, in turn, may depend upon crystal size and crystalline form. Alternatively, delayed absorption of a parenterally-administered drug form is accomplished
15 by dissolving or suspending the drug in an oil vehicle.

Injectable depot forms are made by forming microencapsule matrices of an agent that modulates biomarker expression and/or activity, in biodegradable polymers such as polylactide-polyglycolide. Depending on the ratio of drug to polymer, and the nature of the particular polymer employed, the rate of drug release can be controlled. Examples of other
20 biodegradable polymers include poly(orthoesters) and poly(anhydrides). Depot injectable formulations are also prepared by entrapping the drug in liposomes or microemulsions, which are compatible with body tissue.

When the agents of the present invention are administered as pharmaceuticals, to humans and animals, they can be given per se or as a pharmaceutical composition
25 containing, for example, 0.1 to 99.5% (more preferably, 0.5 to 90%) of active ingredient in combination with a pharmaceutically acceptable carrier.

Actual dosage levels of the active ingredients in the pharmaceutical compositions of this invention may be determined by the methods of the present invention so as to obtain an amount of the active ingredient, which is effective to achieve the desired therapeutic
30 response for a particular subject, composition, and mode of administration, without being toxic to the subject.

The nucleic acid molecules of the invention can be inserted into vectors and used as gene therapy vectors. Gene therapy vectors can be delivered to a subject by, for example,

intravenous injection, local administration (see U.S. Pat. No. 5,328,470) or by stereotactic injection (see *e.g.*, Chen *et al.* (1994) *Proc. Natl. Acad. Sci. USA* 91:3054-3057). The pharmaceutical preparation of the gene therapy vector can include the gene therapy vector in an acceptable diluent, or can comprise a slow release matrix in which the gene delivery vehicle is imbedded. Alternatively, where the complete gene delivery vector can be produced intact from recombinant cells, *e.g.*, retroviral vectors, the pharmaceutical preparation can include one or more cells which produce the gene delivery system.

The present invention also encompasses kits for detecting and/or modulating biomarkers described herein. A kit of the present invention may also include instructional materials disclosing or describing the use of the kit or an antibody of the disclosed invention in a method of the disclosed invention as provided herein. A kit may also include additional components to facilitate the particular application for which the kit is designed. For example, a kit may additionally contain means of detecting the label (*e.g.*, enzyme substrates for enzymatic labels, filter sets to detect fluorescent labels, appropriate secondary labels such as a sheep anti-mouse-HRP, *etc.*) and reagents necessary for controls (*e.g.*, control biological samples or metabolite standards). A kit may additionally include buffers and other reagents recognized for use in a method of the disclosed invention. Non-limiting examples include agents to reduce non-specific binding, such as a carrier protein or a detergent.

Other embodiments of the present invention are described in the following Examples. The present invention is further illustrated by the following examples which should not be construed as further limiting.

EXAMPLES

Example 1: Materials and Methods for Examples 2-8

a. Human subjects

Healthy human donors were recruited at the Kraft family Blood Donor Center, Dana-Farber Cancer Institute (DFCI) with written informed consent following approval by Partners Institutional Review Board. All human subjects with HCV infection were recruited at the Gastrointestinal Unit and the Department of Surgery of the Massachusetts General Hospital (Boston, MA) with written consent in accordance with Institutional Review Board approval from the Partners HealthCare. HCV chronics ($n = 27$) were defined by positive anti-HCV antibody and detectable viral load. HCV resolvers ($n = 14$)

were defined by positive anti-HCV antibody but an undetectable viral load for at least 6 months. All HCV patients were treatment naive and obtained between 5.9 and 237.3 weeks post infection. HCV RNA levels were determined using the VERSANT HCV RNA 3.0 (bDNA 3.0) assay (Bayer Diagnostics).

5 All HIV infected cohorts were recruited after written informed consent from the Ragon Institute at the Massachusetts General Hospital (Boston, USA) and the Peter Medawar Building for Pathogen Research (Oxford, UK) where ethics approval was given by the Oxford Research Committee. HIV controllers included elite controllers (n = 5) defined as having HIV RNA below the level of detection (<75 viral copies per ml); viremic
10 controllers (n = 7) with HIV RNA levels < 2,000 viral copies per ml. HIV chronic progressors (n = 28) were defined as having > 2,000 viral copies per ml. All subjects were off therapy. Viral load in chronic infection was measured using the Roche Amplicor® version 1.5 assay.

15 b. HLA Class I tetramers

Major histocompatibility complex (MHC) class I HIV Gag-specific tetramers were produced as described in Leisner *et al.* (2008) *PloS One* 3:e1678 or obtained from Proimmune. CMV- and EBV-specific MHC class I dextramers conjugated with FITC and APC were purchased from Immudex. Mouse MHC class I tetramers of H-2D^b complexed
20 with LCMV GP₂₇₆₋₂₈₆ as described in Wherry *et al.* (2003) *J. Virol.* 77:4911-4927 and Murali-Krishna *et al.* (1998) *Immunity* 8:177-187. Biotinylated complexes were tetramerized using allophycocyanin-conjugated streptavidin (Molecular Probes). The complete list of multimers can be found in Table 2.

Table 2

Virus	Multimer type	HLA	Peptide used	Antigen derived from	Person	Supplier
HCV	Pentamer	A*02:01	GIDPNRTGV	HCV NS3 1273-1682	David Wolski	Proimmune
HCV	Pentamer	A*02:01	KLVALGINAV	HCV NS3 1406-1415	David Wolski	Proimmune
HCV	Pentamer	A*01:01	ATDALMTGY	HCV NS3 1435-1443	David Wolski	Proimmune
HCV	Pentamer	B*40:01	REISVPAIL	HCV NS5a 2266-2274	David Wolski	Proimmune
HCV	Pentamer	B*07:02	GPRLGVRAI	HCV core 41-49	David Wolski	Proimmune
HCV	Pentamer	A*02:01	VLSDPKTVL	HCV NS5a 1987-1995	David Wolski	Proimmune
HCV	Pentamer	A*02:01	YPYRLWHYFC	HCV E2 616-619	David Wolski	Proimmune
HCV	Pentamer	B*27:01	ARMILMTHF	HCV core 470-478	David Wolski	Proimmune
HCV	Pentamer	A*02:01	QINGVCWTV	HCV NS3 1673-1681	David Wolski	Proimmune
CMV	Dextramer	A*02:01	NLVPMVATC	CMV pp65	Kash Gupta	Immudex
EBV	Dextramer	A*02:01	GLCTLVAML	EBV BMLF-1	Kash Gupta	Immudex
HIV	Tetramer	A*24:02	RYPLTFGW	Nef RW8	Emily Adland	Custom made
HIV	Tetramer	B*57:01	KAFSPEVIPMF	Gag RF11	Emily Adland	Custom made
HIV	Tetramer	B*14:02	DRFYKTLRA	Gag DA9	Emily Adland	Custom made
HIV	Tetramer	B*35:01	HFVHAGPIA	Gag HA9	Emily Adland	Custom made
HIV	Tetramer	B*14:02	DRFYKTLRA	Gag DA9	Emily Adland	Custom made
HIV	Dextramer	A*02:01	SLYNTVATL	Gag SL9	Cormac Cosgrove	Immudex
HIV	Pentamer	B*07:02	TPQRLTML	Gag FL9	Cormac Cosgrove	Proimmune
HIV	Dextramer	A*02:01	SLYNTVATL	Gag SL9	Cormac Cosgrove	Immudex
HIV	Dextramer	B*57:01	KAFSPEVIPMF	Gag RF11	Cormac Cosgrove	Immudex
HIV	Tetramer	B*08:01	EYKRWII	Gag EIS	Cormac Cosgrove	Custom made
HIV	Tetramer	B*35:01	VPLRFMTY	Nef VY8	Cormac Cosgrove	Berkman
HIV	Dextramer	B*07:02	GPGHKARVL	Gag GL9	Cormac Cosgrove	Immudex
LCMV	Tetramer	H-2Db	SGVENPGGYCL	GP276-286	Jean Godec	Dr. E. John Wherry

c. Antibodies and flow cytometry

5 The following anti-human (anti-hu) and anti-mouse (anti-m) fluorochrome-conjugated antibodies were used for flow cytometry: huCD8a (RPA-T8), huCD4 (OKT4), huCD3 (OKT3), huCD39 (A1), huPD-1 (EG12.2H7), huCD25 (BC96), huCCR7 (G043H7), huCD45RA (HI100), huT-bet (4B10), mCD8 α (53-6.7), mCD4 (GK1.5), mCD3 (145-2C11), mCD244.2 (m2B4 (B6)458.1), mPD-1 (RMP1-30), mLAG3 (C9B7W),
10 mCD44 (IM7), mCD127 (A7R34) (all from Biolegend), mT-bet (04-46; BD Pharmingen), mCD39 (24DMS1), huEomes (WD1928) and mEomes (Dan11mag) (eBioscience). Intracellular staining was performed following surface stains and fixed and permeabilized using the FoxP3/Transcription Factor Staining Buffer Set (eBioscience). Cells were sorted by BD FACS ARIA[®] II and all other analyses were performed on BD LSR II and BD LSR
15 Fortessa[®] flow cytometers equipped with FACSDiva[®] v6.1. Gates were set using Full Minus One (FMO) controls. Data were analyzed using FlowJo software (Treestar).

d. Mice and infections

20 All mice were used according to the Harvard Medical School Standing Committee on Animals and National Institutes of Animal Healthcare Guidelines. Wildtype C57BL/6J

mice were purchased from The Jackson Laboratory. Female mice (6-8 weeks old) were infected with 2×10^5 plaque forming units (p.f.u.) of LCMV-Armstrong intraperitoneally or 4×10^6 p.f.u. of LCMV-Clone 13 intravenously and analyzed at indicated time points by homogenizing the spleen into a single-cell suspension, ACK lysis of red blood cells, followed by antibody staining. Viruses were propagated as described in Wherry *et al.* (2003) *J. Virol.* 77:4911-4927, Murali-Krishna *et al.* (1998) *Immunity* 8:177-187, and Ahmed *et al.* (1984) *J. Exp. Med.* 160:521-540.

e. HPLC analysis of ATP levels

The concentration of ATP hydrolyzed by CD8⁺ T cells from subjects with HCV infection (n = 6) was assessed by high performance liquid chromatography (HPLC) as described in Lazarowski *et al.* (2004) *J. Biol. Chem.* 279:36855-36864. Briefly, 10,000 CD39⁺ CD8⁺ T cells were sorted and placed on ice to minimize ATP production by cells. Twenty μ M of ATP was added and incubated for 1 h. at 37°C in 5% CO₂ to allow for cellular activity to increase and CD39-mediated ATP hydrolysis to occur. Samples were then placed in an ice bath for 10 min. to halt enzymatic activity, collected, and centrifuged for 10 min at 380 x g rpm and 0°C. Cells were discarded and supernatant centrifuged again to remove remaining cells (2350 x g rpm, 5 min, 0°C). The resulting RPMI samples (160 μ l) were treated with 10 μ l of an 8 M perchloric acid solution (Sigma-Aldrich) and centrifuged at 15,900 x g for 10 min. at 0°C to precipitate proteins. In order to neutralize the pH of the resulting solutions and to remove lipids, supernatants (80 μ l) were treated with 4 M K₂HPO₄ (8 μ l) and tri-N-octylamine (50 μ l). These samples were mixed with 50 μ l of 1,1,2-trichloro-trifluoroethane and centrifuged (15,900 x g, 10 min., 0°C) and this last lipid extraction step was repeated once. The resulting supernatants were subjected to the following procedure to generate fluorescent etheno-adenine products: 150 μ l supernatant (or nucleotide standard solution) was incubated at 72°C for 30 min. with 250 mM Na₂HPO₄ (20 μ l) and 1 M chloroacetaldehyde (30 μ l; Sigma-Aldrich) in a final reaction volume of 200 μ l resulting in the formation of 1,N6-etheno derivatives as described in Lazarowski *et al.* (2004) *J. Biol. Chem.* 279:36855-36864. Samples were placed on ice, alkalized with 0.5 M NH₄HCO₃ (50 μ l), filtered with 1 ml syringe and 0.45 μ m filter and analyzed using a Waters HPLC system and Supelcosil 3 μ M LC-18T reverse phase column (Sigma) consisting of a gradient system described previously, a Waters autosampler, and a Waters 474 fluorescence detector (Chen *et al.* (2006) *Science* 314:1792-1795). Empower2

software was used for the analysis of data and all samples were compared with water and ATP standard controls as well as a sample with no cells to determine background degradation of ATP.

5 f. Microarray data acquisition and analysis

CD8⁺ T cells from subjects with HCV infection were sorted and pelleted and re-suspended in TRIzol (Invitrogen). RNA extraction was performed using the RNeasy Tissue Isolation kit (Qiagen). Concentrations of total RNA were determined with a Nanodrop spectrophotometer or Ribogreen RNA quantification kits (Molecular Probes/Invitrogen). RNA purity was determined by Bioanalyzer 2100 traces (Agilent Technologies). Total RNA was amplified with the WT-Ovation Pico RNA Amplification system (NuGEN) according to the manufacturer's instructions. After fragmentation and biotinylation, cDNA was hybridized to Affymetrix HG-U133A 2.0 microarrays.

Prior to analysis, microarray data were pre-processed and normalized using robust multichip averaging, as described in Haining *et al.* (2008) *J. Immunol.* 181:1859-1868. Differentially gene expression and consensus clustering was performed using Gene-E software (available on the World Wide Web at broadinstitute.org/cancer/software/GENE-E/), and gene set enrichment analysis was performed as described using gene sets from MSigDB (Liberzon (2014) *Methods Mol. Biol.* 1150:153-160) or published resources (Doering *et al.* (2012) *Immunity* 37:1130-1144; Subramanian *et al.* (2005) *Proc. Natl. Acad. U.S.A.* 102:15545-15550). EnrichmentMap analysis of GSEA results was performed as described in Merico *et al.* (2010) *PloS One* 5:e13984.

g. CD8⁺ T cell cytokine assays

Ly5.1⁺ (CD45.1⁺) P14 TCR transgenic cells were isolated from peripheral blood, and 500 P14 cells were transferred intravenously (i.v.) into 5-6 week old wild-type female mice one day prior to infection. Mice were infected with 4 x 10⁶ p.f.u. of LCMV-Clone 13 intravenously and analyzed 36 days following infection by homogenizing the spleen into a single-cell suspension. 2 x 10⁶ splenocytes were cultured in the presence of GP₃₃₋₄₁ peptide (0.2 µg/ml) (sequence KAVYNFATM), brefeldin A (BD), and monensin (BD) for 4.5 hours at 37°C. Following staining for surface antigens CD8, CD44, CD45.1, and CD45.2 in order to distinguish transferred CD45.1⁺ P14 CD8⁺ T cells from endogenous CD45.2⁺ CD8⁺ T cells, cells were permeabilized and stained for intracellular cytokines IFNγ and

TNF α with the BD Cytofix/Cytoperm™ kit according to the manufacturer's instructions (BD Biosciences).

h. CD8⁺ T cell tumor assays

5 C57BL/6 wild type mice were injected subcutaneously in the flank with 1 million B16 melanoma cells or MC38 colorectal cancer cells. Mice were analyzed when tumors reached 1,000 mm³, which generally occurred about 3 weeks post-injection. The tumor draining inguinal lymph node, as well as the tumor, were excised and homogenized into single cell suspensions. The tumor was further digested using collagenase and CD8⁺ T cells
10 were enriched using an OptiPrep™ gradient. Lymphocytes from the tumor and lymph node were stained with antibodies to CD45, CD8b, CD44, PD-1, CD39, Tim-3, Lag-3, CD244, T-bet, Eomes, Tox, IL-2, TNF α , and IFN γ . For cytokine analysis, the CD8⁺ T cells were stimulated *in vitro* with phorbol 12-myristate 13-acetate (50 ng/mL) and ionomycin (500 ng/mL) in the presence of brefeldin A (BD) for 4 hours at 37°C. After stimulation, the cells
15 were permeabilized and stained for the intracellular cytokines IL-2, IFN γ , and TNF α with the Foxp3 Fix/Perm® kit (eBioscience). For analysis of the transcription factors, Eomes, Tox, and T-bet, the cells were permeabilized and stained for the intracellular transcription factors Eomes, Tox, and T-bet with the Foxp3 Fix/Perm® kit (eBioscience).

20 **Example 2: CD39 is expressed by CD8⁺ T cells responding to chronic infection**

The expression of CD39 by CD8⁺ T cells from healthy adult subjects without chronic viral infection was analyzed. Consistent with previous reports, it was found that only a small fraction (mean 7%) of CD8⁺ T cells in healthy individuals expressed CD39 (Figure 1A) (Kansas *et al.* (1991) *J. Immunol.* 146:2235-2244; Moncrieffe *et al.* (2010) *J.*
25 *Immunol.* 185:134-143; Pulte *et al.* (2011) *Clin. Lymph. Myeloma Leuk.* 11:367-372; Boer *et al.* (2013) *Eur. J. Immunol.* 43:1925-1932). This small population of CD39⁺ CD8⁺ T cells in healthy donors was primarily found in the effector memory compartment while virtually no naïve CD8⁺ T cells expressed CD39 (Figure 2). CD39 expression by antigen-specific CD8⁺ T cells specific for latent viruses in healthy subjects was also analyzed. It
30 was found that only a very small fraction of CMV- or EBV-specific CD8⁺ T cells expressed CD39 (Figure 1A) (mean 3% and 7% respectively).

In order to analyze CD39 expression by T cells specific for chronic, rather than latent, viruses, peripheral blood samples of individuals with either HCV or HIV infection were analyzed. CD39 expression was measured in 34 subjects with acute HCV infections

(13 with acute resolving infection and 21 with chronically evolving infection), and in 40 subjects with HIV infection (28 chronic progressors and 12 controllers of infection) (clinical characteristics of the subjects are summarized in Table 3). It was found that a mean of 58% of HCV-specific CD8⁺ T cells and 31% of HIV-specific CD8⁺ T cells expressed CD39, a number significantly higher than CD8⁺ T cells specific for EBV or CMV, or in total CD8⁺ T cell populations from healthy individuals (Figures 1A-1B). A significantly greater fraction of virus-specific CD8⁺ T cells from HCV-infected subjects expressed CD39 than did those from HIV-infected subjects.

In subjects with chronic infection, the frequency of CD39-expressing cells in the virus-specific population was significantly higher than in the total CD8⁺ T cell population (Figures 1C-1D). However, the fraction of CD8⁺ T cells expressing CD39 in the CD8⁺ T cell compartment of individuals with chronic infection was slightly increased compared to healthy controls (Figure 1E), consistent with the presence of other, unmeasured virus-specific CD8⁺ T cells that were also CD39⁺ in the tetramer⁺ fraction of CD8⁺ T cells. Thus, CD39 is expressed infrequently by CD8⁺ T cells in healthy donors, but marks a large fraction of pathogen-specific cells CD8⁺ T cells in patients with chronic infection.

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Table 3

Patient ID	Gender	Chronic/Resolver	Viral Load/iu/L	Virus Genotype	ALT/iu/L
00-23 P11 C63B	F	Chronic	<300	1a	18
00-23 P27 C63B	F	Chronic		1b	24
06-42 P3	F	Chronic	532372	1a	280
06-42 P5 143D	F	Chronic	<615	1a	
06K P3 143D	F	Resolver	<600	1a	124
06K P6 143D	F	Resolver	undetected	1a	
06L	M	Resolver		3	
06L P7 4H	M	Resolver	undetected	3	82
07-32 P2 4H	M	Chronic		2b	565
07-32 P5 4H	M	Chronic	69200	2b	263
07-39 P18	M	Chronic	1170	1a	33
07P3	M	Chronic	1162	4a	34
07P4	M	Chronic		1a	1379
08-024 P1250A	F	Chronic	>700000	1	411
08-024 P14 A3Pool	F	Chronic	<43	1	11
08-024 P4 250A	F	Chronic	7540000	1	259
08-024 P5 A3Pool	F	Chronic	<600	1	35
08-024 P6 A3Pool	F	Chronic		1	11
08-027 P1A2-198	M	Chronic	3838	no test	58
08-027 P5 A2-198	M	Chronic	1021	no test	75
08-23 P13	M	Resolver		1	
08-27 P2	M	Resolver		no test	
09-31 P3	M	Chronic	detected	1a	128
09-33 P3	F	Resolver		1a	20
09-33 P5 143D	F	Resolver	undetected	1a	15
09-37 P3 c63b	M	Chronic	<600	1a	32
09B P1 143D	M	Chronic	217000	1a	354
09B P5	M	Chronic	223000	1a	73
10-048 P2 143D	F	Chronic		1a	179
10-054 P1 143D	F	Chronic	1130	1a	209
10-078 P1A2 226D	M	Chronic	69200	3a	875
10-19 P3	F	Resolver	<615		19
11-014 P1 143D	M	Resolver	3150	2a	129
11-017 P4 140G/253F	F	Chronic	25431	1a	461
12-043 P2 143D	M	Resolver	61602		692
12-103 P1 4H	F	Chronic	432	3a	44
12-181 P1 4H	F	Chronic		3a	
13-024 P1 140G	M	Chronic	147	1a	205
BR-3000 P12 A2 Mix2	M	Resolver	undetected	1a	24
BR-3000 P2 A2 Mix2	M	Resolver	47272	1a	36
BR-554 P13 C63B	F	Chronic	2038	1a	9
BR-554 P17 C63B	F	Chronic	6463017	1a	45
BR-554 P3 C63B	F	Chronic	64497	1a	39
BR1036 P13 C63B	F	Resolver	<1000	undetectable	28
BR1036 P9 C63B	F	Resolver	<1000	undetectable	4
BR1144 P10 C63B	F	Resolver	<1000	undetectable	13
BR1144 P5 C63B	F	Resolver	<1000	undetectable	2
BR554 P13 C63B	F	Chronic	2038	1a	9
BR554 P17 C63B	F	Chronic	6463017	1a	45
BR943 P5 C63B	F	Chronic	70047	1	36
CP54 P2 4H	F	Chronic	detected	1	237
CP54 P3 4H	F	Chronic	detected	1	103
Total = 32 (22 chronics and 10 resolvers)					

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Table 3 (cont.)

Patient ID	Gender	Progressor/Controller	ON/OFF Rx	Viral Load/cpm	CD4 Count	HLA A	HLA B	HLA C
254567	M	Chronic	OFF	1823	806	0101.0201	0801.1501	0303.0701
350103	F	Chronic	OFF	431	825	0201.0301	1501.5701	0401.0602
350534	M	Chronic	OFF	24500	154	0101.0201	4402.5301	0602.0602
358280	M	Chronic	OFF	10322	541	0101.0101	0801.1202	0602.0701
384682	M	Chronic	ON	147	510	1101.7411	1503.3501	0210.0401
387879	M	Chronic	OFF	14600	677	2902.3002	0702.3501	0401.1505
403996	F	Chronic	OFF	2100	877	0101.0201	4402.5701	0602.1203
126019	M	Viraemic Controllers	OFF	unknown	unknown	2402.6901	3801.5701	0602.1203
186089	M	Viraemic Controllers	OFF	82	740	0101.0201	4001.5201	0304.1202
237883	F	Viraemic Controllers	OFF	189	1232	3201.3201	2705.4402	0102.0501
370345	M	Viraemic Controllers	OFF	15	unknown	0201.0301	0801.4405	0202.0701
302325	M	Viraemic Controllers	OFF	65	484	0101.2301	4501.5701	0802.0602
711960	M	Viraemic Controllers	OFF	300	700	0201.0205	5201.5801	0701.1202
732751	M	Viraemic Controllers	OFF	1880	1550	0201.3001	1705.4201	0301.17
255875	M	Elite Controllers	OFF	103	963	0201.0201	3705.5701	0102.0602
289188	M	Elite Controllers	OFF	unknown	unknown	0101.2402	3801.5701	0602.1203
285287	F	Elite Controllers	OFF	118	1246	0101.0201	5101.5701	0602.1502
321797	M	Elite Controllers	OFF	unknown	unknown	2402.2501	2705.5701	0103.0602
631969	F	Elite Controllers	OFF	unknown	unknown	0301.3501	4501.5701	0802.0602
R060	M	Chronic	OFF	117234	480	0101.2402	0702.3501	0303.0702
R088	M	Chronic	OFF	172888	410	0101.2402	1801.1801	0702.1203
R089	M	Chronic	OFF	44000	680	0301.2402	0702.3701	0602.0702
R048	M	Chronic	OFF	28445	510	0101.0301	4402.5701	0501.0602
R050	M	Chronic	OFF	30310	440	0101.0101	0702.5701	0502.0701
R041	M	Chronic	OFF	8435	320	0101.2402	0801.1402	0701.0802
R017	M	Chronic	OFF	172885	410	2402.8001	0702.5801	0302.0302
N034	M	Chronic	OFF	44000	680	2402.3101	4402.4901	0701.1601
R134	M	Chronic	OFF	500000	430	0301.3401	0801.3501	0401.0701
N012	M	Chronic	OFF	36695	7	0101.2402	0702.0801	0701.0702
N090	F	Chronic	OFF	3362	490	0201.2402	4001.4001	0304.0304
N104	M	Chronic	OFF	4533	390	1101.2402	0702.5501	0303.0702
ON019	F	Chronic	OFF	42912	740	0101.2402	0801.3906	0701.0702
R051	M	Chronic	OFF	500000	560	0101.3502	1801.3501	0401.0501
R089	M	Chronic	OFF	68257	450	0301.0301	0702.3501	0401.0702
N004	M	Chronic	OFF	500000	430	6802.6802	3501.3501	0401.0401
N093	F	Chronic	OFF	2216	700	3001.3402	1510.3501	0304.0401
ON034	M	Chronic	OFF	124153	430	0201.1101	0702.3501	0401.0702
H005	M	Chronic	OFF	747	640	3004.7401	3501.5602	0401.0602
H033	M	Chronic	OFF	8036	430	3601.7401	3501.5301	0401.0401
R103	F	Chronic	OFF	8435	320	3201.3303	1402.5301	0401.0802

Example 3: CD39 expressed by CD8⁺ T cells hydrolyzes ATP

CD39 expressed by regulatory T cells catalyzes the hydrolysis of ADP to 5'-AMP (Kansas *et al.* (1991) *J. Immunol.* 146:2235-2244; Deaglio *et al.* (2007) *J. Exp. Med.*

- 5 204:1257-1265; Borsellino *et al.* (2007) *Blood* 110:1225-1232). Therefore, the enzymatic function of CD39 expressed by CD8⁺ T cells from patients infected with chronic HCV using ATP hydrolysis as a surrogate marker of CD39 activity was tested. CD39⁺ and CD39⁻ CD8⁺ T cells were sorted from six HCV-infected individuals (four with chronic infection and two with resolved infection) and equal numbers of cells were incubated in the
- 10 presence of extracellular ATP (eATP). The remaining levels of eATP were measured in the

supernatant by HPLC. As control, ATP hydrolysis by CD4⁺ CD25⁺ CD39⁺ regulatory T cells (Tregs) sorted from the same individuals was assessed.

Within the CD39⁺ CD8⁺ T cell population, the level of CD39 expression was lower than in Tregs (Figures 3A-3B). However, ATP hydrolysis by CD39⁺ CD8⁺ T cells was significantly greater than that of CD39⁺ cells (Figure 4C). Consistent with reduced CD39 expression relative to Tregs (Figure 3A-3B), ATP hydrolysis by CD39⁺ CD8⁺ T cells was less than that by Tregs (Figure 3C). These data indicate that CD39 expressed by CD8⁺ T cells in HCV infection is enzymatically active and capable of hydrolyzing ATP.

Example 4: CD39 is co-expressed with PD-1 on virus-specific CD8⁺ T cells and correlates with viral load in both HCV and HIV infection

CD8⁺ T cells specific for chronic viruses, such as HCV and HIV, express increased levels of PD-1 (Day *et al.* (2006) *Nature* 443:350-354; Kasproiewicz *et al.* (2008) *J. Virol.* 82:3154-3160). Thus, the relationship between CD39 and PD-1 expression by virus specific CD8⁺ T cells in 40 patients infected with HIV (21 chronic progressors, 7 viremic controllers and 5 elite controllers) and 39 patients with HCV (21 chronically infected and 13 resolvers) was examined. In both diseases, a significant association between the level of expression (mean fluorescence intensity, MFI) of CD39 and PD-1 on antigen-specific CD8⁺ T cells both in subjects with HCV and with HIV ($R^2=0.56$, $P<0.0001$ and $R^2=0.3$, $P<0.05$, respectively) was identified (Figures 4A-4B and Figure 5).

It was next asked whether CD39 expression on viral-specific CD8⁺ T cells in chronic viral infection could differentiate between patients with varying disease severity. Higher levels of PD-1 expression have been associated with surrogates of poor clinical outcome in HIV although the relationship is less clear for HCV (Day *et al.* (2006) *Nature* 443:350-354; Kasproiewicz *et al.* (2008) *J. Virol.* 82:3154-3160; Urbani *et al.* (2006) *J. Virol.* 80:11398-11403). In HCV, it was found that the fraction of CD8⁺ T cells expressing both CD39 and PD-1 was significantly higher in subjects with chronic infection, compared to those who with resolved infection (Figure 4C, left panel). Similarly in HIV, it was found that the fraction of CD39⁺ PD-1⁺ virus-specific CD8⁺ T cells was significantly higher in patients with chronic disease than in controllers (Figure 4C, right panel).

The relationship between CD39 and PD-1 expression and viral load in HCV and HIV infection was also analyzed. It was found that both the HCV and HIV subject groups demonstrated a significant positive correlation between viral load and the level of CD39

expression on viral-specific CD8⁺ T cells (Figure 4D, left panel). The association between viral load and CD39 expression by HCV-specific CD8⁺ T cells was slightly stronger than in HIV-specific CD8⁺ T cells (Figure 4D). Consistent with previous reports, PD-1 expression also correlated with the viral load in HIV-infected patients (Figure 4E) (Day *et al.* (2006) *Nature* 443:350-354; Kasproiewicz *et al.* (2008) *J. Virol.* 82:3154-3160). These data indicate that increased the antigen burden and inflammatory environment present in chronic HIV and chronic HCV infection is associated with increased expression of CD39 by virus-specific CD8⁺ T cells.

10 **Example 5: Transcriptional analysis of CD39⁺ CD8⁺ T cells in HCV infection**

In order to characterize more broadly the phenotype of CD39⁺ CD8⁺ T cells from individuals with chronic infection, the global gene expression profiles of sorted CD39⁺ and CD39⁻ CD8⁺ T cells from 8 HCV-infected subjects (3 with acute resolving infection and 5 with chronically evolving infection) was compared. Clinical characteristics and information on cell sorting and cDNA quantification can be found in Table 4 and Figure 6. Limited numbers of cells precluded the comparison of CD39⁺ and CD39⁻ CD8⁺ T cells within HCV-specific cells, leading to a focus on the total CD8⁺ population of antigen-experienced CD8⁺ T cells (Table 4). Because naive CD8⁺ T cells express little CD39 (Figure 2), this population was excluded from the sorted cells (Figure 6) in order to enable direct comparison of antigen-experienced CD39⁺ and CD39⁻ CD8⁺ T cells. Unsupervised analysis of gene expression profiles using consensus hierarchical clustering (Figure 7A) showed two distinct clusters of samples which corresponded almost exactly to CD39⁺ and CD39⁻ populations, indicating that that CD39 expression demarcates two types of CD8⁺ T cells with markedly different patterns of gene expression. Supervised analysis of differential gene expression identified 619 genes differentially expressed (FDR<0.15) between CD39⁺ and CD39⁻ CD8⁺ T cells (Table 4). Inspection of the list of differentially expressed genes revealed many with known roles in CD8⁺ T cell biology including increased expression of the inhibitory receptors PD-1 and CTLA-4 in CD39⁺ CD8⁺ T cells.

30

Table 4

Gene	Affymetrix ProbeSet Number	Signal to Noise	Rank	p-value	FDR(BH)	Fold Change
ENTPD1	228585_at	1.6166	3	0.001865	0.1043	5.7818
CTLA4	236341_at	1.5189	8	0.0006216	0.08198	3.8931
BCAT1	226517_at	0.8707	338	0.00404	0.1192	3.7141
CHN1	212624_s_at	1.3749	19	0.0009324	0.0867	3.6246
TOP2A	237469_at	0.9373	245	0.00404	0.1192	3.4747
PASK	216945_x_at	1.0923	103	0.002176	0.1073	3.0861
HLA-DRA	210982_s_at	0.9644	212	0.00404	0.1192	2.5181
SPRY1	230212_at	0.9938	184	0.004662	0.1285	2.5022
TNFRSF25	219423_x_at	1.1711	71	0.001554	0.1014	2.4302
TIAM1	213135_at	1.2308	48	0.001243	0.09507	2.339
CCNE1	242105_at	0.9869	188	0.003108	0.1141	2.2869
POU2AF1	205267_at	1.0855	110	0.001243	0.09507	2.2527
TRIB1	239818_x_at	1.2677	41	0.0006216	0.08198	2.2411
NGFRAP1	217963_s_at	1.1219	90	0.0006216	0.08198	2.2196
SNED1	213493_at	1.4009	13	0.0003108	0.07173	2.1733
AKAP5	230846_at	0.7793	535	0.005594	0.1372	2.1278
RCAN3	229064_s_at	1.7913	1	0.0003108	0.07173	2.1042
ICOS	210439_at	0.9978	180	0.00373	0.1192	2.0859
MYB	215152_at	0.9376	244	0.003419	0.1181	2.084
PHEX	239229_at	0.9058	283	0.00404	0.1192	2.061
CC2D2B	243534_at	1.277	37	0.0006216	0.08198	2.0535
AIF1	215051_x_at	0.9386	242	0.00404	0.1192	2.0438
CXCL13	205242_at	0.7096	772	0.002797	0.1126	2.0253
CCR4	208376_at	0.9371	246	0.003419	0.1181	2.0074
JAG1	231183_s_at	0.8535	361	0.001554	0.1014	2.0002
MEOX1	205619_s_at	0.8474	374	0.007148	0.1493	1.9779
ESPN	234281_at	1.057	127	0.002176	0.1073	1.9585
ZC2HC1A	241808_at	1.0797	114	0.0009324	0.0867	1.952
BUB1	216277_at	1.2001	62	0.0003108	0.07173	1.9324
MIR1204	222087_at	1.029	152	0.003108	0.1141	1.8742
USP36	227093_at	0.9968	181	0.0003108	0.07173	1.8693
TACC3	218308_at	1.0244	157	0.003419	0.1181	1.8655
CD28	211861_x_at	1.1224	88	0.001243	0.09507	1.8519
FKBP5	224856_at	0.8617	352	0.005905	0.1406	1.8418
FAM134B	218532_s_at	0.8621	350	0.006838	0.1475	1.7984
ITM2A	202747_s_at	0.9947	183	0.002176	0.1073	1.7762
CCDC64	228320_x_at	1.01	172	0.002176	0.1073	1.7529
CAMK4	241871_at	1.1362	81	0.001554	0.1014	1.6948

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LMCD1	227317_at	1.2828	34	0.0009324	0.0867	1.6858
MFGE8	210605_s_at	0.9448	237	0.00373	0.1192	1.6769
HIA-DOA	226878_at	1.0575	126	0.001554	0.1014	1.672
MIDIIP1	218251_at	1.0447	134	0.001554	0.1014	1.654
POLR1E	231041_at	1.238	47	0.001243	0.09507	1.6397
FLJ13224	220211_at	1.1922	66	0.001243	0.09507	1.6371
ASAP1-IT1	220694_at	0.8612	355	0.005284	0.1352	1.6268
INTS1	212212_s_at	1.581	5	0.0003108	0.07173	1.6224
SYNJ2	240257_at	1.1955	64	0.0009324	0.0867	1.6214
CD7	214551_s_at	0.9165	270	0.004662	0.1285	1.6204
CD74	209619_at	1.317	29	0.001243	0.09507	1.6103
GNA15	205349_at	1.0357	143	0.003108	0.1141	1.6005
SHMT2	214437_s_at	0.9797	198	0.0009324	0.0867	1.5858
UX51	225583_at	1.0347	147	0.001243	0.09507	1.5698
LIMD2	218600_at	1.0731	117	0.001554	0.1014	1.5658
CD79A	205049_s_at	1.2543	44	0.0003108	0.07173	1.5641
UBE2S	202779_s_at	1.1038	96	0.0006216	0.08198	1.5641
PRKAR1B	212559_at	1.2049	59	0.0009324	0.0867	1.5641
CENPO	226118_at	1.0167	163	0.002176	0.1073	1.5639
ZEB1	239952_at	1.1401	80	0.0006216	0.08198	1.5586
GYPC	202947_s_at	1.3787	16	0.0009324	0.0867	1.5515
TBXA2R	336_at	1.0191	160	0.002797	0.1126	1.5346
ZNF335	78330_at	0.9035	290	0.006838	0.1475	1.5271
MCM5	216237_s_at	0.7582	603	0.003108	0.1141	1.5265
PBK	219148_at	0.9477	234	0.004662	0.1285	1.5127
ADRBK2	228771_at	0.9401	240	0.002486	0.1089	1.5054
MLLT1	224993_at	1.2092	57	0.0009324	0.0867	1.5011
C17orf48	223401_at	0.9041	288	0.006216	0.1445	1.5007
C16orf45	212736_at	0.8615	353	0.005594	0.1372	1.497
LINC00312	240306_at	0.8172	444	0.007148	0.1493	1.4928
PRRG4	238513_at	1.0034	177	0.003108	0.1141	1.4913
LGALS2	208450_at	0.8456	377	0.007148	0.1493	1.49
LOC441666	216469_at	0.9687	208	0.001865	0.1043	1.4797
CNOT3	229143_at	1.1635	74	0.002176	0.1073	1.479
SLC19A1	229639_s_at	0.9586	218	0.0009324	0.0867	1.4771
SEC14L2	240024_at	0.9212	264	0.00373	0.1192	1.4728
E2F8	219990_at	0.7759	542	0.003108	0.1141	1.4676
PDIA5	203857_s_at	1.059	125	0.002486	0.1089	1.4642
C19orf6	230089_s_at	1.2051	58	0.0009324	0.0867	1.4635
ADRBK1	38447_at	1.0157	164	0.0009324	0.0867	1.4631
MYO9B	217297_s_at	1.2785	35	0.0009324	0.0867	1.4598
ADCY3	209321_s_at	1.0122	167	0.001243	0.09507	1.4586

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MED15	222175_s_at	1.0916	104	0.0006216	0.08198	1.4552
COL6A3	201438_at	0.9549	222	0.002176	0.1073	1.4518
HSP1	213756_s_at	1.5899	4	0.0003108	0.07173	1.4454
CHMP7	212313_at	0.8836	320	0.006527	0.1462	1.4306
RAD54L	204558_at	0.9647	211	0.0009324	0.0867	1.4297
FAM108B1	228872_at	0.9388	241	0.004662	0.1285	1.4267
ZBTB48	205025_at	0.9019	292	0.006216	0.1445	1.4256
ETV1	221911_at	1.1624	75	0.001554	0.1014	1.4196
ECE1	201750_s_at	0.7817	530	0.007148	0.1493	1.4194
MECP2	241924_at	0.8589	357	0.006216	0.1445	1.4147
CCDC94	204335_at	1.0401	138	0.0009324	0.0867	1.4143
CYP4F11	206153_at	1.0791	115	0.003108	0.1141	1.4053
PDCD1	207634_at	1.0186	162	0.002486	0.1089	1.3992
AGPAT3	225440_at	1.2296	50	0.0009324	0.0867	1.3958
EPB41	225051_at	1.0982	97	0.001554	0.1014	1.3944
DTX2	215732_s_at	0.984	190	0.003108	0.1141	1.3941
ARHGD1A	213606_s_at	0.8844	319	0.00404	0.1192	1.39
KLF13	225390_s_at	0.978	201	0.003108	0.1141	1.3877
AURKAIP1	228800_x_at	0.8636	347	0.005594	0.1372	1.3874
TCEB3	213604_at	1.2999	31	0.0009324	0.0867	1.386
PPP1R7	213465_s_at	0.8799	328	0.006838	0.1475	1.3831
CDC37	209953_s_at	0.9299	253	0.004662	0.1285	1.3827
EIF3A	200597_at	0.8531	363	0.002797	0.1126	1.3818
ASNA1	202024_at	1.1055	95	0.001865	0.1043	1.374
BTBD2	207722_s_at	0.883	324	0.002797	0.1126	1.3731
AP3D1	210974_s_at	1.1529	78	0.001554	0.1014	1.3716
OGDH	201282_at	1.0981	98	0.002486	0.1089	1.3711
NR2F2	229092_at	1.0777	116	0.0006216	0.08198	1.3708
POLR2E	217854_s_at	0.7512	627	0.004351	0.1241	1.3702
NA82	216017_s_at	1.1187	91	0.0006216	0.08198	1.37
TLR8	229560_at	1.3757	18	0.001554	0.1014	1.3698
R3HDM4	55705_at	0.9036	289	0.005284	0.1352	1.3674
SMOX	217074_at	0.8996	297	0.003419	0.1181	1.3654
OTUB1	38710_at	0.8949	302	0.006527	0.1462	1.3654
RBFOX2	216215_s_at	0.9073	282	0.003419	0.1181	1.3649
DNMT3L	220139_at	1.3772	17	0.0006216	0.08198	1.362
BAI3	211568_at	1.3393	27	0.0003108	0.07173	1.3617
MYO7B	235383_at	1.2227	53	0.0006216	0.08198	1.3584
RFX2	226872_at	1.1614	76	0.002797	0.1126	1.358
CHAF1A	229808_at	0.8502	367	0.006527	0.1462	1.3576
CSF3R	203591_s_at	0.9518	225	0.004351	0.1241	1.3572
LMNB2	216952_s_at	1.0084	173	0.0009324	0.0867	1.3568

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SRM	201516_at	0.9723	204	0.002486	0.1089	1.3561
ASCL2	229215_at	0.8975	300	0.003419	0.1181	1.3546
F3	204363_at	1.1498	79	0.0003108	0.07173	1.3511
TBXAS1	236345_at	0.9024	291	0.007148	0.1493	1.3498
MRPL12	229165_at	0.965	210	0.0006216	0.08198	1.3494
CLPB	224510_s_at	1.0053	175	0.0009324	0.0867	1.3478
RAB9BP1	208245_at	0.8935	305	0.004662	0.1285	1.3454
MICAL1	55081_at	0.8136	448	0.005284	0.1352	1.3435
RFX1	226786_at	1.0357	144	0.002176	0.1073	1.3427
USE1	221706_s_at	1.0559	129	0.002797	0.1126	1.3419
NFRKB	237210_at	0.8421	384	0.005905	0.1406	1.3413
CCNL2	232274_at	1.0409	137	0.001243	0.09507	1.3391
HAPLN2	220142_at	1.2256	52	0.0003108	0.07173	1.3387
LMTK2	235307_at	1.1306	82	0.002486	0.1089	1.3387
CLK3	238072_at	1.0569	128	0.0006216	0.08198	1.3383
WIF1	204712_at	0.9548	223	0.004973	0.1317	1.3382
DEAF1	230059_at	1.2261	51	0.0009324	0.0867	1.3357
CLN6	222539_at	0.8746	332	0.005284	0.1352	1.3338
BSG	208677_s_at	0.8824	325	0.004351	0.1241	1.3327
PARD6A	205245_at	1.0353	145	0.001243	0.09507	1.332
POU3F2	242455_at	1.5791	6	0.0006216	0.08198	1.3309
MLNR	221365_at	0.8848	317	0.003419	0.1181	1.3299
LYL1	210044_s_at	1.0671	121	0.001865	0.1043	1.3297
RBM47	229440_at	1.0046	176	0.003108	0.1141	1.3296
POLDIP3	243411_at	0.9099	276	0.005594	0.1372	1.3296
AKT2	236664_at	0.8991	298	0.005594	0.1372	1.3288
EDAR	220048_at	0.9075	281	0.006216	0.1445	1.3232
SPANXA1	224032_x_at	1.1266	85	0.0009324	0.0867	1.3228
PPP4C	208932_at	0.8189	439	0.005594	0.1372	1.3227
LRRC61	218907_s_at	0.8183	442	0.004973	0.1317	1.3211
ANKRD2	221232_s_at	1.0629	124	0.001243	0.09507	1.3197
GTPBP10	239773_at	1.256	43	0.0009324	0.0867	1.3162
PITX3	208277_at	1.2969	32	0.0009324	0.0867	1.316
STMN3	222557_at	0.8746	333	0.006527	0.1462	1.3154
MED8	213696_s_at	0.9005	295	0.003419	0.1181	1.3126
GREB1	210855_at	1.089	107	0.001243	0.09507	1.3115
MAP2K2	213490_s_at	1.129	83	0.001243	0.09507	1.3106
FOIR2	229619_at	1.2393	46	0.0006216	0.08198	1.3092
OR7A17	208509_s_at	0.973	203	0.00373	0.1192	1.3091
MGAT4B	224598_at	0.9225	262	0.005284	0.1352	1.3074
C9orf53	220505_at	1.0879	108	0.001865	0.1043	1.3055
PRODH2	243614_s_at	1.3045	30	0.0006216	0.08198	1.3053

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SEC13	207707_s_at	1.2138	55	0.001865	0.1043	1.3041
RRP18	212846_at	1.164	73	0.0003108	0.07173	1.3039
CPNE7	219707_at	1.043	136	0.001243	0.09507	1.3022
RFPL2	207227_x_at	1.0473	131	0.0009324	0.0867	1.3008
INPP5K	202782_s_at	0.8269	412	0.007148	0.1493	1.2989
GYG2	215695_s_at	1.5733	7	0.0003108	0.07173	1.2974
CCR3	208304_at	0.7616	589	0.002176	0.1073	1.2971
DNAJB12	214338_at	0.8124	449	0.006838	0.1475	1.2967
ATXN7	243259_at	0.924	260	0.00373	0.1192	1.2966
KRT18	201596_x_at	1.0322	149	0.002486	0.1089	1.296
SH3GL1	201851_at	1.2892	33	0.0003108	0.07173	1.29
CHST15	244874_at	0.8217	431	0.006838	0.1475	1.2886
CD4	216424_at	0.8471	375	0.006527	0.1462	1.2885
FSD1	219170_at	0.9858	189	0.003108	0.1141	1.2877
NOS2	210037_s_at	1.0802	113	0.002176	0.1073	1.2863
HOXD3	217076_s_at	1.0828	112	0.003108	0.1141	1.285
SOX14	208574_at	0.8207	435	0.001865	0.1043	1.2838
FMO3	40665_at	0.9275	256	0.00373	0.1192	1.2835
GADD45GIP1	225495_x_at	1.0705	119	0.0003108	0.07173	1.2829
RHBG	220510_at	1.3928	14	0.0003108	0.07173	1.2811
NOX1	210808_s_at	1.1696	72	0.001865	0.1043	1.2805
AKAP6	217669_s_at	1.0721	118	0.001554	0.1014	1.2803
PNPLA3	233030_at	0.8261	415	0.004973	0.1317	1.2792
RS1	216937_s_at	0.8467	376	0.006838	0.1475	1.2789
EHMT1	225461_at	0.9574	220	0.001554	0.1014	1.2788
BRD4	240360_at	1.0326	148	0.00404	0.1192	1.2785
ZNRF4	215461_at	1.4331	11	0.0006216	0.08198	1.278
SPI8	232739_at	0.8114	451	0.005284	0.1352	1.2771
DLGAP1	235527_at	0.8623	348	0.006216	0.1445	1.277
PSMD8	200820_at	0.8306	407	0.007148	0.1493	1.2759
SLC22A14	207408_at	1.1229	86	0.002176	0.1073	1.2741
FLG	215704_at	1.1062	94	0.0006216	0.08198	1.274
CDX1	206430_at	1.0453	133	0.001554	0.1014	1.2712
IPAR1	204038_s_at	1.2036	60	0.0003108	0.07173	1.2707
PEG3	209243_s_at	0.8924	306	0.006216	0.1445	1.2696
C7orf26	47083_at	1.2783	36	0.0006216	0.08198	1.2691
HLX	214438_at	1.1812	69	0.002176	0.1073	1.2686
PCSK2	204870_s_at	1.1988	63	0.0006216	0.08198	1.2676
LOC284244	214162_at	1.0118	168	0.00404	0.1192	1.2667
RPS6KB1	226660_at	0.9169	268	0.003108	0.1141	1.2664
PAX3	231666_at	1.0641	122	0.002486	0.1089	1.2659

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AMFR	202204_s_at	0.9452	236	0.004973	0.1317	1.2653
DGCR6	208024_s_at	0.9507	229	0.002797	0.1126	1.265
TRIM29	211002_s_at	0.9618	214	0.002486	0.1089	1.2643
FKBP6	206763_at	1.0112	169	0.00373	0.1192	1.2632
PTPN13	243792_x_at	0.7114	762	0.003419	0.1181	1.263
RANBP9	243108_at	0.8144	446	0.006216	0.1445	1.2622
CCIN	210642_at	1.3469	26	0.0006216	0.08198	1.2621
ALOXE3	222383_s_at	0.8484	372	0.006527	0.1462	1.2621
TNNT1	213201_s_at	1.1787	70	0.0006216	0.08198	1.262
CX3CL1	823_at	1.3554	24	0.0003108	0.07173	1.2618
GIF	207033_at	0.9502	230	0.001865	0.1043	1.2618
CSF1	211839_s_at	1.0351	146	0.002176	0.1073	1.2618
MAGEB1	207534_at	1.0278	153	0.002176	0.1073	1.2611
FOXJ1	243409_at	0.96	216	0.003419	0.1181	1.2611
TM4SF5	206242_at	0.9805	196	0.002486	0.1089	1.2603
MSX1	228473_at	0.9326	251	0.001865	0.1043	1.26
GDF10	206159_at	1.0383	140	0.002486	0.1089	1.2596
MYCNOS	216188_at	0.8742	334	0.006527	0.1462	1.2588
DDAH1	243711_at	0.8767	330	0.005905	0.1406	1.2569
CGB	205387_s_at	1.3582	23	0.0003108	0.07173	1.2567
SRGAP3	232869_at	0.8534	362	0.0003108	0.07173	1.2567
MCHR1	230498_at	0.9018	293	0.005594	0.1372	1.2567
GPRC5A	235563_at	1.037	142	0.0009324	0.0867	1.2553
DKKL1	220284_at	0.8683	340	0.006527	0.1462	1.2551
AKAP8L	240554_at	0.8915	307	0.007148	0.1493	1.2535
EIF3C	236700_at	0.9721	205	0.00404	0.1192	1.2533
EHD2	45297_at	0.86	356	0.0009324	0.0867	1.2525
WNT8B	207612_at	1.4476	10	0.0003108	0.07173	1.2508
CORO2B	209789_at	0.8521	365	0.007148	0.1493	1.2505
PFDN6	242048_at	0.8061	469	0.007148	0.1493	1.2493
ACTR3B	218868_at	0.7666	574	0.006527	0.1462	1.2486
OBSL1	238776_x_at	1.1151	93	0.002486	0.1089	1.2483
CDK5RAP2	243153_at	0.981	195	0.004351	0.1241	1.2477
ATXN3L	216539_at	1.0379	141	0.001243	0.09507	1.2475
ZNF592	227507_at	0.9194	265	0.002797	0.1126	1.2472
PPP2R1A	200695_at	0.976	202	0.00373	0.1192	1.2463
SERPINA3	202376_at	0.9299	254	0.00404	0.1192	1.2458
HAO1	220274_at	0.852	366	0.006527	0.1462	1.2452
CNTLN	241696_at	0.9138	272	0.005284	0.1352	1.2451
CNN1	203951_at	0.9698	207	0.003419	0.1181	1.2449
FGF3	214571_at	1.0251	156	0.002176	0.1073	1.2446
A4GALT	219488_at	1.091	105	0.001243	0.09507	1.2427

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CNN2	201605_x_at	0.9295	255	0.004351	0.1241	1.2425
GNB1L	223564_s_at	0.949	231	0.005594	0.1372	1.2421
RAIY	201771_s_at	0.8502	368	0.006527	0.1462	1.2415
HTR5A	221362_at	0.996	182	0.001243	0.09507	1.2411
DLG1	230229_at	1.1583	77	0.001865	0.1043	1.2407
CFHR5	208088_s_at	0.9088	278	0.006527	0.1462	1.24
UHRB4	210152_at	1.0689	120	0.002176	0.1073	1.2383
NAT9	204382_at	0.8804	327	0.005594	0.1372	1.2376
AZGP1P1	217013_at	1.2577	42	0.0009324	0.0867	1.2371
BEST2	207432_at	0.7508	628	0.001865	0.1043	1.2365
CATSPERG	234353_at	0.9482	233	0.00404	0.1192	1.2364
SF5WAP	240078_at	0.7262	709	0.00404	0.1192	1.2359
SPOCK3	235342_at	1.2757	38	0.0009324	0.0867	1.2352
GAST	208138_at	1.095	102	0.002176	0.1073	1.235
GABRA2	216039_at	1.4211	12	0.0003108	0.07173	1.2344
KHSRP	227555_s_at	0.7978	489	0.003419	0.1181	1.2341
FAM176B	229998_x_at	0.8229	427	0.007148	0.1493	1.2334
MYO1E	203072_at	0.8573	359	0.006838	0.1475	1.2328
TWF2	202009_at	0.9091	277	0.003108	0.1141	1.2327
OSGIN1	219475_at	0.964	213	0.00404	0.1192	1.2327
P2RX1	210401_at	0.9597	217	0.002176	0.1073	1.2307
MRC1	204438_at	0.8948	303	0.00404	0.1192	1.2301
PRAME	204086_at	0.9011	294	0.004662	0.1285	1.2288
UBXN1	210623_at	1.0217	158	0.001865	0.1043	1.2283
GEMIN7	222821_s_at	0.9356	248	0.004351	0.1241	1.2278
UGT2A1	207958_at	0.7546	619	0.005284	0.1352	1.2275
SLITRK5	214930_at	1.2308	49	0.001243	0.09507	1.2273
EFNA3	210132_at	0.8646	346	0.00404	0.1192	1.2264
FGF4	206783_at	0.8114	452	0.006838	0.1475	1.2259
FBR5	242217_s_at	0.9899	186	0.002486	0.1089	1.2252
S8NO2	215760_s_at	1.1859	67	0.0006216	0.08198	1.2249
NYX	234496_x_at	0.8357	393	0.004662	0.1285	1.2242
CCDC40	239254_at	1.0436	135	0.002797	0.1126	1.2232
NTRK2	236095_at	0.8266	414	0.006216	0.1445	1.223
IL23A	234865_at	0.8877	311	0.00404	0.1192	1.2228
AAK1	238100_at	0.8322	400	0.005594	0.1372	1.2225
PA2G4	214794_at	0.956	221	0.00404	0.1192	1.2223
AP2M1	200613_at	1.3502	25	0.0009324	0.0867	1.221
CNTER	205723_at	1.1227	87	0.001554	0.1014	1.2208
NR1H2	207203_s_at	0.9916	185	0.004662	0.1285	1.2197
CWH43	220724_at	0.922	263	0.006527	0.1462	1.2196
ACOT1	202982_s_at	0.918	267	0.004662	0.1285	1.2194

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IL13	207844_at	0.9513	226	0.005594	0.1372	1.2194
TBX4	220634_at	0.9603	215	0.002486	0.1089	1.2191
CHAC1	219270_at	0.9782	200	0.002176	0.1073	1.2186
CSPG5	39966_at	0.888	310	0.004351	0.1241	1.2179
PDZRN3	238165_at	0.9897	187	0.002797	0.1126	1.2172
PNMA2	209598_at	0.9384	243	0.003108	0.1141	1.2169
TEX11	234296_s_at	0.7109	765	0.002176	0.1073	1.2166
HIST1H4G	208551_at	0.7939	495	0.006527	0.1462	1.2163
ETV4	211603_s_at	0.8911	308	0.004973	0.1317	1.2162
MYH6	214468_at	0.9332	250	0.005284	0.1352	1.2161
ADRA1D	210961_s_at	1.2113	56	0.001554	0.1014	1.216
RBFox1	235070_at	0.9576	219	0.0006216	0.08198	1.2159
DLGAP2	216916_s_at	1.1925	65	0.0003108	0.07173	1.2154
PYY	211253_x_at	1.0067	174	0.00373	0.1192	1.2152
BMP15	221332_at	0.7255	713	0.00404	0.1192	1.2145
ADAMTS13	223844_at	0.9169	269	0.004662	0.1285	1.2145
DIO3	207154_at	1.0903	106	0.002797	0.1126	1.2144
IL20RA	222829_s_at	1.0189	161	0.002797	0.1126	1.2137
GJB5	206156_at	1.379	15	0.0003108	0.07173	1.2133
GRIK2	215655_at	0.9041	287	0.005594	0.1372	1.2133
NRXN3	229649_at	0.8723	336	0.005905	0.1406	1.2132
KRT15	204734_at	0.8683	341	0.006838	0.1475	1.213
TRAF3IP1	238494_at	1.098	100	0.002797	0.1126	1.2112
CDKN2B	236313_at	0.8313	403	0.006838	0.1475	1.2109
GUCA2B	207502_at	0.8325	399	0.006838	0.1475	1.2098
JUP	212236_x_at	0.8215	432	0.003419	0.1181	1.208
GUCY1A2	242342_at	1.064	123	0.003419	0.1181	1.2075
SLC6A14	219795_at	1.2723	40	0.0003108	0.07173	1.2065
PXDC1	212923_s_at	0.9352	249	0.004973	0.1317	1.2061
SIRPA	202897_at	0.8401	387	0.007148	0.1493	1.2055
B3GNT3	204856_at	1.0254	155	0.002797	0.1126	1.2043
DNASE1L3	205554_s_at	1.4971	9	0.0003108	0.07173	1.204
PNPLA6	203718_at	0.9118	275	0.006838	0.1475	1.204
SCNN1A	217264_s_at	0.9811	194	0.002797	0.1126	1.2033
HDHD3	221256_s_at	0.7338	678	0.006838	0.1475	1.2031
C16orf59	219556_at	0.8107	453	0.004973	0.1317	1.2029
AGPAT2	32837_at	1.2154	54	0.0006216	0.08198	1.2025
MRAS	225185_at	1.2478	45	0.001554	0.1014	1.2022
FAM198B	223204_at	0.8873	312	0.006216	0.1445	1.2013
DSG3	235075_at	1.3706	20	0.0006216	0.08198	1.2011
SLC15A1	211349_at	1.0307	150	0.001865	0.1043	1.201
OR2J2	216818_s_at	0.876	331	0.004351	0.1241	1.2009

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ADAM5P	217003_s_at	1.0197	159	0.002176	0.1073	1.1995
VAV2	226063_at	0.8658	345	0.002176	0.1073	1.1995
FA8P4	235978_at	1.2746	39	0.0009324	0.0867	1.1985
ADTRP	229070_at	0.8452	379	0.003108	0.1141	1.1975
GDNF	230090_at	0.8731	335	0.003419	0.1181	1.1968
MIR3917	217714_x_at	0.9512	227	0.004351	0.1241	1.1955
KCNJ16	222901_s_at	1.098	99	0.0009324	0.0867	1.1944
EDF1	209059_s_at	1.039	139	0.00404	0.1192	1.1932
CSF3	207442_at	0.7837	526	0.004351	0.1241	1.1928
CDKN1C	219534_x_at	1.1186	92	0.001865	0.1043	1.1926
DHR59	224009_x_at	0.8851	316	0.0009324	0.0867	1.192
CDH7	220679_s_at	1.122	89	0.003108	0.1141	1.1919
SLC25A6	212826_s_at	0.9357	247	0.004351	0.1241	1.1914
GPR88	220313_at	1.0131	166	0.001554	0.1014	1.1913
TRPV6	206827_s_at	1.2019	61	0.001554	0.1014	1.1896
SART1	231998_at	0.7947	494	0.005905	0.1406	1.1888
EPCAM	201839_s_at	1.3614	22	0.0003108	0.07173	1.1867
MOBP	242765_at	1.1274	84	0.001554	0.1014	1.1864
CYP2A13	208327_at	1.7671	2	0.0003108	0.07173	1.186
ABO	216929_x_at	0.9686	209	0.002176	0.1073	1.186
HOXD9	205605_at	0.9821	193	0.00404	0.1192	1.1854
TSSK2	217275_at	0.8103	455	0.005905	0.1406	1.1851
SLC6A1	205152_at	0.9404	239	0.004973	0.1317	1.1848
HGC6.3	211111_at	0.9832	191	0.00373	0.1192	1.1836
IQSEC3	242694_at	1.0976	101	0.0009324	0.0867	1.1835
GPR85	234303_s_at	0.8696	339	0.003419	0.1181	1.1834
KRT20	213953_at	1.0261	154	0.002176	0.1073	1.1827
KRT6A	214580_x_at	0.899	299	0.005284	0.1352	1.1826
HNF4A	230914_at	0.9141	271	0.00373	0.1192	1.1812
TFDP3	207385_at	0.8832	323	0.003419	0.1181	1.1783
GPR162	205056_s_at	0.943	238	0.002797	0.1126	1.178
NR1H4	243800_at	0.7533	621	0.005594	0.1372	1.1772
PHOX2B	207009_at	0.9238	261	0.002797	0.1126	1.1766
DCLK1	230962_at	0.9531	224	0.00373	0.1192	1.1766
CCNJL	219227_at	0.8708	337	0.003108	0.1141	1.1757
TRPC4	224220_x_at	0.9186	266	0.001865	0.1043	1.1755
PKDREJ	220548_at	0.9458	235	0.006216	0.1445	1.1755
MMP7	204259_at	0.9002	296	0.002176	0.1073	1.1748
HSPB3	206375_s_at	1.0851	111	0.001554	0.1014	1.1716
MMP26	220541_at	1.0863	109	0.004662	0.1285	1.1701
PON3	213695_at	0.9047	286	0.001865	0.1043	1.169
ARNT2	202986_at	1.0455	132	0.0003108	0.07173	1.1687

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MYF5	207424_at	0.9508	228	0.0009324	0.0867	1.1658
HRH1	205580_s_at	0.8662	344	0.00404	0.1192	1.1649
NDST4	208334_at	0.9123	273	0.007148	0.1493	1.1649
LMF2	31837_at	1.0135	165	0.002486	0.1089	1.1616
PFKL	211065_x_at	1.011	170	0.001554	0.1014	1.16
SCGN	205697_at	0.8806	326	0.00404	0.1192	1.158
C1QL1	214346_at	0.9824	192	0.00404	0.1192	1.1573
MAPK10	237413_at	0.8441	380	0.003108	0.1141	1.1572
TNNT2	215389_s_at	0.8289	410	0.005284	0.1352	1.1563
OR1A1	221388_at	0.8208	434	0.004662	0.1285	1.1556
GCKR	206867_at	0.8889	309	0.003419	0.1181	1.1514
LOC100131392	221154_at	0.9486	232	0.002797	0.1126	1.1511
GATA4	243692_at	0.867	342	0.005284	0.1352	1.1507
LPPR4	213496_at	0.8855	315	0.004351	0.1241	1.1492
RPL4	211710_x_at	1.0497	130	0.003108	0.1141	1.1454
PIK3CA	235980_at	0.8455	378	0.005905	0.1406	1.1449
CYP1A1	205749_at	1.0302	151	0.001865	0.1043	1.1418
EEF2	204102_s_at	0.9253	257	0.002486	0.1089	1.1396
HMHA1	212873_at	0.8269	413	0.007148	0.1493	1.1395
BST1	205715_at	1.0023	178	0.0009324	0.0867	1.1376
LGR5	213880_at	0.8229	429	0.004973	0.1317	1.1369
DSC2	226817_at	1.1826	68	0.002176	0.1073	1.1357
SLC13A3	230687_at	0.9324	252	0.00404	0.1192	1.1351
SLC17A2	207097_s_at	0.9699	206	0.00404	0.1192	1.1347
PPP2R4	216105_x_at	0.7654	578	0.006838	0.1475	1.1347
NKX6-1	221366_at	0.7555	614	0.006838	0.1475	1.1286
LRRC49	219338_s_at	0.8218	430	0.005594	0.1372	1.1279
KL	205978_at	0.7996	486	0.007148	0.1493	1.1271
SERPINA7	206386_at	0.9993	179	0.002176	0.1073	1.1228
HMGCS2	240110_at	0.8836	321	0.006216	0.1445	1.1126
NPM1	221923_s_at	1.3622	21	0.0003108	0.07173	1.1079
PTGER1	231201_at	0.8039	476	0.005594	0.1372	1.107
GH1	211151_x_at	1.3316	28	0.0006216	0.08198	1.1055
AMELX	208410_x_at	0.7807	534	0.004973	0.1317	1.1023
RPL8	200936_at	0.9799	197	0.00404	0.1192	1.1011
HRH3	221663_x_at	0.7727	555	0.001243	0.09507	1.0914
RPL7	239493_at	-0.8186	12696	0.002486	0.1089	-1.0672
RP56	211690_at	-1.0334	12844	0.001243	0.09507	-1.0821
RPL27	200025_s_at	-0.8594	12734	0.005905	0.1406	-1.1147
RPS27A	244624_at	-1.0319	12843	0.002797	0.1126	-1.1217
CAMK2B	34846_at	-1.0289	12841	0.001865	0.1043	-1.1364

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CCL5	204655_at	-1.009	12830	0.00373	0.1192	-1.1487
NONO	210470_x_at	-0.9772	12816	0.002797	0.1126	-1.1576
HNRNPA3	211933_s_at	-0.821	12697	0.00404	0.1192	-1.1585
YTHDF2	222430_s_at	-1.1362	12875	0.002486	0.1089	-1.1723
EEF1B2	200705_s_at	-0.9744	12811	0.001554	0.1014	-1.1756
SEC22B	209207_s_at	-1.0085	12829	0.003108	0.1141	-1.1817
LOC100506732	200627_at	-1.2372	12896	0.0006216	0.08198	-1.1827
KDM3B	210878_s_at	-1.1015	12868	0.002176	0.1073	-1.191
FLJ11292	220828_s_at	-0.93	12784	0.004973	0.1317	-1.204
TRIM3	213885_at	-0.8459	12723	0.005905	0.1406	-1.2204
CALR	214315_x_at	-0.9771	12815	0.003419	0.1181	-1.2227
CUTC	218970_s_at	-0.767	12631	0.005284	0.1352	-1.2251
PTP4A2	216988_s_at	-1.9067	12924	0.0001	0	-1.2278
GGNBP2	233937_at	-0.8231	12702	0.005284	0.1352	-1.2297
MSN	200600_at	-0.7682	12632	0.004973	0.1317	-1.2308
SAR1A	210790_s_at	-0.7685	12633	0.006527	0.1462	-1.2319
KIF1B	228657_at	-0.8909	12753	0.004662	0.1285	-1.2349
USP1	218082_s_at	-0.9056	12766	0.004351	0.1241	-1.2424
MGEA5	235868_at	-0.9597	12802	0.004662	0.1285	-1.2435
TMEM59	241018_at	-1.3999	12915	0.0001	0	-1.2436
DMTF1	203301_s_at	-1.1502	12880	0.0003108	0.07173	-1.2465
ABI1	209028_s_at	-1.0074	12828	0.003419	0.1181	-1.2485
DICER1	216281_at	-1.0285	12840	0.002486	0.1089	-1.2502
ZNF358	226260_x_at	-0.9047	12763	0.003108	0.1141	-1.2506
ROCK1	235854_x_at	-0.9852	12820	0.00373	0.1192	-1.251
MAPK1	229847_at	-1.0021	12827	0.007148	0.1493	-1.2513
DSTNP2	211325_x_at	-0.8463	12724	0.0009325	0.0867	-1.2528
PRPF38B	230270_at	-0.977	12814	0.00373	0.1192	-1.2534
HNRNPU	235603_at	-1.0436	12849	0.0009325	0.0867	-1.2573
RAP2B	238622_at	-0.9754	12812	0.007148	0.1493	-1.2612
WWP2	210200_at	-0.8035	12679	0.006838	0.1475	-1.2622
SMAP1	218137_s_at	-0.8588	12733	0.00404	0.1192	-1.2642
SLTM	217828_at	-1.0985	12867	0.002486	0.1089	-1.2656
PSMD7	201705_at	-1.0548	12852	0.002486	0.1089	-1.2665
DDR1	210749_x_at	-0.9248	12779	0.002797	0.1126	-1.2692
CTAGE5	235790_at	-0.933	12786	0.005594	0.1372	-1.2702
RFC5	213734_at	-1.0312	12842	0.002797	0.1126	-1.2716
VDAC3	208846_s_at	-1.3	12907	0.0006216	0.08198	-1.2718
C6orf62	213875_x_at	-1.3338	12912	0.0001	0	-1.2748
PPP1R11	201500_s_at	-1.0625	12855	0.002797	0.1126	-1.2753
YWHAZ	214848_at	-1.1416	12877	0.001865	0.1043	-1.2776

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PPID	228469_at	-0.8815	12748	0.005284	0.1352	-1.2824
FAM65A	45749_at	-0.9054	12765	0.002486	0.1089	-1.2839
DCUN1D1	240781_x_at	-0.9546	12795	0.003419	0.1181	-1.2839
SAP30	213963_s_at	-0.7529	12600	0.007148	0.1493	-1.2844
CRBN	222533_at	-1.0508	12851	0.001865	0.1043	-1.2858
GATAD2A	238324_at	-1.1395	12876	0.0006216	0.08198	-1.2893
RAB6A	210406_s_at	-1.1114	12871	0.0003108	0.07173	-1.2912
ARF6	224788_at	-1.0124	12833	0.002176	0.1073	-1.2949
WDR44	235485_at	-0.8795	12746	0.005594	0.1372	-1.2969
PXN	211823_s_at	-0.9265	12781	0.004662	0.1285	-1.3009
EP515	217887_s_at	-0.9554	12797	0.00373	0.1192	-1.3043
LOC100506060	237464_at	-0.7397	12572	0.00373	0.1192	-1.3067
UBE2G1	226005_at	-0.8641	12736	0.005905	0.1406	-1.3074
ADAM8	205180_s_at	-0.8771	12744	0.00404	0.1192	-1.3077
CD164	208654_s_at	-1.0194	12838	0.001865	0.1043	-1.3125
OTUD3	213216_at	-1.0795	12859	0.001554	0.1014	-1.3159
TMED9	208757_at	-0.9255	12780	0.001243	0.09507	-1.3187
FBXO9	238472_at	-0.9448	12791	0.001865	0.1043	-1.3228
MYL12B	221474_at	-1.2719	12903	0.0001	0	-1.3278
KDM2A	208989_s_at	-0.9059	12768	0.005594	0.1372	-1.3309
FYCO1	218204_s_at	-0.8949	12757	0.004973	0.1317	-1.3311
DNAJA3	205963_s_at	-0.7026	12496	0.006838	0.1475	-1.3327
PPP2R5E	229322_at	-0.9132	12772	0.002797	0.1126	-1.3329
CDK8	204831_at	-0.9187	12774	0.004973	0.1317	-1.3357
TOMM70A	201519_at	-1.0354	12846	0.0003108	0.07173	-1.3367
KIAA0494	229524_at	-1.1918	12890	0.0009325	0.0867	-1.3387
VPS13C	235023_at	-0.9027	12761	0.006838	0.1475	-1.3402
TM7SF3	226478_at	-0.9943	12822	0.001554	0.1014	-1.3436
HIPK1	212293_at	-0.9311	12785	0.00404	0.1192	-1.3468
UFM1	242669_at	-1.0119	12831	0.001554	0.1014	-1.347
LTN1	233819_s_at	-0.8846	12751	0.005905	0.1406	-1.3471
PIGF	205078_at	-0.8521	12728	0.004973	0.1317	-1.3481
RCOR3	241433_at	-0.9298	12783	0.00404	0.1192	-1.3502
VP54B	218171_at	-0.8774	12745	0.006216	0.1445	-1.3531
ATP6AP2	201444_s_at	-1.2974	12905	0.0009325	0.0867	-1.3542
ZNF562	219163_at	-1.0021	12826	0.002486	0.1089	-1.359
TGOLN2	212043_at	-1.2854	12904	0.0003108	0.07173	-1.3608
AP5M1	222531_s_at	-0.8456	12722	0.006838	0.1475	-1.3615
KIAA0485	214295_at	-1.3268	12910	0.001243	0.09507	-1.3636
EIF4E	242674_at	-1.0221	12839	0.002486	0.1089	-1.3652
RAP1A	228548_at	-0.9502	12793	0.00404	0.1192	-1.3669

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CYP3A5	243015_at	-0.863	12735	0.005594	0.1372	-1.367
TAF7	201023_at	-0.9073	12769	0.001865	0.1043	-1.3675
C17orf101	64438_at	-0.8429	12719	0.006527	0.1462	-1.3705
ARAP2	242402_x_at	-1.199	12891	0.0006216	0.08198	-1.3739
WSB2	201760_s_at	-1.5008	12922	0.0003108	0.07173	-1.3756
C14orf169	219526_at	-1.1472	12879	0.001243	0.09507	-1.3764
SRP9	201273_s_at	-0.9278	12782	0.001243	0.09507	-1.3765
PRICKLE4	223516_s_at	-0.9609	12804	0.001865	0.1043	-1.3859
HU51	217618_x_at	-0.9728	12809	0.002486	0.1089	-1.3909
ZBTB11	242433_at	-0.7887	12662	0.006838	0.1475	-1.3935
C1orf56	230468_s_at	-0.7572	12609	0.006216	0.1445	-1.3958
DNAJB14	226399_at	-0.7533	12602	0.00404	0.1192	-1.4024
TMED10	238886_at	-0.827	12704	0.001865	0.1043	-1.4075
TBKBP1	205424_at	-0.7733	12638	0.004973	0.1317	-1.4075
RBM26	229433_at	-0.9556	12798	0.001865	0.1043	-1.4086
VP526A	243316_x_at	-0.8539	12730	0.006527	0.1462	-1.4133
SLK	206875_s_at	-1.2644	12902	0.0006216	0.08198	-1.4204
GNAZ	204993_at	-0.8741	12742	0.003108	0.1141	-1.4217
PDE4DIP	232509_at	-0.8921	12754	0.00404	0.1192	-1.4221
TPP1	214196_s_at	-0.8765	12743	0.00404	0.1192	-1.4228
RNF5	216018_at	-1.1707	12884	0.0006216	0.08198	-1.4264
PDS5B	242302_at	-0.8955	12758	0.001243	0.09507	-1.4323
MED4	222438_at	-0.9381	12788	0.006527	0.1462	-1.4327
BCL2L13	226798_at	-0.9	12759	0.005284	0.1352	-1.434
ERBB2IP	232896_at	-1.1207	12873	0.0009325	0.0867	-1.4399
PCNP	237577_at	-1.0766	12858	0.003108	0.1141	-1.4412
FAM18B1	218446_s_at	-0.9766	12813	0.001865	0.1043	-1.4417
ELF4	31845_at	-1.1764	12885	0.0001	0	-1.4442
ADCY7	203741_s_at	-0.9049	12764	0.006838	0.1475	-1.4457
VPS13A	231585_at	-1.0576	12854	0.0006216	0.08198	-1.4501
MEAF6	228517_at	-1.4912	12921	0.0001	0	-1.4765
SRSF11	236948_x_at	-1.0158	12835	0.003419	0.1181	-1.4789
FUBP3	239193_at	-0.9538	12794	0.00373	0.1192	-1.4808
RAB9A	221808_at	-1.0957	12866	0.001243	0.09507	-1.4902
RP2	205191_at	-0.8496	12725	0.005905	0.1406	-1.4911
FAM8A1	203420_at	-0.9731	12810	0.004973	0.1317	-1.4963
BICD2	213154_s_at	-0.9685	12808	0.005594	0.1372	-1.5019
ANKRD49	219069_at	-1.0451	12850	0.002486	0.1089	-1.5034
ATF2	212984_at	-1.2594	12899	0.0003108	0.07173	-1.5058
UBQLN2	215884_s_at	-0.957	12800	0.002486	0.1089	-1.5065
AGL	203566_s_at	-1.2146	12893	0.0001	0	-1.515
CASP8	213373_s_at	-0.9334	12787	0.003108	0.1141	-1.5232

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DZANK1	219951_s_at	-0.9801	12817	0.00404	0.1192	-1.5514
UEVLD	220775_s_at	-0.8363	12712	0.00373	0.1192	-1.5562
C1D	200056_s_at	-1.4076	12916	0.001865	0.1043	-1.5637
QKI	241938_at	-1.332	12911	0.0003108	0.07173	-1.5651
BCL10	205263_at	-0.8137	12690	0.005284	0.1352	-1.5731
DSIN	230933_at	-0.9564	12799	0.002486	0.1089	-1.5771
MAP4K5	211081_s_at	-1.1676	12883	0.003108	0.1141	-1.5815
ARL5A	243176_at	-1.0387	12847	0.001243	0.09507	-1.5866
NKG7	213915_at	-0.9405	12789	0.00373	0.1192	-1.5884
CA11	209726_at	-0.7067	12507	0.007148	0.1493	-1.5954
SPINLW1	206319_s_at	-1.3118	12909	0.001243	0.09507	-1.5986
RAP1GAP2	213280_at	-0.9187	12775	0.004973	0.1317	-1.603
PANK3	221751_at	-1.0948	12865	0.0006216	0.08198	-1.6069
TMA16	218513_at	-0.8647	12737	0.005905	0.1406	-1.6161
MST4	224407_s_at	-1.4622	12919	0.0001	0	-1.6189
XPNPEP2	216910_at	-0.9975	12825	0.006527	0.1462	-1.621
MICB	206247_at	-0.8585	12731	0.007148	0.1493	-1.622
NPTN	202228_s_at	-1.4245	12918	0.0001	0	-1.6221
S1PR5	233743_x_at	-1.1848	12889	0.0006216	0.08198	-1.6397
CACNB3	34726_at	-1.3554	12914	0.0006216	0.08198	-1.6523
SLC20A1	230494_at	-1.4102	12917	0.0003108	0.07173	-1.659
TDRD7	213361_at	-1.0745	12857	0.0003108	0.07173	-1.6619
FAM3C	240062_at	-0.9075	12770	0.001243	0.09507	-1.6633
CHSY1	203044_at	-0.9212	12776	0.005905	0.1406	-1.6708
LOC100509751	228019_s_at	-0.9648	12807	0.002486	0.1089	-1.6933
SPRYD7	230151_at	-1.1444	12878	0.0006216	0.08198	-1.6958
PAK6	219461_at	-0.9418	12790	0.00373	0.1192	-1.697
CLCF1	219500_at	-0.9969	12824	0.003108	0.1141	-1.7058
SSX2IP	210871_x_at	-1.1155	12872	0.001865	0.1043	-1.7475
GOLGA8IP	213737_x_at	-1.0709	12856	0.002486	0.1089	-1.752
IFNGR1	242903_at	-0.9212	12777	0.001554	0.1014	-1.7701
RHOC	235742_at	-1.0559	12853	0.003108	0.1141	-1.7934
CPEB3	243651_at	-1.221	12894	0.0003108	0.07173	-1.7952
TGFBR3	226625_at	-0.9961	12823	0.003108	0.1141	-1.7999
PPP3CA	202457_s_at	-1.0337	12845	0.002176	0.1073	-1.8039
GAUNT10	230906_at	-1.0852	12862	0.005594	0.1372	-1.8054
ZNF137P	207394_at	-1.3036	12908	0.0006216	0.08198	-1.8262
RAB11FIP5	210879_s_at	-1.0158	12836	0.003108	0.1141	-1.8307
SNX24	239739_at	-0.9861	12821	0.00373	0.1192	-1.8719
RCAN1	215254_at	-0.8229	12701	0.00373	0.1192	-1.8819
XBP1	242021_at	-1.1825	12887	0.001554	0.1014	-1.9028

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NAA40	222369_at	-1.2516	12898	0.0006216	0.08198	-1.9045
DPY19L1	215433_at	-0.8661	12739	0.00404	0.1192	-1.9074
PPP2R2B	213849_s_at	-0.894	12756	0.006838	0.1475	-1.9443
MCTP2	243109_at	-0.9057	12767	0.006527	0.1462	-1.9686
HERC5	219863_at	-0.8798	12747	0.004351	0.1241	-1.9733
GNPTAB	240106_at	-1.1841	12888	0.0003108	0.07173	-1.9914
IGF2R	201393_s_at	-1.2358	12895	0.0003108	0.07173	-2.0166
SLC35G2	219569_s_at	-0.9607	12803	0.004973	0.1317	-2.0201
TTC38	218272_at	-1.0917	12863	0.002486	0.1089	-2.0559
LPAL2	210909_x_at	-0.9117	12771	0.005905	0.1406	-2.0607
MAF	209348_s_at	-1.0125	12834	0.002797	0.1126	-2.0716
UBE2E3	210024_s_at	-1.3387	12913	0.0001	0	-2.0872
BMI1	202265_at	-1.2995	12906	0.0003108	0.07173	-2.0904
ARHGEF12	234544_at	-1.21	12892	0.0006216	0.08198	-2.1042
MAN1A1	221760_at	-0.9571	12801	0.00404	0.1192	-2.1058
G8E1	203282_at	-1.2602	12900	0.0001	0	-2.1332
B3GAT1	219521_at	-0.9029	12762	0.006527	0.1462	-2.1587
ENPP4	204161_s_at	-1.0943	12864	0.001865	0.1043	-2.1683
VAV3	224221_s_at	-1.0424	12848	0.002797	0.1126	-2.187
SOX13	38918_at	-0.9633	12805	0.005594	0.1372	-2.2081
SETBP1	227478_at	-0.9643	12806	0.00373	0.1192	-2.2191
EFHD2	222483_at	-1.135	12874	0.001554	0.1014	-2.2398
FAM49A	230276_at	-1.0164	12837	0.001865	0.1043	-2.3099
SESN1	218346_s_at	-1.0119	12832	0.002176	0.1073	-2.314
GZMH	210321_at	-0.9823	12818	0.00373	0.1192	-2.4241
ZEB2	235593_at	-1.0848	12861	0.0006216	0.08198	-2.4852
KLRG1	210288_at	-0.9548	12796	0.00404	0.1192	-2.5442
SLCO4C1	222071_s_at	-1.4875	12920	0.0003108	0.07173	-2.6663
KLRAP1	207229_at	-1.1575	12882	0.0001	0	-2.9092
ADR82	206170_at	-1.2637	12901	0.0009325	0.0867	-3.1899
KLRD1	210606_x_at	-1.103	12869	0.002486	0.1089	-3.2576
PSTPIP2	219938_s_at	-1.1531	12881	0.0003108	0.07173	-3.3844
SLC4A4	211494_s_at	-1.0845	12860	0.001865	0.1043	-3.5152
FGR	208438_s_at	-1.1813	12886	0.001554	0.1014	-3.8525
GPR56	212070_at	-1.2429	12897	0.001243	0.09507	-4.074
CACNA2D2	204811_s_at	-1.6569	12923	0.0009325	0.0867	-4.4381
PRSS23	229441_at	-1.1073	12870	0.002486	0.1089	-4.6908
KLRF1	220646_s_at	-0.9015	12760	0.004351	0.1241	-4.9476
PTCH1	209816_at	-0.9827	12819	0.003108	0.1141	-5.1609
CX3CR1	205898_at	-0.9172	12773	0.005905	0.1406	-5.8299

In order to identify biological processes that were differentially active in CD39⁺ vs. CD39⁻ cells, gene set enrichment analysis using the Gene Ontology collection of gene sets (Ashburner *et al.* (2000) *Nat. Genet.* 25:25-29) was performed. No significant enrichment of GO terms in the CD39⁻ CD8⁺ subset was identified. By contrast, 21 gene sets
 5 significantly enriched (FDR < 0.1) in the CD39⁺ population, almost all of which were related to mitosis and cell cycle related genes or cytoskeleton organization (Figure 7B), were identified. These results indicate that CD39⁺ CD8⁺ T cells show coordinate up-regulation of genes related to proliferation.

CD39 is expressed by CD8⁺ T cells in chronic, but not acute/latent infection,
 10 indicating that it may be a marker of T cell exhaustion. It was tested whether the profile of CD39⁺ CD8⁺ T cells was enriched for genes expressed by exhausted CD8⁺ cells. Previous studies of gene expression in CD8⁺ T cells in the mouse model of chronic viral infection with the Clone 13 strain of LCMV have identified global signatures of T cell exhaustion that are conserved in exhausted CD8⁺ T cells in humans (Doering *et al.* (2012) *Immunity*
 15 37:1130-1144; Quigley *et al.* (2010) *Nat. Med.* 16:1147-1151; Baitsch *et al.* (2011) *J. Clin. Invest.* 121:2350-2360). Thus, a signature of 200 genes up-regulated by exhausted CD8⁺ T cells responding to chronic infection relative to functional memory CD8⁺ T cells generated by acute infection (LCMV Armstrong strain) was curated. The exhausted CD8⁺ T cell signature from LCMV model was found to be significantly enriched in CD39⁺ vs. CD39⁻
 20 CD8⁺ T cells in subjects with HCV infection (Figure 7C). The "leading edge" genes contributing most to the enrichment (Subramanian *et al.* (2005) *Proc. Natl. Acad. U.S.A.* 102:15545-15550), which correspond to genes up-regulated both in the mouse exhausted signature and in the human CD39⁺ profile, were focused upon. As expected, the leading edge genes included PD-1 (PDCD1), a feature of both human CD39⁺ CD8⁺ T cells and of
 25 exhausted CD8⁺ T cells in the mouse model (Figure 7D). In addition, it was found that up-regulation of many genes associated with proliferation, including BUB1, TOP2A and MKI67, was common to mouse exhausted CD8⁺ T cells and human CD39⁺ CD8⁺ T cells. Thus, CD39⁺ CD8⁺ T cells in HCV infection share transcriptional features with exhausted CD8⁺ T cells in a mouse model of chronic infection that are predominantly related to
 30 pathways representing proliferation.

Example 6: CD39 is increased in exhausted CD8⁺ T cells in the mouse model of chronic viral infection

Since the mouse signature of CD8⁺ T cell exhaustion was significantly enriched in the transcriptional profile of CD39⁺ CD8⁺ T cells in HCV-infected patients, it was next
 5 asked whether CD39 was up-regulated by CD8⁺ T cells in the mouse model of chronic viral infection. To address this question, two well-described mouse models of viral infection using two strains of Lymphocytic choriomeningitis virus (LCMV), LCMV Armstrong that causes acute infection that is resolved in up to 8 days and LCMV Clone 13 that persists in mice for up to 3 months and leads to T cell exhaustion, were compared. CD39 expression
 10 was measured and the levels were compared to PD-1 expression levels (Wherry *et al.* (2007) *Immunity* 27:670-684; Barber *et al.* (2006) *Nature* 439:682-687) in CD8⁺ T cells responding to each infection. While naive CD8⁺ T cells expressed neither CD39 nor PD-1 (Figure 8A), both were rapidly up-regulated in antigen-experienced cells following either infection (day 7 post infection [d7 p.i.]) (Figure 8B). However, in acute infection, the
 15 fraction of CD39 bright PD-1⁺ population decreased with time. In contrast, high expression of CD39 and PD-1 was maintained in Clone 13 infection. While there was a trend in accumulation of CD39 bright PD-1⁺ cells among total CD8⁺ population, this was most apparent in the H-2D^b GP₂₇₆₋₂₈₆ tetramer-specific CD8⁺ T cells (Figure 8B).

Thus, after chronic viral infection, exhausted antigen-specific CD8⁺ T cells can be
 20 identified by both high CD39 and PD-1 expression. This difference in expression of both markers between chronic and acute infection is noticeable as early as d7 p.i., but becomes even more pronounced as the infection progresses.

**Example 7: CD39 identifies terminally exhausted CD8⁺ T cells in humans and in a
 25 mouse model**

Having determined that high, persistent expression of CD39 is a feature of LCMV-specific CD8⁺ T cells in mouse chronic infection models, it was next sought to further characterize the phenotype of CD39⁺ CD8⁺ T cells during Clone 13 infection. CD39 expression in antigen-experienced, CD44⁺ CD8⁺ T cells and found that mice infected with
 30 Clone 13 developed a population of cells with high expression of CD39 (CD39^{high}) was analyzed. This population was entirely absent in mice infected with the acute LCMV Armstrong strain, which only exhibited the presence of intermediate levels of CD39 staining (CD39^{int}) (Figure 9A). Further characterization of the two sub-populations in

Clone 13 infected mice revealed that the CD39^{high} cells showed down-regulated CD127 (Figure 9B) and expressed significantly higher levels of PD-1 (Figure 9C) than did the CD39^{int} population.

Because the highest levels of PD-1 are characteristic of terminally exhausted CD8 T cells in chronic infection (Blackburn *et al.* (2008) *Proc. Natl. Acad. Sci. U.S.A.* 105:15016-15021; Blackburn *et al.* (2009) *Nat. Immunol.* 10:29-37), it was determined whether CD39^{high} T cells in chronic infection showed other phenotypic characteristics of terminal exhaustion. Analysis of expression of two additional co-inhibitory receptors, CD244 (2B4) and Lag3, showed that a significantly higher fraction of CD39^{high} cells co-expressed multiple receptors, consistent with terminal exhaustion. By contrast, CD39^{int} CD8⁺ T cells were generally negative for all three receptors analyzed (Figures 9D-9E). The expression of transcription factors, T-bet and Eomes, were also analyzed. It was found that the CD39^{high} subset of CD8⁺ T cells was comprised primarily of the Eomes^{high} T-bet^{low} terminally exhausted phenotype, while the CD39^{int} CD8⁺ T cells showed an equal distribution of both (Figure 9F). Similarly, it was found that in CD8⁺ T cells from subjects with HIV infection, a significantly higher fraction of CD39⁺ CD8⁺ T cells were Eomes^{high} T-bet^{low} compared to CD39⁻ CD8⁺ T cells (Figure 10). Thus, in both humans and mice with chronic viral infection, CD39⁺ CD8⁺ T cells show a phenotype of terminal exhaustion.

The identification of CD39 as a marker of terminally exhausted CD8⁺ T cells in humans and in a mouse model was further confirmed based on analyzing the function of such T cells. Figure 11 shows that the CD39^{high} cells in the context of chronic viral infection produce the least amount of proinflammatory cytokines in a ex vivo reactivation challenge with viral antigen. Figure 11 shows that both the fraction of cytokine production and the amount of cytokine by the positive cells is lower in the CD8⁺ CD39^{high} T cell population as compared to CD8⁺ T cells expressing intermediate CD39 (CD39^{int}).

Similarly, Figure 12 shows that CD39^{high} cells are present in cancer (e.g., mouse melanoma and colorectal tumors) and the CD39 expression status indicates significant dysfunction (e.g., CD39^{high} cells were the most dysfunctional).

30 **Example 8: CD39-deficient mice exhibit increased immune responses and mortality**

Moreover, CD39 deficient mice exhibit increased mortality to LCMV-Clone 13 due to exacerbated immune response in target organs. Severely increased immunopathology in

different organs in CD39 knock-out animals as compared to wild-type animals following LCMV-Clone 13 infection was observed (Figures 13A-13D).

The state of CD8⁺ T cell exhaustion is characterized by widespread changes in gene expression relative to functional memory CD8⁺ T cells (Wherry *et al.* (2007) *Immunity* 27:670-684). However, in humans, identifying specific markers of T cell exhaustion that are not shared by more functional CD8⁺ T cell populations has been challenging (Duraisswamy *et al.* (2011) *J. Immunol.* 186:4200-4212). It is demonstrated herein that high-level expression of the ectonucleotidase CD39 is characteristic of CD8⁺ T cells specific for chronic viral infections in humans and mice, but is otherwise rare in the CD8⁺ T cell compartment of healthy donors. Persistent, high-level expression is also seen in the mouse model of chronic viral infection, and CD39^{High} CD8⁺ T cells express the highest levels of PD-1, co-express multiple inhibitory receptors, and are Tbet^{hi}/Eomes^{hi}. These data indicate that CD39 expression by CD8⁺ T cells in humans is a pathological finding and demarcates terminal exhaustion.

The fact that peripheral blood CD8⁺ T cells in humans can express CD39 is surprising. Previous data have shown that CD39 expression is restricted to CD4⁺ regulatory T cells, Th17 cells, and small populations of regulatory-like CD8⁺ T cells (Kansas *et al.* (1991) *J. Immunol.* 146:2235-2244; Moncrieffe *et al.* (2010) *J. Immunol.* 185:134-143; Pulte *et al.* (2011) *Clin. Lymph. Myeloma Leuk.* 11:367-372; Boer *et al.* (2013) *Eur. J. Immunol.* 43:1925-1932). Indeed, it was found herein that in the bulk population of CD8⁺ T cells in healthy donors, only a small minority of CD8⁺ T cells expresses CD39. However, CD39 is abundantly expressed by virus-specific CD8⁺ T cells in two human chronic infections (HIV and HCV). This helps explain why CD39⁺ CD8⁺ T cells have not been appreciated in earlier studies that have focused on healthy individuals, and indicates that, in steady-state conditions, the expression of CD39 by CD8⁺ T cells is a pathological occurrence related to the development of T cell exhaustion.

Several features of CD39-expressing CD8⁺ T cells described herein indicate that it is a marker of T cell exhaustion. First, in both human and mouse CD8⁺ T cells responding to chronic infection, CD39 is co-expressed with PD-1, which is an inhibitory receptor expressed by the majority of exhausted T cells (Wherry *et al.* (2007) *Immunity* 27:670-684; Barber *et al.* (2006) *Nature* 439:682-687). Second, CD39 expression correlates with viral load in subjects with HIV and HCV infection, indicating that the conditions of high levels of inflammation and antigen load that lead to exhaustion also increase CD39 expression in

the virus-specific pool of CD8⁺ T cells, as has been observed for PD-1 (Day *et al.* (2006) *Nature* 443:350-354; Trautmann *et al.* (2006) *Nat. Med.* 12:1198-1202). The fact that a larger fraction of HCV-specific CD8⁺ T cells express CD39 than do HIV-specific CD8⁺ T cells is believed to be related to differences in the timing of blood sampling during the course of infection, or due to differences in the extent of antigen-load and inflammation in the two infections. Third, gene signatures characteristic of exhausted mouse CD8⁺ T cells are enriched in CD39⁺ cells relative to CD39⁻ CD8⁺ T cells in subjects with HCV infection, underscoring the association between CD39 expression and T cell exhaustion.

The expression of molecules that inhibit T cell function has been used to identify exhausted CD8⁺ T cells in several studies of human chronic infection and cancer (Wherry (2011) *Nat. Immunol.* 12:492-499). However, there are important distinctions between the pattern of CD39 expression and that of inhibitory receptors. Many inhibitory receptors, such as PD-1 (Day *et al.* (2006) *Nature* 443:350-354; Duraiswamy *et al.* (2011) *J. Immunol.* 186:4200-4212; Petrovas *et al.* (2006) *J. Exp. Med.* 203:2281-2292) and CD244 (Pita-Lopez *et al.* (2009) *Immun. Ageing* 6:11; Rey *et al.* (2006) *Eur. J. Immunol.* 36:2359-2366) are also expressed by a substantial fraction of CD8⁺ T cells in healthy donors that are not exhausted. In contrast, CD39 expression is found only in a very small minority of CD8⁺ T cells from healthy donors. This indicates that CD39 expression, particularly in combination with PD-1, is useful as a specific phenotype of exhausted CD8⁺ T cells, at least in HCV and HIV infection. Moreover, CD39 provides a useful marker to isolate exhausted CD8⁺ T cells in settings such as tumor-specific responses where very few reagents are available to identify antigen-specific T cells. Importantly, while CD39 is rare in the CD8⁺ compartment in healthy donors, it is expressed by CD4⁺ Tregs (as is PD-1) making it relatively more difficult to distinguish between exhausted CD4⁺ T cells and Tregs alone.

Analysis of global expression profiles of CD39⁺ versus CD39⁻ CD8⁺ T cells in HCV infection showed that the CD39⁺ fraction was strongly enriched for genes related to proliferation. This may at first seem counterintuitive, given the functional defects that have been described in exhausted CD8⁺ T cells (Wherry (2011) *Nat. Immunol.* 12:492-499; Wherry *et al.* (2007) *Immunity* 27:670-684). However, data from the mouse model of chronic infection indicate that, unlike memory CD8⁺ T cells, exhausted CD8⁺ T cells are dependent on continuous exposure to viral antigen to ensure their survival and undergo extensive cell division at a rate higher than that seen in physiological homeostatic proliferation of the memory CD8⁺ T cell pool (Shin *et al.* (2009) *Immunity* 31:309-320).

Exhausted CD8⁺ T cells therefore have a paradoxical increase in their proliferation history but reduced proliferative potential (Migueles *et al.* (2002) *Nat. Immunol.* 3:1061-1068) explaining the increased expression of proliferation-associated genes in CD39⁺ CD8⁺ T cells in HCV infection and in mouse exhausted CD8⁺ T cells (Paley *et al.* (2012) *Science* 338:1220-1225; Shin *et al.* (2007) *J. Exp. Med.* 204:941-949).

Recent studies of exhausted CD8⁺ T cells have revealed that two distinct states of virus-specific CD8⁺ T cells exist in chronically infected mice and humans (Paley *et al.* (2012) *Science* 338:1220-1225). Differential expression of the T-box transcription factors T-bet and Eomes characterize two populations, which form a progenitor-progeny relationship. T-bet^{high} cells display low intrinsic turnover but are capable of proliferation in response to persisting antigen, giving rise to Eomes^{high} terminal progeny. In contrast, Eomes^{high} CD8⁺ T cells responding to chronic infection had reduced capacity to undergo additional proliferation *in vivo*. Indeed, in HCV, virus-specific CD8⁺ T cells from individuals with chronic infection show a higher level of Eomes than do resolvers (Bugger *et al.* (2014) *PLoS Pathogens* 10:e1004251), consistent with the difference we found in CD39 expression (Figures 4C and 10). The data described herein demonstrate that in the mouse model of chronic infection and in HIV infection, the CD39^{high} subset of CD8⁺ T cells demarcates terminally exhausted Eomes^{high}/Tbet^{low} cells. Consistent with this, CD39⁺ CD8⁺ T cells in the mouse model express the highest levels of PD-1 and co-express multiple inhibitory receptors. These findings indicate that CD39 is a marker not only of the exhausted state, but specifically of the most terminally exhausted cells. The ability to distinguish between “reversible” and “irreversible” T cell exhaustion on the basis of surface expression of CD39 provides an effective correlate of T cell function in chronic viral infection, and a useful tool for studying this population *ex vivo*.

It is further believed that expression of CD39 contributes to the dysfunction of exhausted T cells. For instance, the expression of CD39 is believed to enable CD8⁺ T cells to provide negative regulation in an autocrine or juxtacrine fashion via adenosine in the same manner as Tregs (Deaglio *et al.* (2007) *J. Exp. Med.* 204:1257-1265). The fact that CD39 requires both a substrate (ATP) and a downstream enzyme (CD73) to generate adenosine could provide a mechanism to ensure that this negative signaling occurred only in certain contexts, such as in inflamed, damaged tissues, where the extracellular concentrations of ATP are high and CD73-expressing cells are present. Moreover, CD39-expressing CD8⁺ T cells may contribute to the general inhibitory milieu by contributing to

the inhibition of activated T cells that express the adenosine receptor but are not yet exhausted.

Incorporation by Reference

5 All publications, patents, and patent applications mentioned herein are hereby incorporated by reference in their entirety as if each individual publication, patent or patent application was specifically and individually indicated to be incorporated by reference. In case of conflict, the present application, including any definitions herein, will control.

Also incorporated by reference in their entirety are any polynucleotide and
10 polypeptide sequences which reference an accession number correlating to an entry in a public database, such as those maintained by The Institute for Genomic Research (TIGR) on the world wide web and/or the National Center for Biotechnology Information (NCBI) on the world wide web.

15 Equivalents

Those skilled in the art will recognize, or be able to ascertain using no more than routine experimentation, many equivalents to the specific embodiments of the invention described herein. Such equivalents are intended to be encompassed by the following claims.

SEQUENCE LISTING

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President And Fellows Of Harvard College

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Prevention, And Treatment Of T-Cell Exhaustion Using CD39
Biomarkers And Modulators

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 actatcaact atctgctggg caaattcagt cagaaaacaa ggtgggttcag catagtccca 600
 tatgaaacca ataatacagga aacctttgga gctttggacc ttggggggagc ctctacacaa 660
 gtcacttttg taccacaaaa ccagactatc gagtccccag ataatgctct gcaatttcgc 720
 ctctatggca aggactacaa tgtctacaca catagcttct tgtgctatgg gaaggatcag 780
 gcactctggc agaaactggc caaggacatt cagcagtttg aaatccaggg tattggaaac 840
 tatcaacaat gccatcaaag catcctggag ctcttcaaca ccagttactg cccttactcc 900
 cagtgtgcct tcaatgggat tttcttgcca ccactccagg gggatttttg ggcattttca 960

gctttttact ttgtgatgaa gttttttaaac ttgacatcag agaaagtctc tcaggaaaag 1020
 gtgactgaga tgatgaaaaa gttctgtgct cagccttggg aggagataaa aacatcttac 1080
 gctggagtaa aggagaagta cctgagtgaat tactgctttt ctggtaccta cattctctcc 1140
 ctctttctgc aaggctatca tttcacagct gattcctggg agcacatcca tttcattggc 1200
 aagatccagg gcagcgacgc cggctggact ttgggctaca tgctgaacct gaccaacatg 1260
 atcccagctg agcaaccatt gtccacacct ctctcccact ccacctatgt cttcctcatg 1320
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 ccttcatatt tctggaaaga tatggtatag 1410

<210> 8
 <211> 469
 <212> PRT
 <213> Homo sapiens
 <400> 8

Met Glu Asp Thr Lys Glu Ser Asn Val Lys Thr Phe Cys Ser Lys Asn
1 5 10 15

Ile Leu Ala Ile Leu Gly Phe Ser Ser Ile Ile Ala Val Ile Ala Leu
20 25 30

Leu Ala Val Gly Leu Thr Gln Asn Lys Ala Leu Pro Glu Asn Val Lys
35 40 45

Tyr Gly Ile Val Leu Asp Ala Gly Ser Ser His Thr Ser Leu Tyr Ile
50 55 60

Tyr Lys Trp Pro Ala Glu Lys Glu Asn Asp Thr Gly Val Val His Gln
65 70 75 80

Val Glu Glu Cys Arg Val Lys Gly Pro Gly Ile Ser Lys Phe Val Gln
85 90 95

Lys Val Asn Glu Ile Gly Ile Tyr Leu Thr Asp Cys Met Glu Arg Ala
100 105 110

Arg Glu Val Ile Pro Arg Ser Gln His Gln Glu Thr Pro Val Tyr Leu
115 120 125

Gly Ala Thr Ala Gly Met Arg Leu Leu Arg Met Glu Ser Glu Glu Leu
130 135 140

Ala Asp Arg Val Leu Asp Val Val Glu Arg Ser Leu Ser Asn Tyr Pro
145 150 155 160

Phe Asp Phe Gln Gly Ala Arg Ile Ile Thr Gly Gln Glu Glu Gly Ala
 165 170 175
 Tyr Gly Trp Ile Thr Ile Asn Tyr Leu Leu Gly Lys Phe Ser Gln Lys
 180 185 190
 Thr Arg Trp Phe Ser Ile Val Pro Tyr Glu Thr Asn Asn Gln Glu Thr
 195 200 205
 Phe Gly Ala Leu Asp Leu Gly Gly Ala Ser Thr Gln Val Thr Phe Val
 210 215 220
 Pro Gln Asn Gln Thr Ile Glu Ser Pro Asp Asn Ala Leu Gln Phe Arg
 225 230 235 240
 Leu Tyr Gly Lys Asp Tyr Asn Val Tyr Thr His Ser Phe Leu Cys Tyr
 245 250 255
 Gly Lys Asp Gln Ala Leu Trp Gln Lys Leu Ala Lys Asp Ile Gln Gln
 260 265 270
 Phe Glu Ile Gln Gly Ile Gly Asn Tyr Gln Gln Cys His Gln Ser Ile
 275 280 285
 Leu Glu Leu Phe Asn Thr Ser Tyr Cys Pro Tyr Ser Gln Cys Ala Phe
 290 295 300
 Asn Gly Ile Phe Leu Pro Pro Leu Gln Gly Asp Phe Gly Ala Phe Ser
 305 310 315 320
 Ala Phe Tyr Phe Val Met Lys Phe Leu Asn Leu Thr Ser Glu Lys Val
 325 330 335
 Ser Gln Glu Lys Val Thr Glu Met Met Lys Lys Phe Cys Ala Gln Pro
 340 345 350
 Trp Glu Glu Ile Lys Thr Ser Tyr Ala Gly Val Lys Glu Lys Tyr Leu
 355 360 365
 Ser Glu Tyr Cys Phe Ser Gly Thr Tyr Ile Leu Ser Leu Leu Leu Gln
 370 375 380
 Gly Tyr His Phe Thr Ala Asp Ser Trp Glu His Ile His Phe Ile Gly
 385 390 395 400
 Lys Ile Gln Gly Ser Asp Ala Gly Trp Thr Leu Gly Tyr Met Leu Asn
 405 410 415
 Leu Thr Asn Met Ile Pro Ala Glu Gln Pro Leu Ser Thr Pro Leu Ser

420

425

430

His Ser Thr Tyr Val Phe Leu Met Val Leu Phe Ser Leu Val Leu Phe
 435 440 445

Thr Val Ala Ile Ile Gly Leu Leu Ile Phe His Lys Pro Ser Tyr Phe
 450 455 460

Trp Lys Asp Met Val
 465

<210> 9
 <211> 1209
 <212> DNA
 <213> Homo sapiens

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 ctggatgtgg tggagaggag cctcagcaac tacccttttg acttccaggg tgccaggatc 180
 attactggcc aagaggaagg tgcctatggc tggattacta tcaactatct gctgggcaaa 240
 ttcagtcaga aaacaaggtg gttcagcata gtcccatatg aaaccaataa tcaggaaacc 300
 tttggagctt tggaccttgg gggagcctct acacaagtca cttttgtacc ccaaaaccag 360
 actatcgagt cccagataa tgctctgcaa tttcgctct atggcaagga ctacaatgtc 420
 tacacacata gcttcttgtg ctatgggaag gatcaggcac tctggcagaa actggccaag 480
 gacattcagg ttgcaagtaa tgaaattctc agggacccat gctttcatcc tggatataag 540
 aaggtagtga acgtaagtga cttttacaag acccctgca ccaagagatt tgagatgact 600
 cttccattcc agcagtttga aatccagggg attggaaact atcaacaatg ccatcaaagc 660
 atcctggagc tcttcaacac cagttactgc cttactccc agtgtgcctt caatgggatt 720
 ttcttgccac cactccaggg ggattttggg gcattttcag ctttttactt tgtgatgaag 780
 tttttaaact tgacatcaga gaaagtctct caggaaaagg tgactgagat gatgaaaaag 840
 ttctgtgctc agccttggga ggagataaaa acatcttacg ctggagtaaa ggagaagtac 900
 ctgagtgaat actgcttttc tgggtacctac attctctccc tccttctgca aggctatcat 960
 ttcacagctg attcctggga gcacatccat ttcattggca agatccaggg cagcgacgcc 1020
 ggctggactt tgggctacat gctgaacctg accaacaatga tcccagctga gcaaccattg 1080
 tccacacctc tctcccactc cacctatgtc ttcctcatgg ttctattctc cctggtcctt 1140
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 atggtatag 1209

<210> 10

<211> 402
 <212> PRT
 <213> Homo sapiens

<400> 10

Met Glu Arg Ala Arg Glu Val Ile Pro Arg Ser Gln His Gln Glu Thr
 1 5 10 15

Pro Val Tyr Leu Gly Ala Thr Ala Gly Met Arg Leu Leu Arg Met Glu
 20 25 30

Ser Glu Glu Leu Ala Asp Arg Val Leu Asp Val Val Glu Arg Ser Leu
 35 40 45

Ser Asn Tyr Pro Phe Asp Phe Gln Gly Ala Arg Ile Ile Thr Gly Gln
 50 55 60

Glu Glu Gly Ala Tyr Gly Trp Ile Thr Ile Asn Tyr Leu Leu Gly Lys
 65 70 75 80

Phe Ser Gln Lys Thr Arg Trp Phe Ser Ile Val Pro Tyr Glu Thr Asn
 85 90 95

Asn Gln Glu Thr Phe Gly Ala Leu Asp Leu Gly Gly Ala Ser Thr Gln
 100 105 110

Val Thr Phe Val Pro Gln Asn Gln Thr Ile Glu Ser Pro Asp Asn Ala
 115 120 125

Leu Gln Phe Arg Leu Tyr Gly Lys Asp Tyr Asn Val Tyr Thr His Ser
 130 135 140

Phe Leu Cys Tyr Gly Lys Asp Gln Ala Leu Trp Gln Lys Leu Ala Lys
 145 150 155 160

Asp Ile Gln Val Ala Ser Asn Glu Ile Leu Arg Asp Pro Cys Phe His
 165 170 175

Pro Gly Tyr Lys Lys Val Val Asn Val Ser Asp Leu Tyr Lys Thr Pro
 180 185 190

Cys Thr Lys Arg Phe Glu Met Thr Leu Pro Phe Gln Gln Phe Glu Ile
 195 200 205

Gln Gly Ile Gly Asn Tyr Gln Gln Cys His Gln Ser Ile Leu Glu Leu
 210 215 220

Phe Asn Thr Ser Tyr Cys Pro Tyr Ser Gln Cys Ala Phe Asn Gly Ile
 225 230 235 240

[illegible]

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<210> 11
<211> 1119
<212> DNA
<213> Homo sapiens
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tggattacta	tcaactatat	gctgggcaaa	ttcagtcaga	aaacaagggtg	gttcagcata		180
gtcccataatg	aaaccaataa	tcaggaaaacc	tttggagctt	tggaccttgg	gggagcctct		240
acacaagtca	cttttgtacc	ccaaaaccag	actatcgagt	ccccagataa	tgctctgcaa		300
tttcgcctct	atggcaagga	ctacaatgtc	tacacacata	gcttcttggtg	ctatgggaag		360
gatcaggcac	tctggcagaa	actggccaag	gacattcagg	ttgcaagtaa	tgaaattctc		420

agggacccat gctttcatcc tggatataag aaggtagtga acgtaagtga cctttacaag	480
accccctgca ccaagagatt tgagatgact cttccattcc agcagtttga aatccagggt	540
attggaaact atcaacaatg ccatcaaagc atcctggagc tcttcaacac cagttactgc	600
ccttactccc agtgtgcctt caatgggatt ttcttgccac cactccaggg ggattttggg	660
gcattttcag ctttttactt tgtgatgaag tttttaaaact tgacatcaga gaaagtctct	720
caggaaaagg tgactgagat gatgaaaaag ttctgtgctc agccttggga ggagataaaa	780
acatcttacg ctggagtaaa ggagaagtac ctgagtgaat actgcttttc tggtagctac	840
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ttcattggca agatccaggg cagcgacgcc ggctggactt tgggctacat gctgaacctg	960
accaacatga tcccagctga gcaaccattg tccacacctc tctcccactc cacctatgtc	1020
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tttcacaagc cttcatatct ctggaaagat atggtatag	1119

<210> 12
 <211> 1119
 <212> DNA
 <213> Homo sapiens

<400> 12	
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tggattacta tcaactatct gctgggcaaa ttcagtcaga aaacaagggtg gttcagcata	180
gtcccatatg aaaccaataa tcaggaaacc tttggagctt tggaccttgg gggagcctct	240
acacaagtca cttttgtacc ccaaaaccag actatcgagt ccccagataa tgctctgcaa	300
tttcgcctct atggcaagga ctacaatgtc tacacacata gcttcttgtg ctatgggaag	360
gatcaggcac tctggcagaa actggccaag gacattcagg ttgcaagtaa tgaaattctc	420
agggacccat gctttcatcc tggatataag aaggtagtga acgtaagtga cctttacaag	480
accccctgca ccaagagatt tgagatgact cttccattcc agcagtttga aatccagggt	540
attggaaact atcaacaatg ccatcaaagc atcctggagc tcttcaacac cagttactgc	600
ccttactccc agtgtgcctt caatgggatt ttcttgccac cactccaggg ggattttggg	660
gcattttcag ctttttactt tgtgatgaag tttttaaaact tgacatcaga gaaagtctct	720
caggaaaagg tgactgagat gatgaaaaag ttctgtgctc agccttggga ggagataaaa	780
acatcttacg ctggagtaaa ggagaagtac ctgagtgaat actgcttttc tggtagctac	840
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ttcattggca agatccaggg cagcgacgcc ggctggactt tgggctacat gctgaacctg	960
accaacatga tcccagctga gcaaccattg tccacacctc tctcccactc cacctatgtc	1020

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 tttcacaagc cttcatatct ctggaaagat atggtatag 1119

<210> 13
 <211> 372
 <212> PRT
 <213> Homo sapiens

<400> 13

Met Glu Ser Glu Glu Leu Ala Asp Arg Val Leu Asp Val Val Glu Arg
 1 5 10 15

Ser Leu Ser Asn Tyr Pro Phe Asp Phe Gln Gly Ala Arg Ile Ile Thr
 20 25 30

Gly Gln Glu Glu Gly Ala Tyr Gly Trp Ile Thr Ile Asn Tyr Leu Leu
 35 40 45

Gly Lys Phe Ser Gln Lys Thr Arg Trp Phe Ser Ile Val Pro Tyr Glu
 50 55 60

Thr Asn Asn Gln Glu Thr Phe Gly Ala Leu Asp Leu Gly Gly Ala Ser
 65 70 75 80

Thr Gln Val Thr Phe Val Pro Gln Asn Gln Thr Ile Glu Ser Pro Asp
 85 90 95

Asn Ala Leu Gln Phe Arg Leu Tyr Gly Lys Asp Tyr Asn Val Tyr Thr
 100 105 110

His Ser Phe Leu Cys Tyr Gly Lys Asp Gln Ala Leu Trp Gln Lys Leu
 115 120 125

Ala Lys Asp Ile Gln Val Ala Ser Asn Glu Ile Leu Arg Asp Pro Cys
 130 135 140

Phe His Pro Gly Tyr Lys Lys Val Val Asn Val Ser Asp Leu Tyr Lys
 145 150 155 160

Thr Pro Cys Thr Lys Arg Phe Glu Met Thr Leu Pro Phe Gln Gln Phe
 165 170 175

Glu Ile Gln Gly Ile Gly Asn Tyr Gln Gln Cys His Gln Ser Ile Leu
 180 185 190

Glu Leu Phe Asn Thr Ser Tyr Cys Pro Tyr Ser Gln Cys Ala Phe Asn
 195 200 205

Gly Ile Phe Leu Pro Pro Leu Gln Gly Asp Phe Gly Ala Phe Ser Ala

210

215

220

Phe Tyr Phe Val Met Lys Phe Leu Asn Leu Thr Ser Glu Lys Val Ser
225 230 235 240

Gln Glu Lys Val Thr Glu Met Met Lys Lys Phe Cys Ala Gln Pro Trp
245 250 255

Glu Glu Ile Lys Thr Ser Tyr Ala Gly Val Lys Glu Lys Tyr Leu Ser
260 265 270

Glu Tyr Cys Phe Ser Gly Thr Tyr Ile Leu Ser Leu Leu Leu Gln Gly
275 280 285

Tyr His Phe Thr Ala Asp Ser Trp Glu His Ile His Phe Ile Gly Lys
290 295 300

Ile Gln Gly Ser Asp Ala Gly Trp Thr Leu Gly Tyr Met Leu Asn Leu
305 310 315 320

Thr Asn Met Ile Pro Ala Glu Gln Pro Leu Ser Thr Pro Leu Ser His
325 330 335

Ser Thr Tyr Val Phe Leu Met Val Leu Phe Ser Leu Val Leu Phe Thr
340 345 350

Val Ala Ile Ile Gly Leu Leu Ile Phe His Lys Pro Ser Tyr Phe Trp
355 360 365

Lys Asp Met Val
370

<210> 14
<211> 1533
<212> DNA
<213> Mus musculus

<400> 14
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aaacctttgc cagaaaatgt taagtatggg attgtgttgg atgcgggggtc atctcacacc 180
aacctgtaca tctacaagtg gccggccgag aaggagaatg acacaggggt ggtgcagcag 240
ttagaggaat gccaaagtga aggtcctgga atctcaaaat atgctcagaa aacagatgaa 300
atcggtgcgt acctggccga atgcatggaa ctgtccaccg aactgatacc aacatccaag 360
catcaccaga ctctgttcta cctgggagcc acagcaggca tgcgcttgct tagaatggaa 420
agcgaacaat cggcagacga ggtcctggct gcagtgtcaa caagccttaa gagctacccc 480

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tttgacttcc aggggtgccaa gatcatcact ggacaagagg aagggtgccta tgggtggatt      540
actattaact atctgctggg cagattcact caggaacaga gttggctaag cctcatctca      600
gacagtcaga aacaggaaac ctttggcgct ttggatctcg gcggagcctc cacacagatc      660
accttcgtgc cccaaaacag cactatagag tccccagaaa actctctgca attccgtctc      720
tatggcgagg actatactgt gtacacacac agcttcctgt gctatgggaa ggatcaggct      780
ctctggcaga aactggccaa ggacattcag gtttcaagtg gtggcgtcct taaggacca      840
tgctttaacc caggatacga gaaggttgtg aatgtaagtg agctctatgg cactccctgc      900
acaaaagat tcgaaaagaa gctaccatth gatcagtttc gaatccaggg cactggagac      960
tacgaacagt gccaccagag catccttgag ctcttcaaca acagccactg cccttactcc     1020
cagtgtgcct tcaatggcgt cttcctgcc a cctctccatg ggagttttgg ggcgttttct     1080
gctttctact ttgtgatgga tttttttaag aaggtagcga aaaacagtgt catctctcag     1140
gagaaaatga ccgagataac aaaaaatttt tgctcaaat cttgggaaga gacaaagaca     1200
tcttatcctt cagtaaagga gaagtacctg agtgagtact gcttctcggg cgcctacatc     1260
ctctctctcc tgcaaggcta taacttcaca gacagctcct gggaacagat tcattttatg     1320
ggcaagatca aagacagcaa cgcgggggtgg actttgggct acatgctgaa cttgaccaac     1380
atgatcccag ctgaacagcc gttgtccccg cctctccctc actccaccta catcggcctc     1440
atggtttctt tctccctgct cttggttgct gtggccatca caggcctggt catctatagc     1500
aagccttcat atttctggaa agaggcagta tag                                  1533

```

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<210> 15
<211> 510
<212> PRT
<213> Mus musculus

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<400> 15
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Met Glu Asp Ile Lys Asp Ser Lys Val Lys Arg Phe Cys Ser Lys Asn
1           5           10          15
```

```
Ile Leu Ile Ile Leu Gly Phe Thr Ser Ile Leu Ala Val Ile Ala Leu
20           25          30
```

```
Ile Ala Val Gly Leu Thr Gln Asn Lys Pro Leu Pro Glu Asn Val Lys
35           40          45
```

```
Tyr Gly Ile Val Leu Asp Ala Gly Ser Ser His Thr Asn Leu Tyr Ile
50           55          60
```

```
Tyr Lys Trp Pro Ala Glu Lys Glu Asn Asp Thr Gly Val Val Gln Gln
65           70          75          80
```

```
Leu Glu Glu Cys Gln Val Lys Gly Pro Gly Ile Ser Lys Tyr Ala Gln
```

85

90

95

Lys Thr Asp Glu Ile Gly Ala Tyr Leu Ala Glu Cys Met Glu Leu Ser
 100 105 110

Thr Glu Leu Ile Pro Thr Ser Lys His His Gln Thr Pro Val Tyr Leu
 115 120 125

Gly Ala Thr Ala Gly Met Arg Leu Leu Arg Met Glu Ser Glu Gln Ser
 130 135 140

Ala Asp Glu Val Leu Ala Ala Val Ser Thr Ser Leu Lys Ser Tyr Pro
 145 150 155 160

Phe Asp Phe Gln Gly Ala Lys Ile Ile Thr Gly Gln Glu Glu Gly Ala
 165 170 175

Tyr Gly Trp Ile Thr Ile Asn Tyr Leu Leu Gly Arg Phe Thr Gln Glu
 180 185 190

Gln Ser Trp Leu Ser Leu Ile Ser Asp Ser Gln Lys Gln Glu Thr Phe
 195 200 205

Gly Ala Leu Asp Leu Gly Gly Ala Ser Thr Gln Ile Thr Phe Val Pro
 210 215 220

Gln Asn Ser Thr Ile Glu Ser Pro Glu Asn Ser Leu Gln Phe Arg Leu
 225 230 235 240

Tyr Gly Glu Asp Tyr Thr Val Tyr Thr His Ser Phe Leu Cys Tyr Gly
 245 250 255

Lys Asp Gln Ala Leu Trp Gln Lys Leu Ala Lys Asp Ile Gln Val Ser
 260 265 270

Ser Gly Gly Val Leu Lys Asp Pro Cys Phe Asn Pro Gly Tyr Glu Lys
 275 280 285

Val Val Asn Val Ser Glu Leu Tyr Gly Thr Pro Cys Thr Lys Arg Phe
 290 295 300

Glu Lys Lys Leu Pro Phe Asp Gln Phe Arg Ile Gln Gly Thr Gly Asp
 305 310 315 320

Tyr Glu Gln Cys His Gln Ser Ile Leu Glu Leu Phe Asn Asn Ser His
 325 330 335

Cys Pro Tyr Ser Gln Cys Ala Phe Asn Gly Val Phe Leu Pro Pro Leu
 340 345 350

His Gly Ser Phe Gly Ala Phe Ser Ala Phe Tyr Phe Val Met Asp Phe
 355 360 365
 Phe Lys Lys Val Ala Lys Asn Ser Val Ile Ser Gln Glu Lys Met Thr
 370 375 380
 Glu Ile Thr Lys Asn Phe Cys Ser Lys Ser Trp Glu Glu Thr Lys Thr
 385 390 395 400
 Ser Tyr Pro Ser Val Lys Glu Lys Tyr Leu Ser Glu Tyr Cys Phe Ser
 405 410 415
 Gly Ala Tyr Ile Leu Ser Leu Leu Gln Gly Tyr Asn Phe Thr Asp Ser
 420 425 430
 Ser Trp Glu Gln Ile His Phe Met Gly Lys Ile Lys Asp Ser Asn Ala
 435 440 445
 Gly Trp Thr Leu Gly Tyr Met Leu Asn Leu Thr Asn Met Ile Pro Ala
 450 455 460
 Glu Gln Pro Leu Ser Pro Pro Leu Pro His Ser Thr Tyr Ile Gly Leu
 465 470 475 480
 Met Val Leu Phe Ser Leu Leu Leu Val Ala Val Ala Ile Thr Gly Leu
 485 490 495
 Phe Ile Tyr Ser Lys Pro Ser Tyr Phe Trp Lys Glu Ala Val
 500 505 510

<210> 16
 <211> 1536
 <212> DNA
 <213> Rattus norvegicus

<400> 16
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 aaaccattgc cagaaaatgt taagtatggg attgtgctgg atgccggggtc gtctcacacc 180
 aacctgtaca tctacaagtg gccggctgag aaggagaatg atacaggagt ggtgcagctg 240
 ttagaagaat gccaaagtga aggtcccga atctcaaat acgctcagaa aacagatgaa 300
 atagctgcat atctggctga atgcatgaaa atgtccactg agcggatacc agcgtccaaa 360
 cagcaccaga caccctgtga cctgggagcc accgcgggca tgcgcttgct cagaatggaa 420
 agcaagcaat cggcagacga agtcctggct gcagtgtcta ggagcctgaa gagctacccc 480
 tttgacttcc agggcgccaa gatcatcact gggcaggagg aaggggccta tgggtggatt 540

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actattaact atctgctggg cagattcact caggaacaga gttggctaaa cttcatctca      600
gacagccaga aacaggcaac ctttggcgct ttggatcttg gcggcagttc tacacaagtc      660
accttcgtgc ccctaaatca gactctagag gccccagaaa cctccctgca gttccgtctc      720
tacggcacgg actacaccgt gtacacacac agcttcctgt gctatgggaa ggatcaggca      780
ctctggcaga aactggccca ggacattcag gtttcaagtg gtgggattct caaggacccg      840
tgcttttacc caggatataa gaaggttgtg aatgtaagcg aactctatgg cactccctgc      900
accaagagat ttgagaagaa gctaccgttt aatcagtttc aagttcaggg cactggagat      960
tacgaacagt gccaccagag catcctcaag ttcttcaaca acagccactg cccttactcc     1020
cagtgtgcct tcaacggtgt ctttttacca cctctccagg ggagttttgg ggcattttct     1080
gctttctact ttgtgatgga cttttttaag aagatggcga acgacagtgt ctcctctcag     1140
gagaaaatga ctgagataac aaaaaacttt tgctcaaagc cttgggagga ggtaaaggca     1200
tcttatccta cagtaaagga gaagtacctg agtgaatact gtttctcggg gacctacatc     1260
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aacatgatcc cagctgaaca gccattatcc ccgcctctcc ctcactccac ctacatcagc     1440
ctcatggttc tcttctccct ggtcttggtc gccatggtca tcacagggct gttcatcttt     1500
agcaagcctt cgtatttctg gaaagaggca gtatag                               1536

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```

<210> 17
<211> 511
<212> PRT
<213> Rattus norvegicus

```

```
<400> 17
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Met Glu Asp Ile Lys Asp Ser Lys Val Lys Arg Phe Cys Ser Lys Asn
1           5           10           15
```

```
Ile Leu Ile Ile Leu Gly Phe Ser Ser Val Leu Ala Val Ile Ala Leu
20           25           30
```

```
Ile Ala Val Gly Leu Thr His Asn Lys Pro Leu Pro Glu Asn Val Lys
35           40           45
```

```
Tyr Gly Ile Val Leu Asp Ala Gly Ser Ser His Thr Asn Leu Tyr Ile
50           55           60
```

```
Tyr Lys Trp Pro Ala Glu Lys Glu Asn Asp Thr Gly Val Val Gln Leu
65           70           75           80
```

```
Leu Glu Glu Cys Gln Val Lys Gly Pro Gly Ile Ser Lys Tyr Ala Gln
85           90           95
```

Lys Thr Asp Glu Ile Ala Ala Tyr Leu Ala Glu Cys Met Lys Met Ser
 100 105 110
 Thr Glu Arg Ile Pro Ala Ser Lys Gln His Gln Thr Pro Val Tyr Leu
 115 120 125
 Gly Ala Thr Ala Gly Met Arg Leu Leu Arg Met Glu Ser Lys Gln Ser
 130 135 140
 Ala Asp Glu Val Leu Ala Ala Val Ser Arg Ser Leu Lys Ser Tyr Pro
 145 150 155 160
 Phe Asp Phe Gln Gly Ala Lys Ile Ile Thr Gly Gln Glu Glu Gly Ala
 165 170 175
 Tyr Gly Trp Ile Thr Ile Asn Tyr Leu Leu Gly Arg Phe Thr Gln Glu
 180 185 190
 Gln Ser Trp Leu Asn Phe Ile Ser Asp Ser Gln Lys Gln Ala Thr Phe
 195 200 205
 Gly Ala Leu Asp Leu Gly Gly Ser Ser Thr Gln Val Thr Phe Val Pro
 210 215 220
 Leu Asn Gln Thr Leu Glu Ala Pro Glu Thr Ser Leu Gln Phe Arg Leu
 225 230 235 240
 Tyr Gly Thr Asp Tyr Thr Val Tyr Thr His Ser Phe Leu Cys Tyr Gly
 245 250 255
 Lys Asp Gln Ala Leu Trp Gln Lys Leu Ala Gln Asp Ile Gln Val Ser
 260 265 270
 Ser Gly Gly Ile Leu Lys Asp Pro Cys Phe Tyr Pro Gly Tyr Lys Lys
 275 280 285
 Val Val Asn Val Ser Glu Leu Tyr Gly Thr Pro Cys Thr Lys Arg Phe
 290 295 300
 Glu Lys Lys Leu Pro Phe Asn Gln Phe Gln Val Gln Gly Thr Gly Asp
 305 310 315 320
 Tyr Glu Gln Cys His Gln Ser Ile Leu Lys Phe Phe Asn Asn Ser His
 325 330 335
 Cys Pro Tyr Ser Gln Cys Ala Phe Asn Gly Val Phe Leu Pro Pro Leu
 340 345 350

Gln Gly Ser Phe Gly Ala Phe Ser Ala Phe Tyr Phe Val Met Asp Phe
 355 360 365
 Phe Lys Lys Met Ala Asn Asp Ser Val Ser Ser Gln Glu Lys Met Thr
 370 375 380
 Glu Ile Thr Lys Asn Phe Cys Ser Lys Pro Trp Glu Glu Val Lys Ala
 385 390 395 400
 Ser Tyr Pro Thr Val Lys Glu Lys Tyr Leu Ser Glu Tyr Cys Phe Ser
 405 410 415
 Gly Thr Tyr Ile Leu Ser Leu Leu Leu Gln Gly Tyr Asn Phe Thr Gly
 420 425 430
 Thr Ser Trp Asp Gln Ile His Phe Met Gly Lys Ile Lys Asp Ser Asn
 435 440 445
 Ala Gly Trp Thr Leu Gly Tyr Met Leu Asn Leu Thr Asn Met Ile Pro
 450 455 460
 Ala Glu Gln Pro Leu Ser Pro Pro Leu Pro His Ser Thr Tyr Ile Ser
 465 470 475 480
 Leu Met Val Leu Phe Ser Leu Val Leu Val Ala Met Val Ile Thr Gly
 485 490 495
 Leu Phe Ile Phe Ser Lys Pro Ser Tyr Phe Trp Lys Glu Ala Val
 500 505 510

<210> 18
 <211> 1542
 <212> DNA
 <213> Bos taurus

<400> 18
 atggaagata gaagggaatc tgaactgaag gtatttttgct ctaaaaacat actgagcata 60
 cttggtttct cctgcatcat cgctgtgata gcattgctcg ctctgggggct gaccagaaac 120
 aaagcactgc cagaaaatgt taagtttggg attgtgctgg atgcgggctc ctctcatacg 180
 agtttgtaca tctatagatg gccggcagag aaggagaatg acacgggggt ggtgactcag 240
 atagaagaat cgaacgttaa aggtcccga atctcaggct ttgctaaaaa agtaaataa 300
 atcaatgttt atctgacggc atgcatggaa agagcccaga aagtgattcc gtcaatccag 360
 cacatggaaa cacctgtgta cctgggagcc acggccggca tgcggttgct ccggatggaa 420
 aataaacaga tggcagacaa gatcctggct gcagttgcaa gcagcatcag cgagtacccc 480
 ttgacttcc aaggtgccag aatcatcagt ggccaggagg aaggtgccta tggctggatt 540

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actgtcaact atttgctggg caaattcact cagaaattga gttggtttaa cctgaagcca      600
agcaaagacg acactcagga aacctatgga gcttttagacc ttggggggagc ctctacacaa      660
atcacttttg tgccccaata tgaaacgacc gagtctccaa acaacaacct gtacttccgc      720
ctctatggca agaactacag tgtatacaca cacagcttcc tgtgctatgg gaaggaccaa      780
gcacttttgc agaaactggc cctgggactt caggggtacaa atggaatcat ccatgagcca      840
tgcttttact caagatacat gaggaaaata aagatgagcg tcttaaacga aggtttctgt      900
accaagagac atgagttgaa ttcttcattt tatccactcg ttgacattga aatccgtggc      960
gctggaaact tccaacgatg tcggcaaagc atcattcaac tctttaacac cagttactgc     1020
ccttactcca gttgctcctt caatgggggtt ttcttgccgc cactccatgg gcagtttggg     1080
gcattttcag ctttttacta tgtgatggag tttttaaaacc ttacatcaga ggaatcagta     1140
tctgtggaac agttgactga gaagttggaa gagttctgcg cacagcgttg ggaagaggtg     1200
cagaagaatt ttggtgaagt gaaggagaaa tacctgagtg aatactgctt ttctggcacc     1260
tacatcctgg ttctcctcct gaatggctac cattttacag ctgagtcctg gaaaaatatt     1320
cacttcatga acaagggtccg gagcaccgac gttgggtgga ctttgggcta catgctgaac     1380
ctgaccaaca agattccagc tgaagagcca atgtccccac ccctcccca ctccacctat     1440
gtcttcctca tggtcctctt ctccctgatc ctgctcgcag tgatcatcgt aggcatagtt     1500
gtctttcaca agccttcgta tttctggaaa gacatggtat ag                          1542

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<210> 19
<211> 513
<212> PRT
<213> Bos taurus

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<400> 19

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Met Glu Asp Arg Arg Glu Ser Glu Leu Lys Val Phe Cys Ser Lys Asn
 1           5           10          15

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Ile Leu Ser Ile Leu Gly Phe Ser Cys Ile Ile Ala Val Ile Ala Leu
      20          25          30

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Leu Ala Leu Gly Leu Thr Gln Asn Lys Ala Leu Pro Glu Asn Val Lys
      35          40          45

```

```

Phe Gly Ile Val Leu Asp Ala Gly Ser Ser His Thr Ser Leu Tyr Ile
      50          55          60

```

```

Tyr Arg Trp Pro Ala Glu Lys Glu Asn Asp Thr Gly Val Val Thr Gln
      65          70          75          80

```

```

Ile Glu Glu Ser Asn Val Lys Gly Pro Gly Ile Ser Gly Phe Ala Lys
      85          90          95

```

Lys Val Asn Glu Ile Asn Val Tyr Leu Thr Ala Cys Met Glu Arg Ala
 100 105 110

Gln Lys Val Ile Pro Ser Ile Gln His Met Glu Thr Pro Val Tyr Leu
 115 120 125

Gly Ala Thr Ala Gly Met Arg Leu Leu Arg Met Glu Asn Lys Gln Met
 130 135 140

Ala Asp Lys Ile Leu Ala Ala Val Ala Ser Ser Ile Ser Glu Tyr Pro
 145 150 155 160

Phe Asp Phe Gln Gly Ala Arg Ile Ile Ser Gly Gln Glu Glu Gly Ala
 165 170 175

Tyr Gly Trp Ile Thr Val Asn Tyr Leu Leu Gly Lys Phe Thr Gln Lys
 180 185 190

Leu Ser Trp Phe Asn Leu Lys Pro Ser Lys Asp Asp Thr Gln Glu Thr
 195 200 205

Tyr Gly Ala Leu Asp Leu Gly Gly Ala Ser Thr Gln Ile Thr Phe Val
 210 215 220

Pro Gln Asn Glu Thr Thr Glu Ser Pro Asn Asn Asn Leu Tyr Phe Arg
 225 230 235 240

Leu Tyr Gly Lys Asn Tyr Ser Val Tyr Thr His Ser Phe Leu Cys Tyr
 245 250 255

Gly Lys Asp Gln Ala Leu Leu Gln Lys Leu Ala Leu Gly Leu Gln Gly
 260 265 270

Thr Asn Gly Ile Ile His Glu Pro Cys Phe His Ser Arg Tyr Met Arg
 275 280 285

Lys Ile Lys Met Ser Val Leu Asn Glu Gly Phe Cys Thr Lys Arg His
 290 295 300

Glu Leu Asn Ser Ser Phe Tyr Pro Leu Val Asp Ile Glu Ile Arg Gly
 305 310 315 320

Ala Gly Asn Phe Gln Arg Cys Arg Gln Ser Ile Ile Gln Leu Phe Asn
 325 330 335

Thr Ser Tyr Cys Pro Tyr Ser Ser Cys Ser Phe Asn Gly Val Phe Leu
 340 345 350

Pro Pro Leu His Gly Gln Phe Gly Ala Phe Ser Ala Phe Tyr Tyr Val
 355 360 365

Met Glu Phe Leu Asn Leu Thr Ser Glu Glu Ser Val Ser Val Glu Gln
 370 375 380

Leu Thr Glu Lys Leu Glu Glu Phe Cys Ala Gln Arg Trp Glu Glu Val
 385 390 395 400

Gln Lys Asn Phe Gly Glu Val Lys Glu Lys Tyr Leu Ser Glu Tyr Cys
 405 410 415

Phe Ser Gly Thr Tyr Ile Leu Val Leu Leu Leu Asn Gly Tyr His Phe
 420 425 430

Thr Ala Glu Ser Trp Lys Asn Ile His Phe Met Asn Lys Val Arg Ser
 435 440 445

Thr Asp Val Gly Trp Thr Leu Gly Tyr Met Leu Asn Leu Thr Asn Lys
 450 455 460

Ile Pro Ala Glu Glu Pro Met Ser Pro Pro Leu Pro His Ser Thr Tyr
 465 470 475 480

Val Phe Leu Met Val Leu Phe Ser Leu Ile Leu Leu Ala Val Ile Ile
 485 490 495

Val Gly Ile Val Val Phe His Lys Pro Ser Tyr Phe Trp Lys Asp Met
 500 505 510

Val

<210> 20
 <211> 1527
 <212> DNA
 <213> Xenopus laevis

<400> 20
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 ctaggagctc tgtttgtctt ggggtgttatc tcttttagtcg caattgcagt agtgcagaat 120
 aaacctcttc caaagaatat taagtatggc attgtgctgg acgctgggtc gtcccatacc 180
 agtgtgtata tatatgaatg gccggcagaa aaggaaaatg acaccggtgt tgtacagcag 240
 ataaacgagt gcaaagttga aggcaacggt atatccagtt atggccacga gccactgaag 300
 gccggtcttt ctctacagaa gtgtatgaat aaagcccgtc aggtcattcc tgagaagcag 360
 caaagggaga caccagttta tttaggggcc acagcaggaa tgcgtttgct caggctaact 420
 aatgcaacaa tggctgagga agtcctgtct tcagtggaaa atacgctgcg ttcctttccg 480

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tttgattttc aggggtgccag aataattaca ggacaagaag aaggcgctta tggatggatc      540
acaattaatt atctgcttgg aaactttatc caggattcag gttggttcaa atatatacca      600
aattttcaaac ccactgaaac ttccggtgca ctggatcttg gaggtgcttc aacacagatc      660
acctttgagt ccaaaagaga gattgaatcc caagaaaatt ccttgcaactt ccgcctttat      720
ggtaaatacct atgatatcta tacacacagc tttctctgct atggaaagga ccaagctctg      780
cgccttcaga tagctaatag tataaaggat gcaacagatt ccatcctttt ggatccttgc      840
tttaactcag gatatagaag gaacgcaagc accaatgacc tctacagtag tccctgcata      900
tctaaactga ggataccaac agcacccagc accttagata ttagaggcac tggcaattat      960
cagctatgca agagaaatgt ccaggcaatc ttcaacagaa cacattgtac ttactcacat     1020
tgctctttta atgggggtttt tcaaccaagt ttggatggca catttggggc attctcagca     1080
tattattttg ttatgaattt tttaaacctt accaatgagc aaatgtctct tgacaaagta     1140
aaagagacgg tagaaagaca ctgctccaga ccatgggacg aggtaaaaaa agactttcca     1200
aaaattaaag aaaaatacct gagtgaatac tgtttttctg gaacatatat attaaatctt     1260
cttgaatatg gatacggctt tagctctgaa aactggaacg atatcagatt ttaggcaag      1320
atcaaagaca gtgatgcagg atggacactt ggttatatgc tgaacctgac caatatgatc      1380
cctgcagagc tgccttattc tcctccgctg tcccacgctg gttacactgg acttatggtc      1440
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aaatgtctac acaagggcat catctag                                           1527

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<210> 21
<211> 508
<212> PRT
<213> Xenopus laevis

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<400> 21

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Met Asp Glu Pro Lys Ala Ala Lys Gln Lys Lys Thr Trp His Lys Lys
1          5          10          15

```

```

Val Ile Ile Phe Leu Gly Ala Leu Phe Val Leu Gly Val Ile Ser Leu
20          25          30

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```

Val Ala Ile Ala Val Val Gln Asn Lys Pro Leu Pro Lys Asn Ile Lys
35          40          45

```

```

Tyr Gly Ile Val Leu Asp Ala Gly Ser Ser His Thr Ser Val Tyr Ile
50          55          60

```

```

Tyr Glu Trp Pro Ala Glu Lys Glu Asn Asp Thr Gly Val Val Gln Gln
65          70          75          80

```

Ile Asn Glu Cys Lys Val Glu Gly Asn Gly Ile Ser Ser Tyr Gly His
 85 90 95
 Glu Pro Leu Lys Ala Gly Leu Ser Leu Gln Lys Cys Met Asn Lys Ala
 100 105 110
 Arg Gln Val Ile Pro Glu Lys Gln Gln Arg Glu Thr Pro Val Tyr Leu
 115 120 125
 Gly Ala Thr Ala Gly Met Arg Leu Leu Arg Leu Thr Asn Ala Thr Met
 130 135 140
 Ala Glu Glu Val Leu Ser Ser Val Glu Asn Thr Leu Arg Ser Phe Pro
 145 150 155 160
 Phe Asp Phe Gln Gly Ala Arg Ile Ile Thr Gly Gln Glu Glu Gly Ala
 165 170 175
 Tyr Gly Trp Ile Thr Ile Asn Tyr Leu Leu Gly Asn Phe Ile Gln Asp
 180 185 190
 Ser Gly Trp Phe Lys Tyr Ile Pro Asn Phe Lys Pro Thr Glu Thr Ser
 195 200 205
 Gly Ala Leu Asp Leu Gly Gly Ala Ser Thr Gln Ile Thr Phe Glu Ser
 210 215 220
 Lys Arg Glu Ile Glu Ser Gln Glu Asn Ser Leu His Phe Arg Leu Tyr
 225 230 235 240
 Gly Lys Ser Tyr Asp Ile Tyr Thr His Ser Phe Leu Cys Tyr Gly Lys
 245 250 255
 Asp Gln Ala Leu Arg Leu Gln Ile Ala Asn Ser Ile Lys Asp Ala Thr
 260 265 270
 Asp Ser Ile Leu Leu Asp Pro Cys Phe Asn Ser Gly Tyr Arg Arg Asn
 275 280 285
 Ala Ser Thr Asn Asp Leu Tyr Ser Ser Pro Cys Ile Ser Lys Leu Arg
 290 295 300
 Ile Pro Thr Ala Pro Ser Thr Leu Asp Ile Arg Gly Thr Gly Asn Tyr
 305 310 315 320
 Gln Leu Cys Lys Arg Asn Val Gln Ala Ile Phe Asn Arg Thr His Cys
 325 330 335
 Thr Tyr Ser His Cys Ser Phe Asn Gly Val Phe Gln Pro Ser Leu Asp

340	345	350
Gly Thr Phe Gly Ala Phe Ser Ala Tyr Tyr Phe Val Met Asn Phe Leu		
355	360	365
Asn Leu Thr Asn Glu Gln Met Ser Leu Asp Lys Val Lys Glu Thr Val		
370	375	380
Glu Arg His Cys Ser Arg Pro Trp Asp Glu Val Lys Lys Asp Phe Pro		
385	390	395
Lys Ile Lys Glu Lys Tyr Leu Ser Glu Tyr Cys Phe Ser Gly Thr Tyr		
	405	410
Ile Leu Asn Leu Leu Glu Tyr Gly Tyr Gly Phe Ser Ser Glu Asn Trp		
	420	425
Asn Asp Ile Arg Phe Leu Gly Lys Ile Lys Asp Ser Asp Ala Gly Trp		
	435	440
Thr Leu Gly Tyr Met Leu Asn Leu Thr Asn Met Ile Pro Ala Glu Leu		
	450	455
Pro Tyr Ser Pro Pro Leu Ser His Ala Gly Tyr Thr Gly Leu Met Val		
465	470	475
Phe Phe Ser Ile Leu Leu Val Cys Ile Ile Leu Thr Cys Trp Leu Ser		
	485	490
Phe Arg Lys Pro Lys Cys Leu His Lys Gly Ile Ile		
	500	505

<210> 22
 <211> 1479
 <212> DNA
 <213> Danio rerio

<400> 22	
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gttgccgtgg ggattgtcat catggtatcc atttctgttg tccagcacia gcctttaccc	120
caaaagtaca agtatggaat agtcctggat gccggctcct ctacacctc tgtgtttatc	180
tataaatggc cagcagagaa agagaacaac acaggcatgg tacagcagca tcacacgtgc	240
aatgttaaag gcaaaggcat ctccagttac ttcgataaac cacatggggc tgggtgcatct	300
ctggaggagt gcatgaagga ggccaaggag aaaatacctg ctacagaca cagcgaaacc	360
cctgtctacc tgggagccac ggctggcatg agactgctca agatggagga tgaaatggcc	420
tcagaaaaag tgcttacctc cgttgcacat tactgaaga cgtaccctt ctcctatcag	480

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ggagctcgta tcctttcagg ccaagaggag ggagcttttg ggtggattac agtcaactac      540
cttagtgaaa acttgagaaa gcccgagggc actcttgag ctctggacct tggaggagcc      600
tctactcaaa taaccttcgt acctcagcag attattgaat catctgacaa ttcgattgac      660
ttcagactgt atggaaatga ttatcatcta tacacccaca gctttctctg ttatgggaag      720
gaccaagctc tcaagcttgc tatggctgag aaattgcgct caacacctga caagacagat      780
gccattttgt taagggatcc ttgttttcat cctggatata acaccaccaa gacgcttgaa      840
agtgtcaata caccatgtat gaaaccactg aaaatgccaa aggagcagtt ctcccatgtg      900
gggcttgga attggtctca gtgccaagaa tcaatcagaa aggtttttaa tactagccat      960
tgtccttatt caggctgctc attcaatggt gttttccaac ctactgttga aggaaaattt    1020
ggggcttttt ctgctttctt ttttgtaatg gactttttaa atctgaaaaa cgattcattg    1080
gacaaaacaa agcagaggct ggcaatgtac tgctctaccc catggcaaaa gattgtacaa    1140
gatcacccaa aagtaaaaga gaagtacctt tctgaatact gcttctcagc aacatacatt    1200
ctcactctcc tggaacatgg atacaatttc acctcagaca actggaacga catcaagttt    1260
atcaagaaga ttggagacag tgatgcaggc tggactttag gttacatgct taacctgacc    1320
aacatgattc cggctgaaga tccagacaag ccactgatgc ctcattggagg atacgtcaca    1380
tttatgatcc tcttctcact tttgatactc gtcctcatca ttatggccta catttatttc    1440
cgtcgcttta ctaaaacagc ccagaaagac attatttag      1479

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<210> 23
 <211> 492
 <212> PRT
 <213> Danio rerio

<400> 23

Met Glu Val Lys Val Lys Asn Pro Trp His Arg Pro Val Val Ile Phe
 1 5 10 15

Leu Met Ala Val Val Ala Val Gly Ile Val Ile Met Val Ser Ile Ser
 20 25 30

Val Val Gln His Lys Pro Leu Pro Gln Lys Tyr Lys Tyr Gly Ile Val
 35 40 45

Leu Asp Ala Gly Ser Ser His Thr Ser Val Phe Ile Tyr Lys Trp Pro
 50 55 60

Ala Glu Lys Glu Asn Asn Thr Gly Met Val Gln Gln His His Thr Cys
 65 70 75 80

Asn Val Lys Gly Lys Gly Ile Ser Ser Tyr Phe Asp Lys Pro His Gly
 85 90 95

Ala Gly Ala Ser Leu Glu Glu Cys Met Lys Glu Ala Lys Glu Lys Ile
 100 105 110

Pro Ala His Arg His Ser Glu Thr Pro Val Tyr Leu Gly Ala Thr Ala
 115 120 125

Gly Met Arg Leu Leu Lys Met Glu Asp Glu Met Ala Ser Glu Lys Val
 130 135 140

Leu Thr Ser Val Ala His Ser Leu Lys Thr Tyr Pro Phe Ser Tyr Gln
 145 150 155 160

Gly Ala Arg Ile Leu Ser Gly Gln Glu Glu Gly Ala Phe Gly Trp Ile
 165 170 175

Thr Val Asn Tyr Leu Ser Glu Asn Leu Arg Lys Pro Ala Gly Thr Leu
 180 185 190

Gly Ala Leu Asp Leu Gly Gly Ala Ser Thr Gln Ile Thr Phe Val Pro
 195 200 205

Gln Gln Ile Ile Glu Ser Ser Asp Asn Ser Ile Asp Phe Arg Leu Tyr
 210 215 220

Gly Asn Asp Tyr His Leu Tyr Thr His Ser Phe Leu Cys Tyr Gly Lys
 225 230 235 240

Asp Gln Ala Leu Lys Leu Ala Met Ala Glu Lys Leu Arg Ser Thr Pro
 245 250 255

Asp Lys Thr Asp Ala Ile Leu Leu Arg Asp Pro Cys Phe His Pro Gly
 260 265 270

Tyr Asn Thr Thr Lys Thr Leu Glu Ser Val Asn Thr Pro Cys Met Lys
 275 280 285

Pro Leu Lys Met Pro Lys Glu Gln Phe Ser His Val Gly Leu Gly Asn
 290 295 300

Trp Ser Gln Cys Gln Glu Ser Ile Arg Lys Val Phe Asn Thr Ser His
 305 310 315 320

Cys Pro Tyr Ser Gly Cys Ser Phe Asn Gly Val Phe Gln Pro Thr Val
 325 330 335

Glu Gly Lys Phe Gly Ala Phe Ser Ala Phe Phe Phe Val Met Asp Phe
 340 345 350

Leu Asn Leu Lys Asn Asp Ser Leu Asp Lys Thr Lys Gln Arg Leu Ala
 355 360 365

Met Tyr Cys Ser Thr Pro Trp Gln Lys Ile Val Gln Asp His Pro Lys
 370 375 380

Val Lys Glu Lys Tyr Leu Ser Glu Tyr Cys Phe Ser Ala Thr Tyr Ile
 385 390 395 400

Leu Thr Leu Leu Glu His Gly Tyr Asn Phe Thr Ser Asp Asn Trp Asn
 405 410 415

Asp Ile Lys Phe Ile Lys Lys Ile Gly Asp Ser Asp Ala Gly Trp Thr
 420 425 430

Leu Gly Tyr Met Leu Asn Leu Thr Asn Met Ile Pro Ala Glu Asp Pro
 435 440 445

Asp Lys Pro Leu Met Pro His Gly Gly Tyr Val Thr Phe Met Ile Leu
 450 455 460

Phe Ser Leu Leu Ile Leu Val Leu Ile Ile Met Ala Tyr Ile Tyr Phe
 465 470 475 480

Arg Arg Phe Thr Lys Thr Ala Gln Lys Asp Ile Ile
 485 490

<210> 24
 <211> 10
 <212> PRT
 <213> Artificial Sequence

<220>
 <223> /note="Description of Artificial Sequence: HLA Class I tetramer peptide"

<400> 24

Gly Ile Asp Pro Asn Ile Arg Thr Gly Val
 1 5 10

<210> 25
 <211> 10
 <212> PRT
 <213> Artificial Sequence

<220>
 <223> /note="Description of Artificial Sequence: HLA Class I tetramer peptide"

<400> 25

Lys Leu Val Ala Leu Gly Ile Asn Ala Val
 1 5 10

<210> 26
 <211> 9
 <212> PRT
 <213> Artificial Sequence

<220>
 <223> /note="Description of Artificial Sequence: HLA Class I tetramer peptide"

<400> 26

Ala Thr Asp Ala Leu Met Thr Gly Tyr
 1 5

<210> 27
 <211> 10
 <212> PRT
 <213> Artificial Sequence

<220>
 <223> /note="Description of Artificial Sequence: HLA Class I tetramer peptide"

<400> 27

Arg Glu Ile Ser Val Pro Ala Glu Ile Leu
 1 5 10

<210> 28
 <211> 9
 <212> PRT
 <213> Artificial Sequence

<220>
 <223> /note="Description of Artificial Sequence: HLA Class I tetramer peptide"

<400> 28

Gly Pro Arg Leu Gly Val Arg Ala Thr
 1 5

<210> 29
 <211> 9
 <212> PRT
 <213> Artificial Sequence

<220>
 <223> /note="Description of Artificial Sequence: HLA Class I tetramer peptide"

<400> 29

Val Leu Ser Asp Phe Lys Thr Trp Leu
 1 5

<210> 30
 <211> 10
 <212> PRT
 <213> Artificial Sequence

<220>
 <223> /note="Description of Artificial Sequence: HLA Class I tetramer peptide"

<400> 30

Tyr Pro Tyr Arg Leu Trp His Tyr Pro Cys
 1 5 10

<210> 31
 <211> 9
 <212> PRT
 <213> Artificial Sequence

<220>
 <223> /note="Description of Artificial Sequence: HLA Class I tetramer peptide"

<400> 31

Ala Arg Met Ile Leu Met Thr His Phe
 1 5

<210> 32
 <211> 9
 <212> PRT
 <213> Artificial Sequence

<220>
 <223> /note="Description of Artificial Sequence: HLA Class I tetramer peptide"

<400> 32

Cys Ile Asn Gly Val Cys Trp Thr Val
 1 5

<210> 33
 <211> 9
 <212> PRT
 <213> Artificial Sequence

<220>
 <223> /note="Description of Artificial Sequence: HLA Class I tetramer peptide"

<400> 33

Asn Leu Val Pro Met Val Ala Thr Cys
 1 5

<210> 34
 <211> 9
 <212> PRT
 <213> Artificial Sequence

<220>
 <223> /note="Description of Artificial Sequence: HLA Class I tetramer peptide"

<400> 34

Gly Leu Cys Thr Leu Val Ala Met Leu
1 5

<210> 35

<211> 8

<212> PRT

<213> Artificial Sequence

<220>

<223> /note="Description of Artificial Sequence: HLA Class I tetramer peptide"

<400> 35

Arg Tyr Pro Leu Thr Phe Gly Trp
1 5

<210> 36

<211> 11

<212> PRT

<213> Artificial Sequence

<220>

<223> /note="Description of Artificial Sequence: HLA Class I tetramer peptide"

<400> 36

Lys Ala Phe Ser Pro Glu Val Ile Pro Met Phe
1 5 10

<210> 37

<211> 9

<212> PRT

<213> Artificial Sequence

<220>

<223> /note="Description of Artificial Sequence: HLA Class I tetramer peptide"

<400> 37

Asp Arg Phe Tyr Lys Thr Leu Arg Ala
1 5

<210> 38

<211> 9

<212> PRT

<213> Artificial Sequence

<220>

<223> /note="Description of Artificial Sequence: HLA Class I tetramer peptide"

<400> 38

His Pro Val His Ala Gly Pro Ile Ala
1 5

<210> 39
 <211> 9
 <212> PRT
 <213> Artificial Sequence

<220>
 <223> /note="Description of Artificial Sequence: HLA Class I tetramer peptide"

<400> 39

Asp Arg Phe Tyr Lys Thr Leu Arg Ala
 1 5

<210> 40
 <211> 9
 <212> PRT
 <213> Artificial Sequence

<220>
 <223> /note="Description of Artificial Sequence: HLA Class I tetramer peptide"

<400> 40

Ser Leu Tyr Asn Thr Val Ala Thr Leu
 1 5

<210> 41
 <211> 9
 <212> PRT
 <213> Artificial Sequence

<220>
 <223> /note="Description of Artificial Sequence: HLA Class I tetramer peptide"

<400> 41

Thr Pro Gln Asp Leu Asn Thr Met Leu
 1 5

<210> 42
 <211> 9
 <212> PRT
 <213> Artificial Sequence

<220>
 <223> /note="Description of Artificial Sequence: HLA Class I tetramer peptide"

<400> 42

Ser Leu Tyr Asn Thr Val Ala Thr Leu
 1 5

<210> 43
 <211> 11
 <212> PRT
 <213> Artificial Sequence

<220>
 <223> /note="Description of Artificial Sequence: HLA Class I tetramer peptide"

<400> 43

Lys Ala Phe Ser Pro Glu Val Ile Pro Met Phe
 1 5 10

<210> 44
 <211> 8
 <212> PRT
 <213> Artificial Sequence

<220>
 <223> /note="Description of Artificial Sequence: HLA Class I tetramer peptide"

<400> 44

Glu Ile Tyr Lys Arg Trp Ile Ile
 1 5

<210> 45
 <211> 8
 <212> PRT
 <213> Artificial Sequence

<220>
 <223> /note="Description of Artificial Sequence: HLA Class I tetramer peptide"

<400> 45

Val Pro Leu Arg Pro Met Thr Tyr
 1 5

<210> 46
 <211> 9
 <212> PRT
 <213> Artificial Sequence

<220>
 <223> /note="Description of Artificial Sequence: HLA Class I tetramer peptide"

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<210> 47
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<400> 47

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1				5					10	

What is claimed is:

1. A method of identifying exhausted CD8⁺ T cells, the method comprising:
 - a) determining the presence, copy number, amount, and/or activity of at least one
 - 5 biomarker listed in Table 1 in a biological sample comprising CD8⁺ T cells;
 - b) determining the presence, copy number, amount, and/or activity of the at least one biomarker in a control; and
 - c) comparing the presence, copy number, amount, and/or activity of said at least one biomarker detected in steps a) and b);
 - 10 wherein the presence or a significant increase in the copy number, amount, and/or activity of the at least one biomarker in the biological sample relative to the control indicates that the biological sample comprises exhausted CD8⁺ T cells.
2. The method of claim 1, further comprising determining the presence, copy number, amount, and/or activity of at least one T cell exhaustion biomarker in the biological sample;
 - determining the presence, copy number, amount, and/or activity of the at least one T cell exhaustion biomarker in a control; and comparing the presence, copy number, amount, and/or activity of said at least one T cell exhaustion biomarker, wherein the presence or a
 - 15 significant increase in the copy number, amount, and/or activity of the at least one T cell exhaustion biomarker in the biological sample relative to the control indicates that the
 - 20 biological sample comprises exhausted CD8⁺ T cells.
3. The method of claim 2, wherein the T cell exhaustion biomarker is selected from the group consisting of CD39, inhibitory receptors, comesodermin, T-bet, and combinations thereof.
 - 25 thereof.
4. The method of claim 3, wherein the immune checkpoint inhibitor is selected from the group consisting of PD-1, PD-L1, PD-L2, LAG-3, TIM-1, CTLA-4, VISTA, B7-H2, B7-H3, B7-H4, B7-H6, 2B4, ICOS, HVEM, CD160, gp49B, PIR-B, KIR family receptors,
 - 30 TIM-1, TIM-4, BTLA, SIRPalpha (CD47), CD48, 2B4 (CD244), B7.1, B7.2, ILT-2, ILT-4, TIGIT, and A2aR.
5. The method of any one of claims 1-4, wherein the control is a sample comprising CD8⁺ T cells obtained from a subject not afflicted with a chronic immune condition.

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6. The method of any one of claims 1-5, wherein the control is a copy number, amount, and/or activity value determined from a population of CD8+ T cells not afflicted with a chronic immune condition or obtained with a subject not afflicted with a chronic immune condition.
- 5 7. The method of any one of claims 1-6, further comprising determining responsiveness of the subject from which the biological samples was obtained to anti-chronic immune condition therapy measured by at least one criteria selected from the group consisting of clinical benefit rate, survival until mortality, pathological complete response, 10 semi-quantitative measures of pathologic response, clinical complete remission, clinical partial remission, clinical stable disease, recurrence-free survival, metastasis free survival, disease free survival, circulating tumor cell decrease, circulating marker response, and RECIST criteria.
- 15 8. A method of reducing CD8+ T cell exhaustion comprising contacting exhausted CD8+ T cells with an agent that inhibits CD39.
9. The method of claim 8, further comprising contacting the exhausted CD8+ T cells with one or more agents that inhibit an immune checkpoint inhibitor.
- 20 10. The method of claim 8 or 9, wherein the immune checkpoint inhibitor is selected from the group consisting of PD-1, PD-L1, PD-L2, LAG-3, TIM-1, CTLA-4, VISTA, B7-H2, B7-H3, B7-H4, B7-H6, 2B4, ICOS, HVEM, CD160, gp49B, PIR-B, KIR family receptors, TIM-1, TIM-4, BTLA, SIRPalpha (CD47), CD48, 2B4 (CD244), B7.1, B7.2, 25 ILT-2, ILT-4, TIGIT, and A2aR.
11. The method of any one of claims 8-10, wherein the exhausted CD8+ T cells are contacted with the agent(s) *in vitro*, *ex vivo*, or *in vivo*.
- 30 12. The method of claim 11, wherein the exhausted CD8+ T cells are contacted with the agent(s) *in vivo*.
13. The method of claim 12, wherein the exhausted CD8+ T cells are contacted *in vivo* with a therapeutically effective amount of a pharmaceutical composition comprising the 35 agent(s) in a subject in need thereof.

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14. A method of treating a subject afflicted with a chronic immune condition, comprising administering to the subject a therapeutically effective amount of a pharmaceutical composition comprising an agent that inhibits CD39.
- 5 15. The method of claim 14, further comprising administering to the subject a therapeutically effective amount of a pharmaceutical composition comprising one or more anti-chronic immune condition agents.
16. The method of claim 15, wherein the one or more anti-chronic immune condition
10 agents is one or more agents that inhibit an immune checkpoint inhibitor.
17. The method of claim 16, wherein the immune checkpoint inhibitor is selected from the group consisting of PD-1, PD-L1, PD-L2, LAG-3, TIM-1, CTLA-4, VISTA, B7-H2, B7-H3, B7-H4, B7-H6, 2B4, ICOS, HVEM, CD160, gp49B, PIR-B, KIR family receptors,
15 TIM-1, TIM-4, BTLA, SIRPalpha (CD47), CD48, 2B4 (CD244), B7.1, B7.2, ILT-2, ILT-4, TIGIT, and A2aR.
18. A method of assessing the efficacy of an agent for reducing CD8+ T cell exhaustion, comprising:
- 20 a) detecting in a first sample comprising exhausted CD8+ T cells and maintained in the presence of the agent the presence, copy number, amount, and/or activity of at least one biomarker listed in Table 1;
- b) detecting the presence, copy number, amount, and/or activity of the at least one biomarker listed in Table 1 in a second sample comprising exhausted CD8+ T cells and
25 maintained in the absence of the test agent; and
- c) comparing the presence, copy number, amount, and/or activity of the at least one biomarker listed in Table 1 from steps a) and b), wherein the presence or a significantly increased copy number, amount, and/or activity of the at least one biomarker listed in Table 1 in the first sample relative to the second sample, indicates that the agent reduces CD8+ T
30 cell exhaustion.
19. The method of claim 18, further comprising determining the effect of the test agent on the copy number, level of expression, and/or level of activity of at least one immune checkpoint inhibitor in the first sample; determining the effect of the test agent on the copy
35 number, level of expression, and/or level of activity of the at least one immune checkpoint

inhibitor in the second sample; and comparing the differences in the copy number, level of expression, and/or level of activity of the at least one immune checkpoint inhibitor between the samples, wherein a significant decrease in the copy number, level of expression, and/or level of activity of the at least one immune checkpoint inhibitor in the first sample relative to the second sample further indicates that the agent reduces CD8⁺ T cell exhaustion.

20. The method of claim 18 or 19, further comprising determining T cell effector function of the CD8⁺ T cells in the first sample; determining T cell effector function of the CD8⁺ T cells in the second sample; and comparing the T cell effector function determinations, wherein a significant increase in the T cell effector function of the CD8⁺ T cells in the first sample relative to the second sample further indicates that the agent reduces CD8⁺ T cell exhaustion.

21. The method of any one of claims 18-20, wherein one or both samples are obtained from a source selected from the group consisting of an animal model of a chronic immune disorder, a subject afflicted with a chronic immune disorder, and purified population of CD8⁺ T cells.

22. The method of any one of claims 18-21, wherein maintaining the cells of the sample in the presence or absence of the test agent occurs *in vivo*, *ex vivo*, or *in vitro*.

23. The method of any one of claims 18-22, further comprising determining the ability of the test agent to bind to the at least one biomarker listed in Table 1 before or after determining the effect of the test agent on the copy number, level of expression, or level of activity of the at least one biomarker listed in Table 1.

24. A method of monitoring the progression of a chronic immune disorder in a subject, comprising:

- a) detecting at a first point in time the presence, copy number, amount, and/or activity of at least one biomarker listed in Table 1 in CD8⁺ T cells from a subject sample;
- b) repeating step a) during at least one subsequent point in time after administration of a therapeutic agent; and
- c) comparing the presence, copy number, amount, and/or activity detected in steps a) and b), wherein the presence or a significantly increased copy number, amount, and/or activity of the at least one biomarker listed in Table 1 in the CD8⁺ T cells from the first

subject sample relative to at least one subsequent subject sample, indicates that the agent treats the chronic immune disorder in the subject.

25. The method of claim 24, further comprising determining the copy number, level of expression, and/or level of activity of at least one immune checkpoint inhibitor in the CD8+ T cells from the first subject sample; determining the copy number, level of expression, and/or level of activity of the at least one immune checkpoint inhibitor in the CD8+ T cells from the at least one subsequent subject sample; and comparing the differences in the copy number, level of expression, and/or level of activity of the at least one immune checkpoint inhibitor between the samples, wherein a significant decrease in the copy number, level of expression, and/or level of activity of the at least one immune checkpoint inhibitor in the at least one subsequent subject sample relative to the first subject sample further indicates that the agent treats the chronic immune disorder in the subject.

26. The method of claim 24 or 25, further comprising determining T cell effector function of the CD8+ T cells in the first subject sample; determining T cell effector function of the CD8+ T cells in the at least one subsequent subject sample; and comparing the T cell effector function determinations, wherein a significant increase in the T cell effector function of the CD8+ T cells in the at least one subsequent subject sample relative to the first subject sample further indicates that the agent treats the chronic immune disorder in the subject.

27. The method of any one of claims 24-26, wherein the subject has undergone treatment, completed treatment, and/or is in remission for the chronic immune disorder in between the first point in time and the subsequent point in time.

28. The method of any one of claims 24-27, wherein the subject has undergone anti-immune checkpoint inhibitor therapy in between the first point in time and the subsequent point in time.

29. The method of any one of claims 24-28, wherein the first and/or at least one subsequent sample is selected from the group consisting of *ex vivo* and *in vivo* samples.

30. The method of any one of claims 24-29, wherein the first and/or at least one subsequent sample is obtained from an animal model of the chronic immune disorder.

31. The method of any one of claims 24-30, wherein the first and/or at least one subsequent sample is a portion of a single sample or pooled samples obtained from the subject.
- 5 32. The method of any one of claims 1-7 and 18-31, wherein the sample is selected from the group consisting of cells, cell lines, histological slides, paraffin embedded tissue, fresh frozen tissue, fresh tissue, biopsies, blood, plasma, serum, buccal scrape, saliva, cerebrospinal fluid, urine, stool, mucus, bone marrow, and samples obtained from a subject.
- 10 33. The method of any one of claims 1-7 and 18-32, wherein the presence or copy number is assessed by whole exome sequencing, microarray, quantitative PCR (qPCR), high-throughput sequencing, comparative genomic hybridization (CGH), or fluorescent *in situ* hybridization (FISH).
- 15 34. The method of any one of claims 1-7 and 18-32, wherein the amount of the at least one biomarker is assessed by detecting the presence in the samples of a polynucleotide molecule encoding the biomarker or a portion of said polynucleotide molecule.
- 20 35. The method of claim 34, wherein the polynucleotide molecule is a mRNA, cDNA, or functional variants or fragments thereof.
36. The method of claim 34, wherein the step of detecting further comprises amplifying the polynucleotide molecule.
- 25 37. The method of any one of claims 1-7 and 18-32, wherein the amount of the at least one biomarker is assessed by annealing a nucleic acid probe with the sample of the polynucleotide encoding the one or more biomarkers or a portion of said polynucleotide molecule under stringent hybridization conditions.
- 30 38. The method of any one of claims 1-7 and 18-32, wherein the amount of the at least one biomarker is assessed by detecting the presence a polypeptide of the at least one biomarker.
- 35 39. The method of claim 38, wherein the presence of said polypeptide is detected using a reagent which specifically binds with said polypeptide.

40. The method of claim 39, wherein the reagent is selected from the group consisting of an antibody, an antibody derivative, and an antibody fragment.
- 5 41. The method of any one of claims 1-7 and 18-32, wherein the activity of the at least one biomarker is assessed by determining the magnitude of enzymatic activity, cellular proliferation, cell death, or cytokine production.
42. The method of any one of claims 1-41, wherein the agent or therapy is selected from
10 the group consisting of a blocking antibody, small molecule, antisense nucleic acid, interfering RNA, shRNA, siRNA, piwiRNA, aptamer, ribozyme, dominant-negative protein, and combinations thereof.
43. The method of claim 42, wherein the agent or anti-immune checkpoint inhibitor
15 therapy is a blocking antibody of PD-1, PD-L1, PD-L2, LAG-3, TIM-1, CTLA-4, VISTA, B7-H2, B7-H3, B7-H4, B7-H6, 2B4, ICOS, HVEM, CD160, gp49B, PIR-B, KIR family receptors, TIM-1, TIM-4, BTLA, SIRPalpha (CD47), CD48, 2B4 (CD244), B7.1, B7.2, ILT-2, ILT-4, TIGIT, A2aR, and combinations thereof.
- 20 44. The method of claim 43, wherein the agent or anti-immune checkpoint inhibitor therapy is selected from the group consisting of inhibitors of PD-1, PD-L1, PD-L2, CTLA-4, and combinations thereof.
45. The method of any one of claims 1-44, wherein the chronic immune disorder is a
25 chronic infection or cancer.
46. The method of claim 45, wherein the infection is caused by an agent selected from the group consisting of human immunodeficiency virus (HIV), hepatitis C virus (HCV), hepatitis B virus (HBV), adenovirus, cytomegalovirus, Epstein-Barr virus, herpes simplex
30 virus 1, herpes simplex virus 2, human herpesvirus 6, varicella-zoster virus, hepatitis B virus, hepatitis D virus, papilloma virus, parvovirus B19, polyoma virus BK, polyoma virus JC, measles virus, rubella virus, human T cell leukemia virus I, human T cell leukemia virus II, *Leishmania*, *Toxoplasma*, *Trypanosoma*, *Plasmodium*, *Schistosoma*, and *Encephalitozoon*.
- 35 47. The method of claim 46, wherein the chronic infection is not a latent infection.

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48. The method of claim 45, wherein the cancer is a hematological cancer or a solid cancer.
- 5 49. The method of claim 48, wherein the solid cancer is selected from the group consisting of lung cancer, non-small cell lung cancer (NSCLC), skin cancer, melanoma, cervical cancer, uterine cancer, ovarian cancer, breast cancer, pancreatic cancer, stomach cancer, esophageal cancer, colorectal cancer, liver cancer, prostate cancer, kidney cancer, bladder cancer, head and neck cancer, sarcoma, lymphoma, and brain cancer.
- 10 50. The method of any one of claims 1-49, wherein the subject is a mammal.
51. The method of claim 50, wherein the mammal is a chronic immune disorder animal model.
- 15 52. The method of claim 50, wherein the mammal is a human.

Figure 1

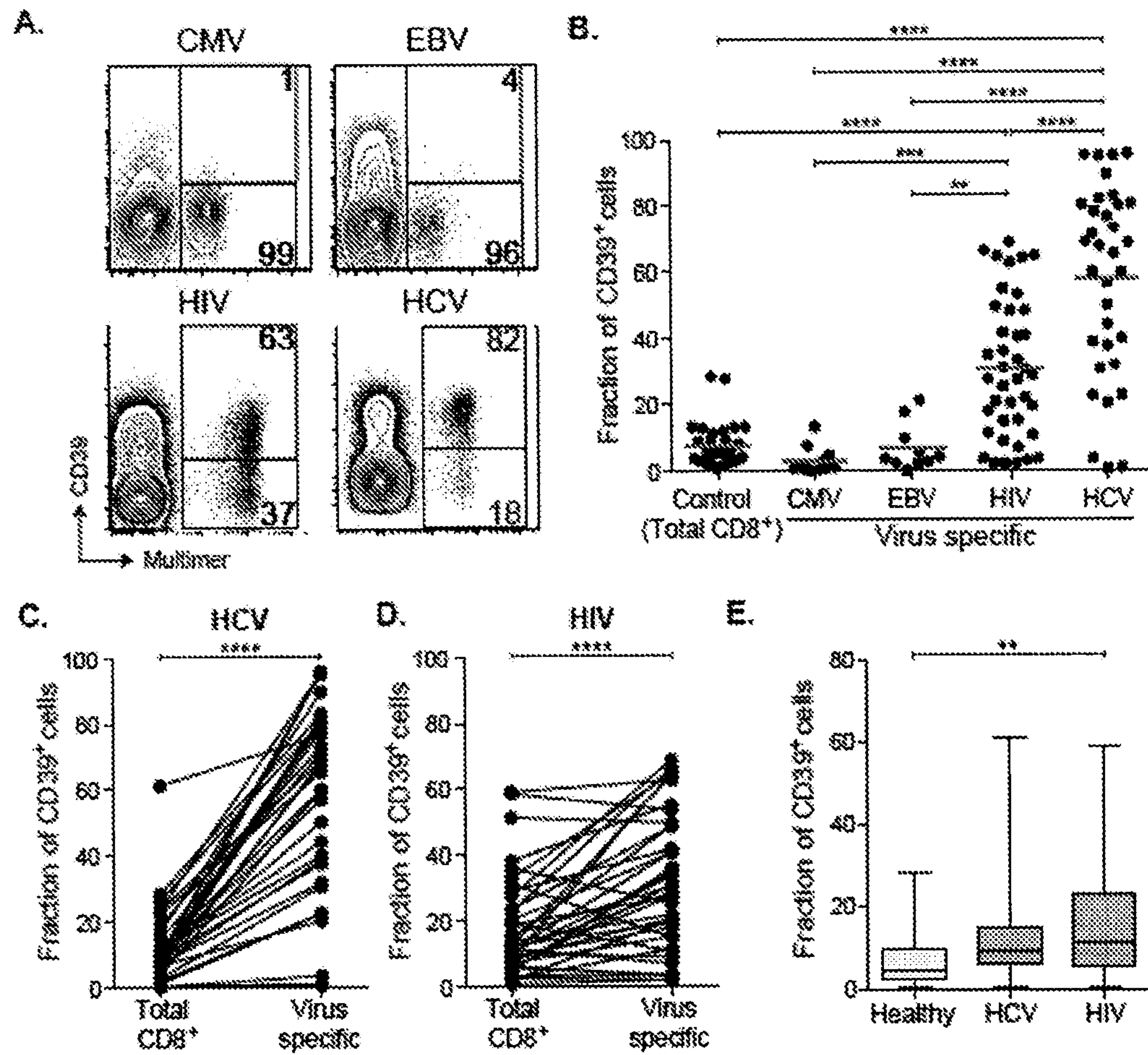
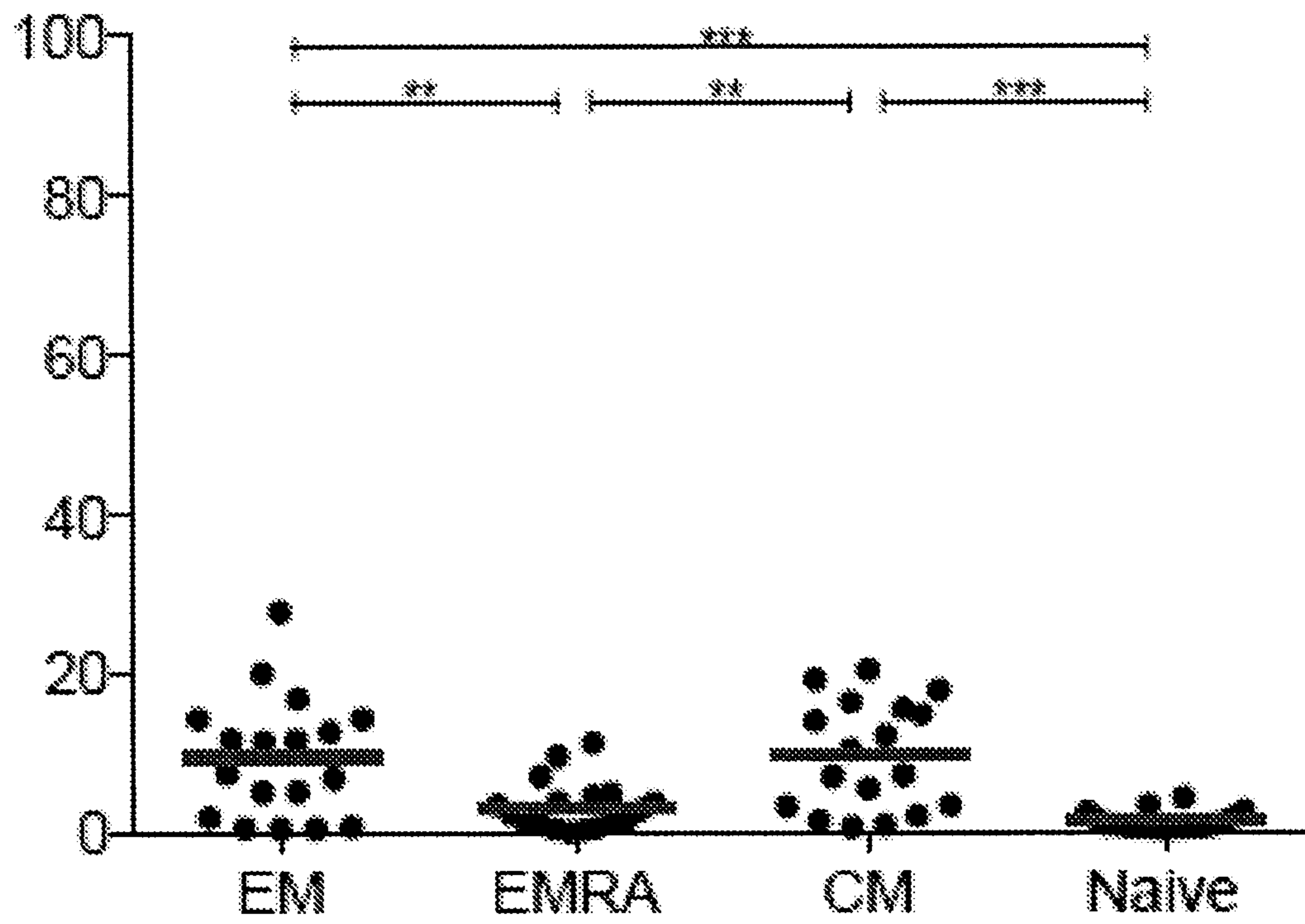
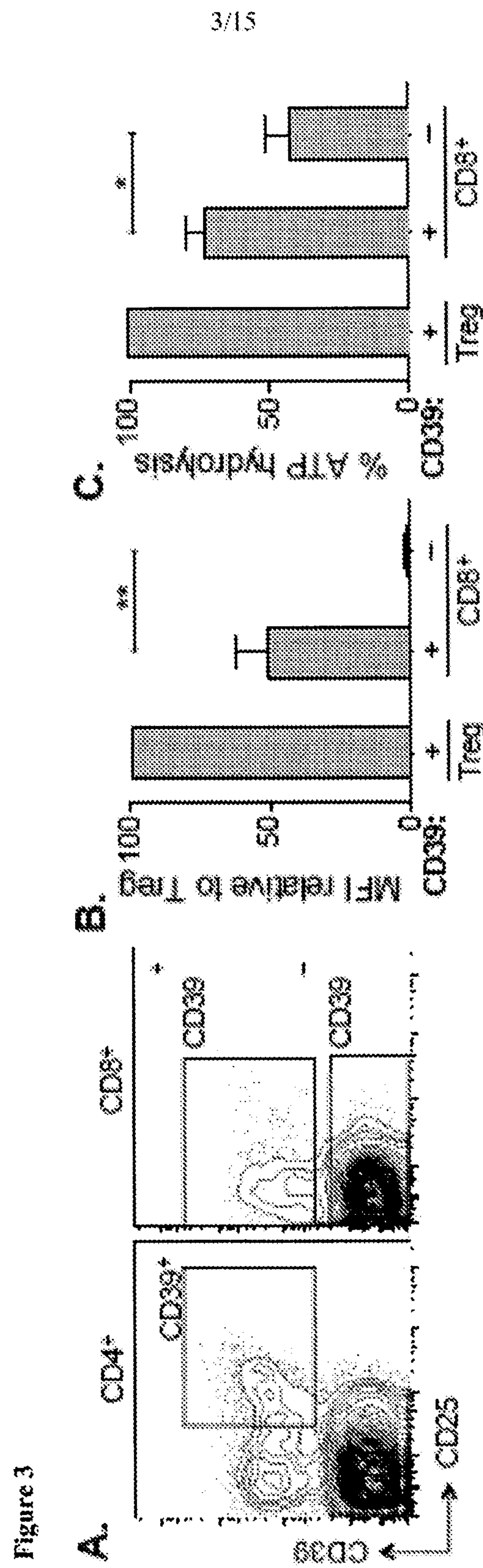


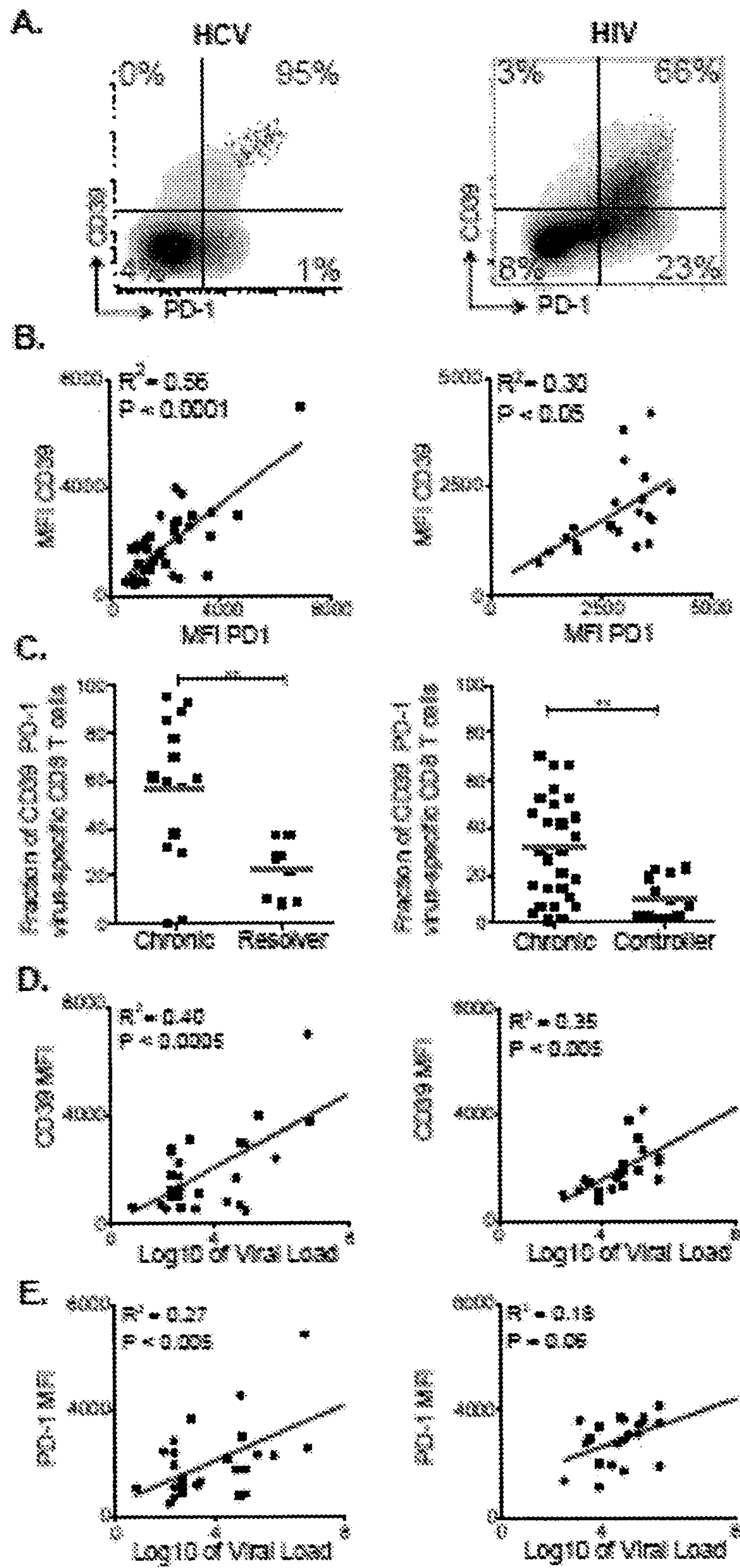
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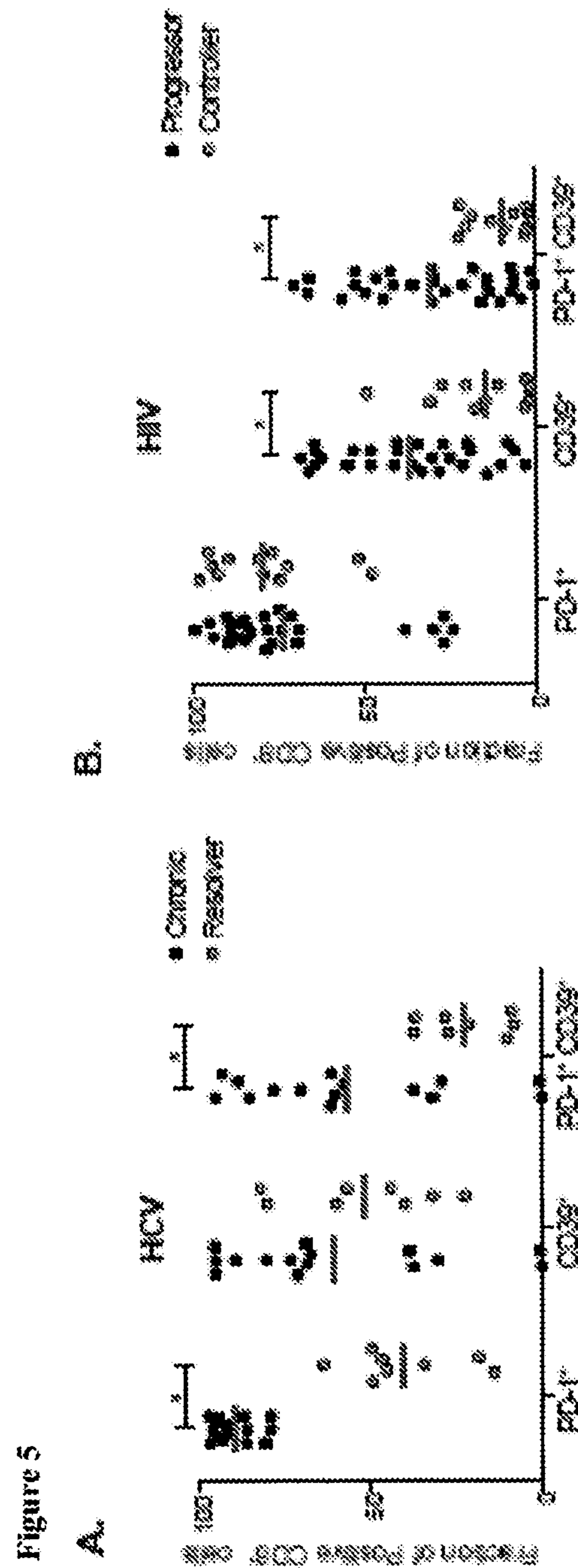


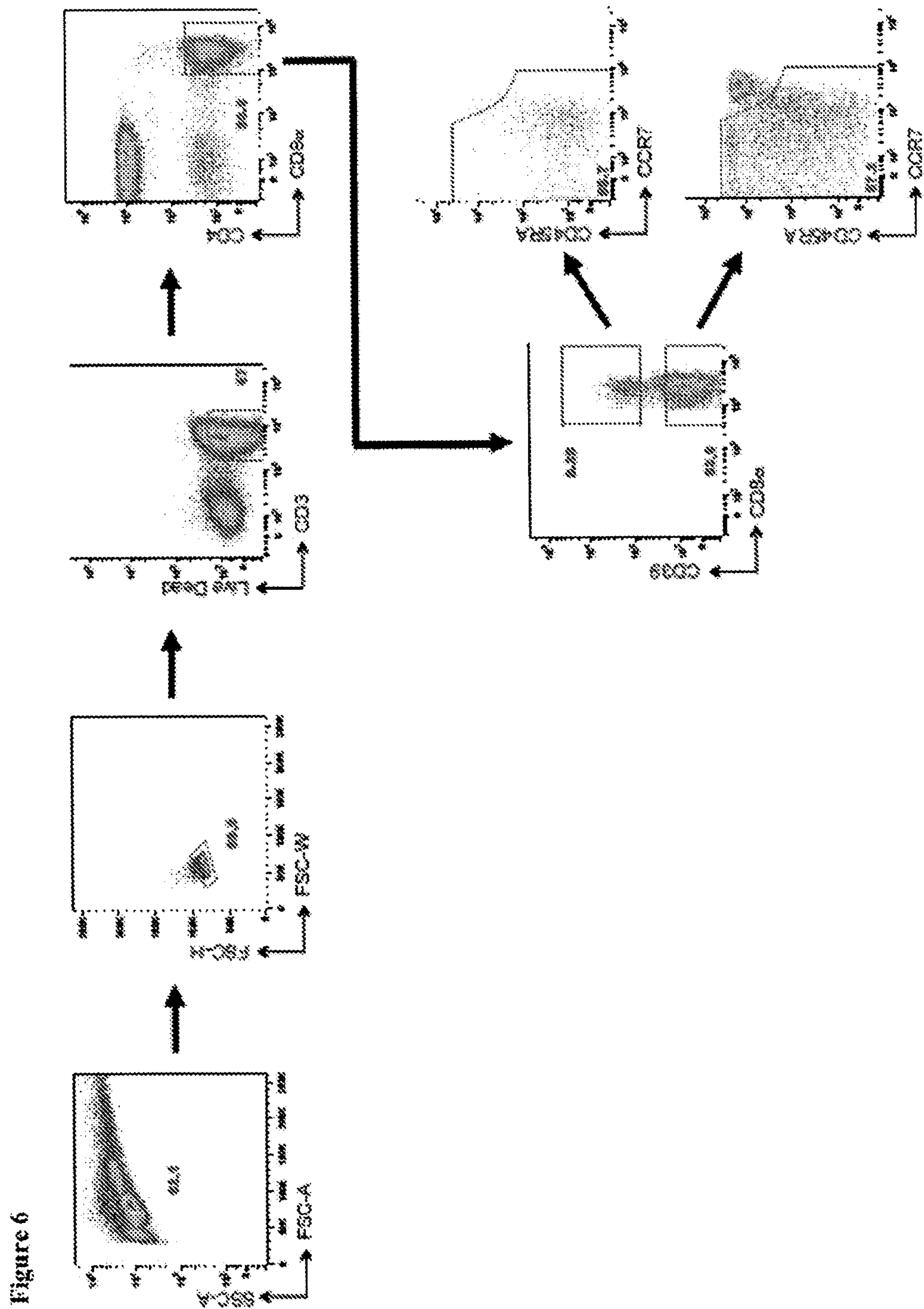
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Figure 4



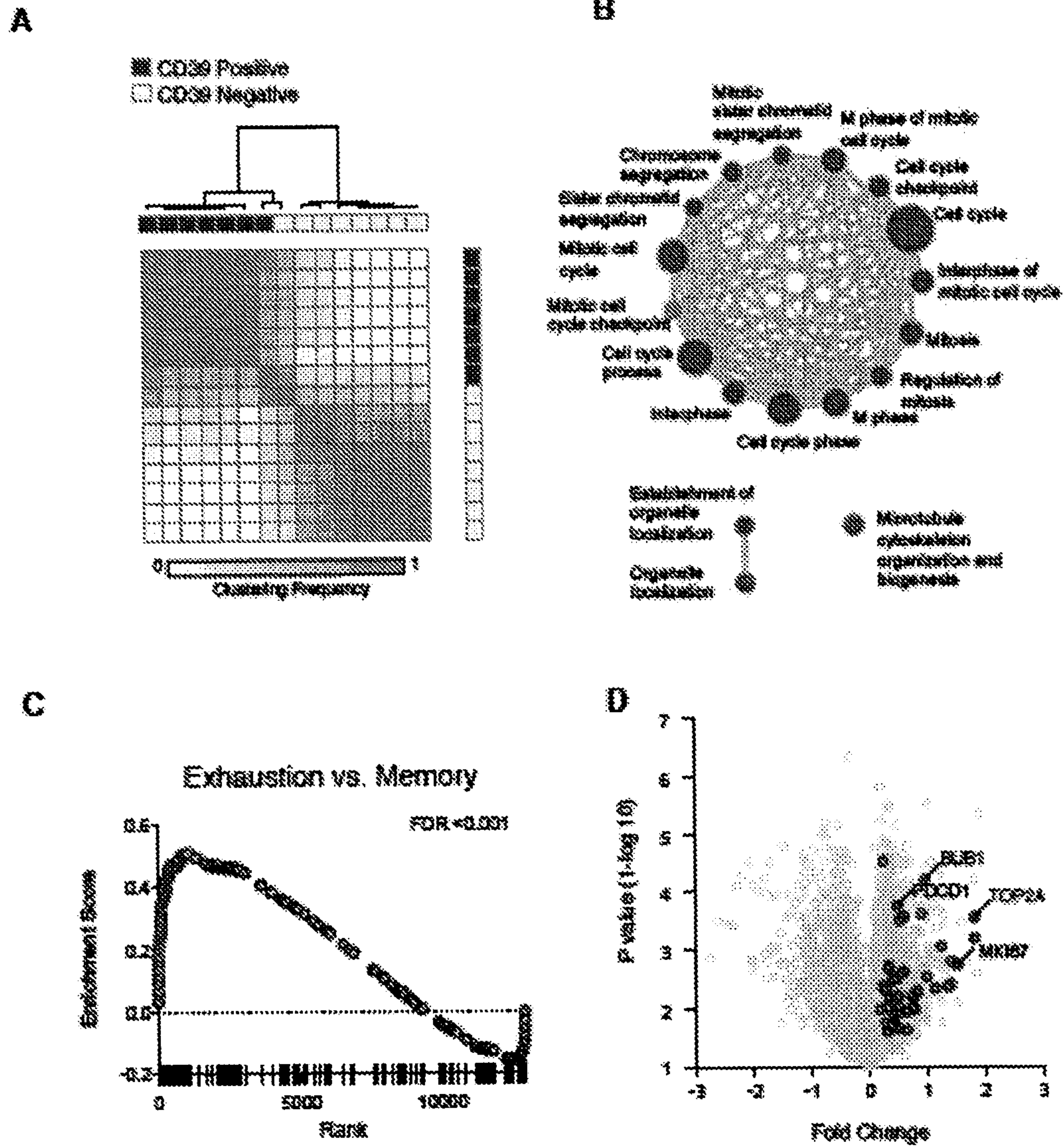
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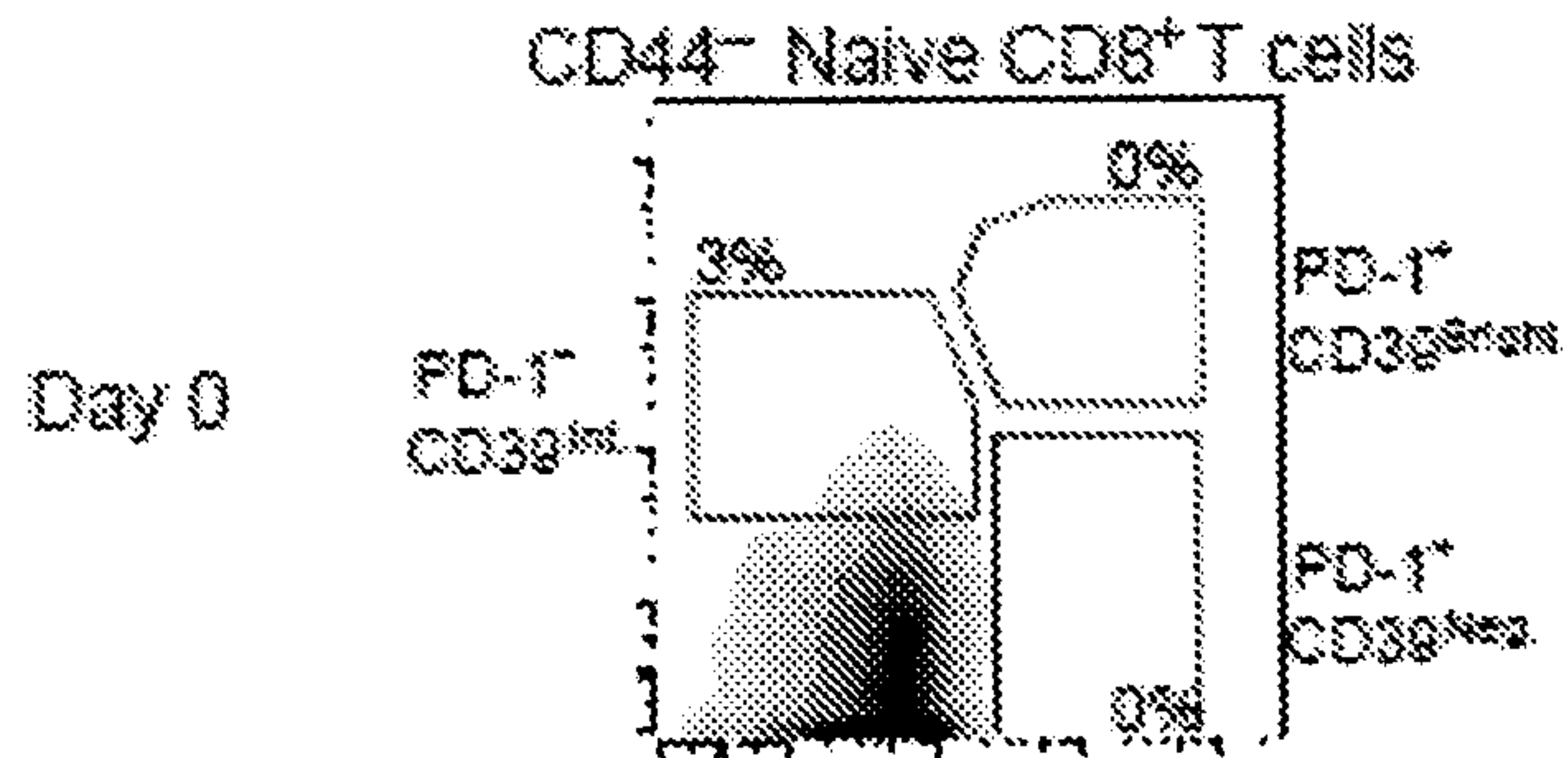
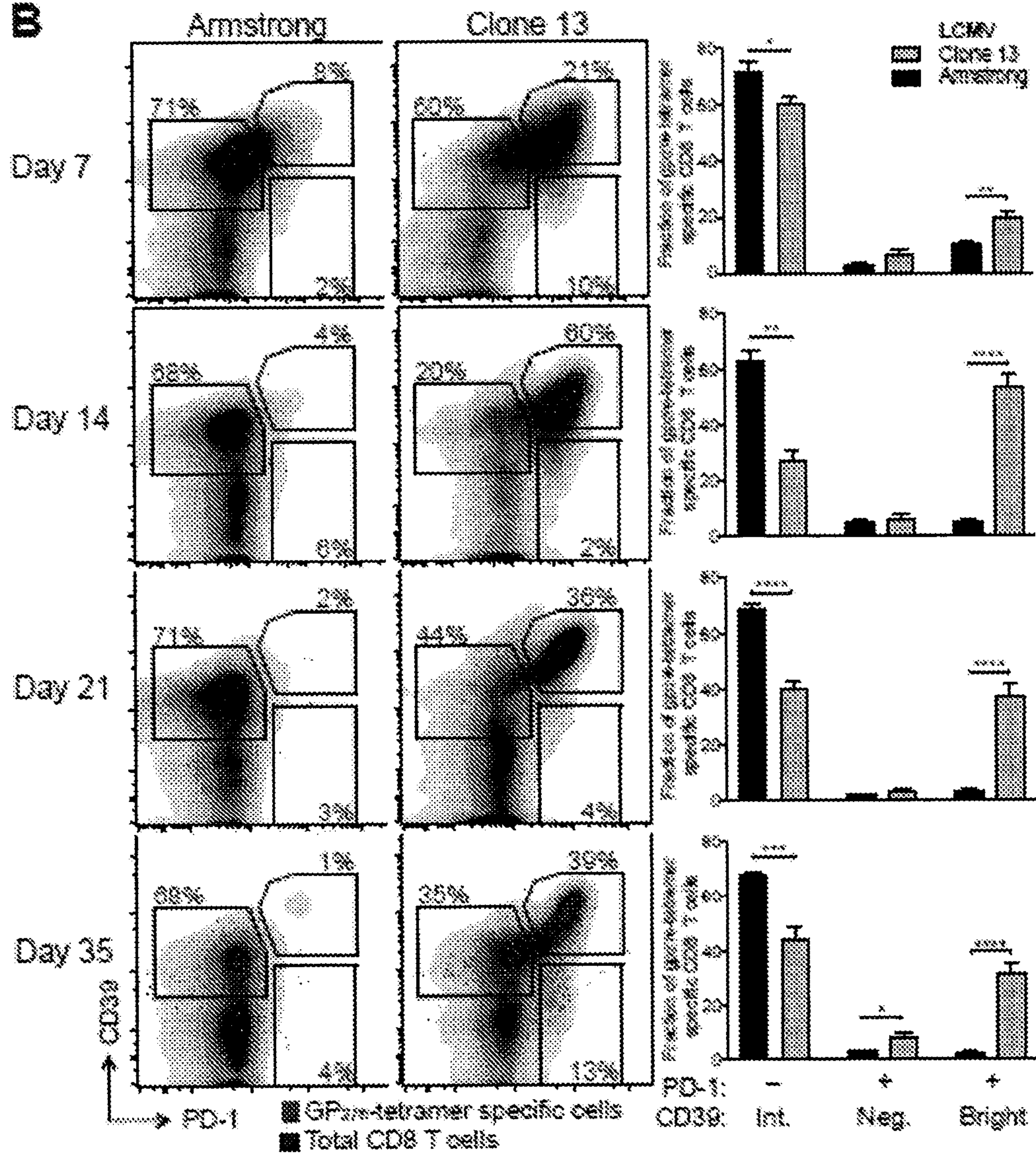
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Figure 7



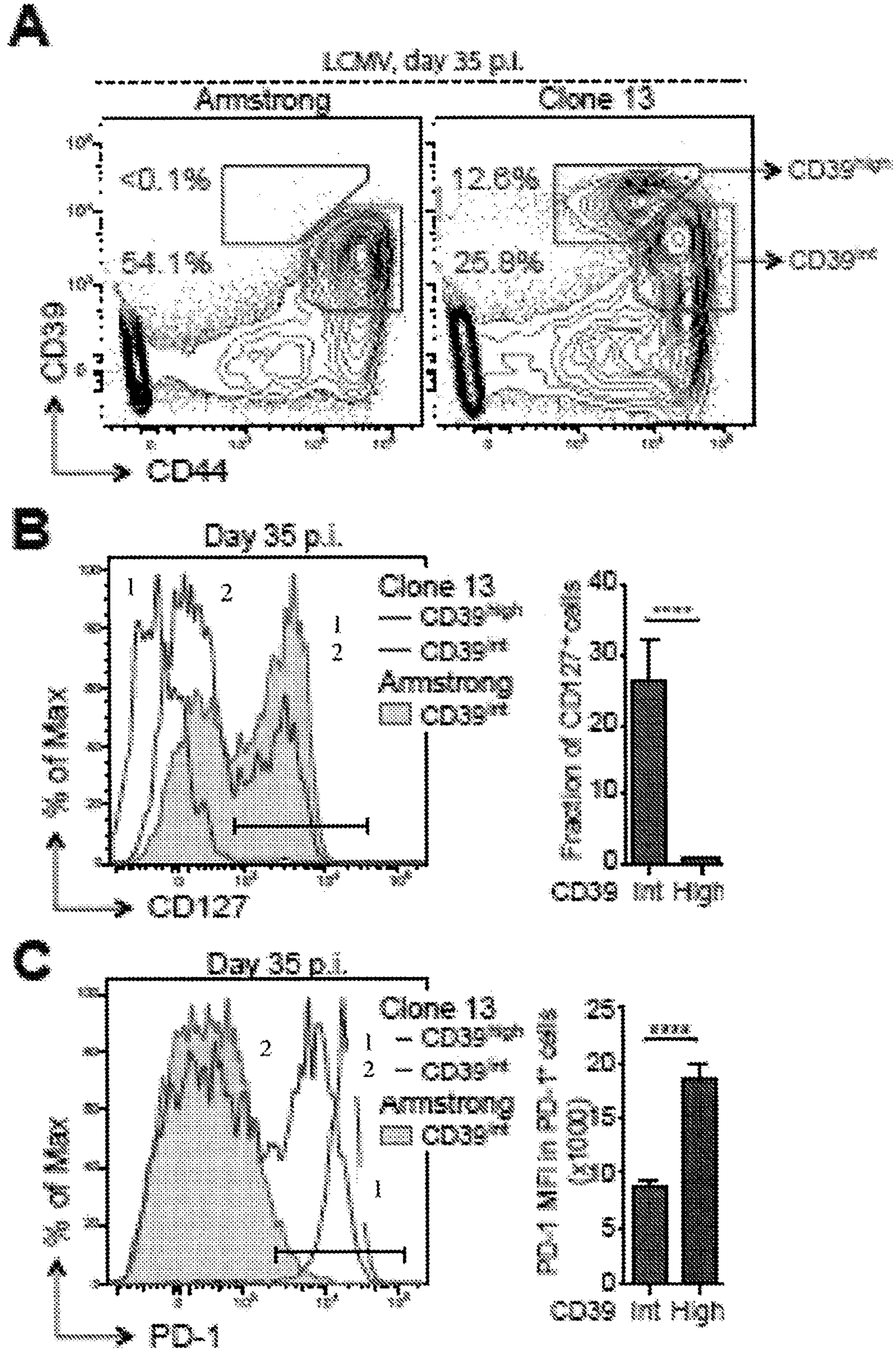
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Figure 8

A**B**

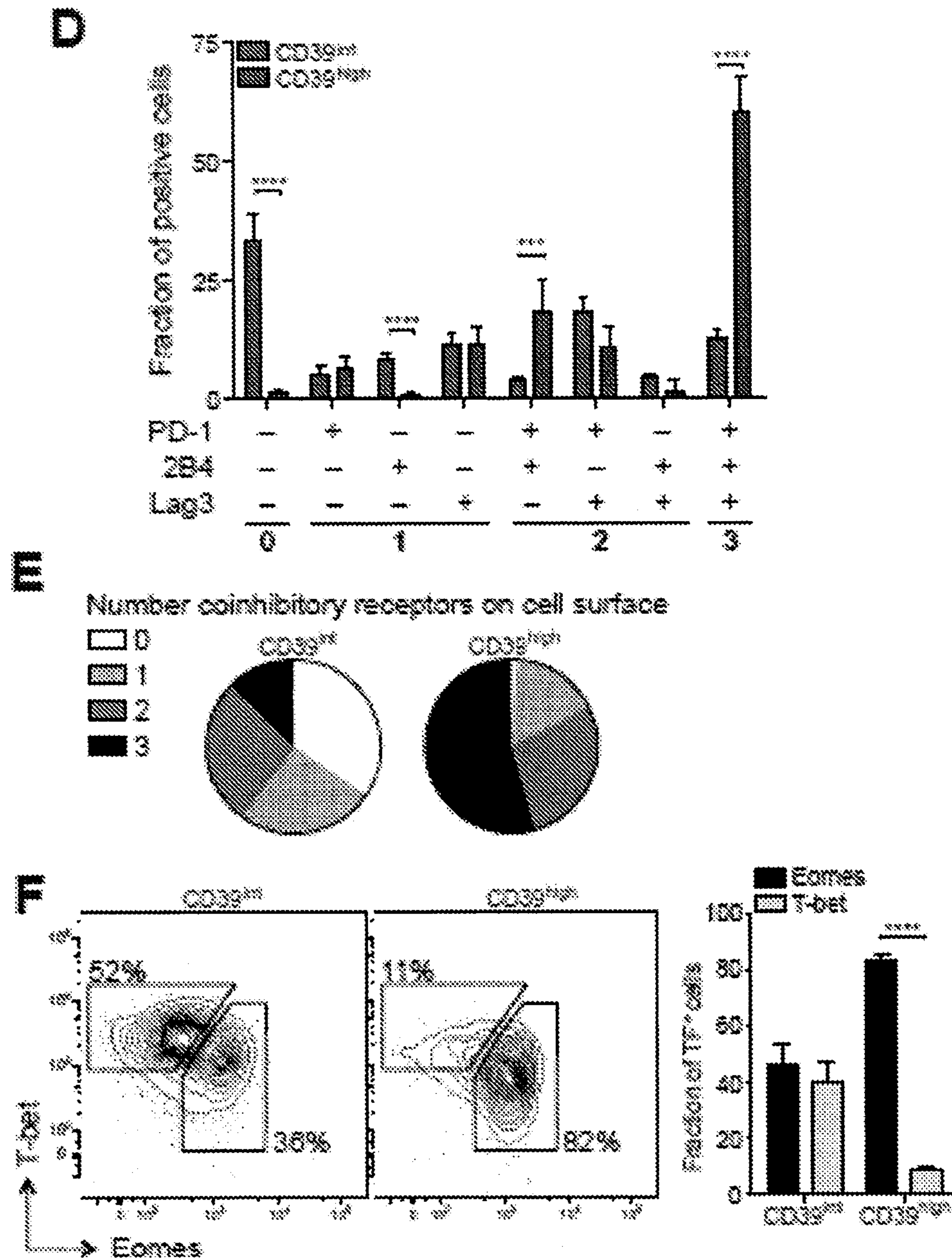
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Figure 9



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Figure 9 (cont.)



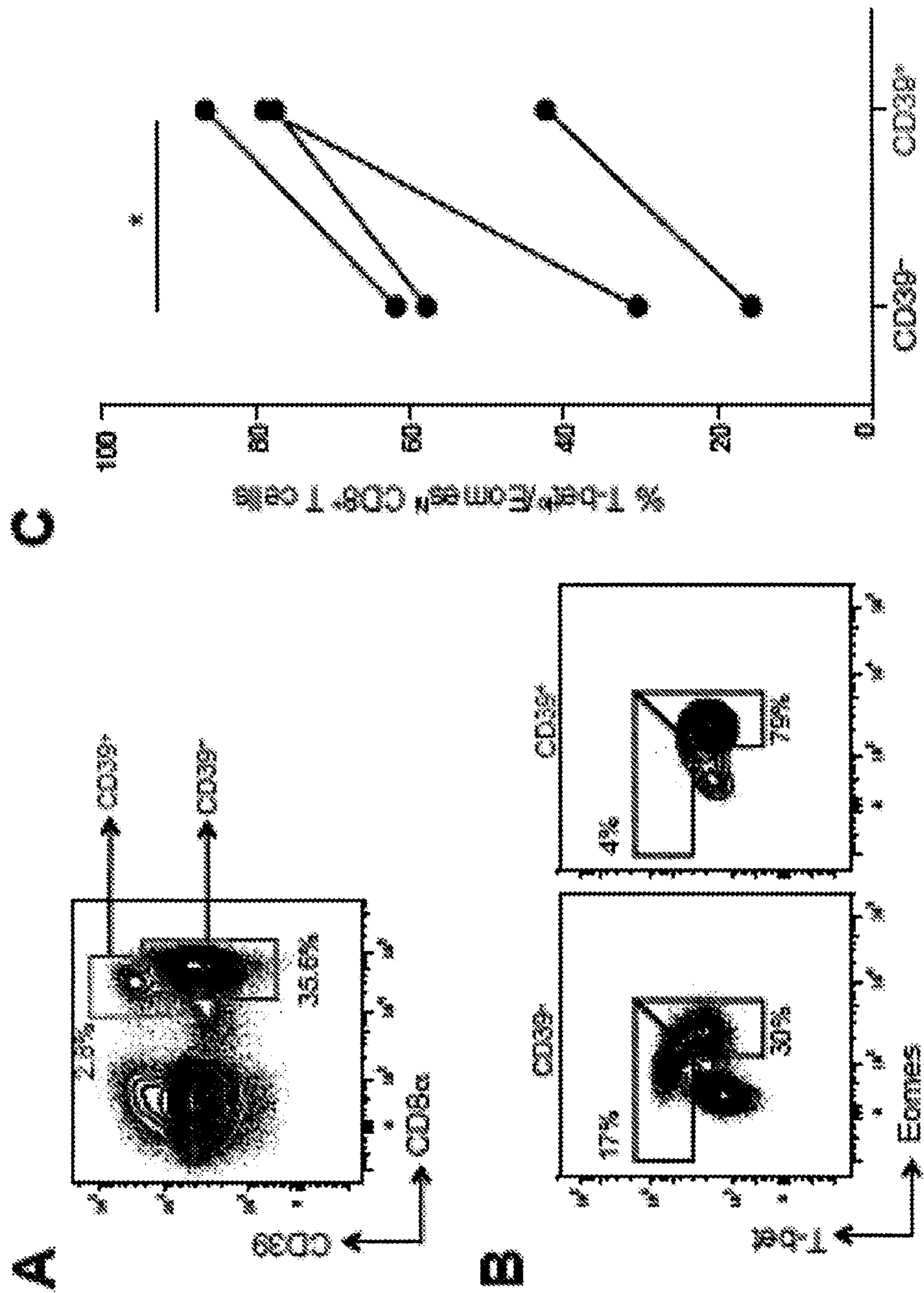
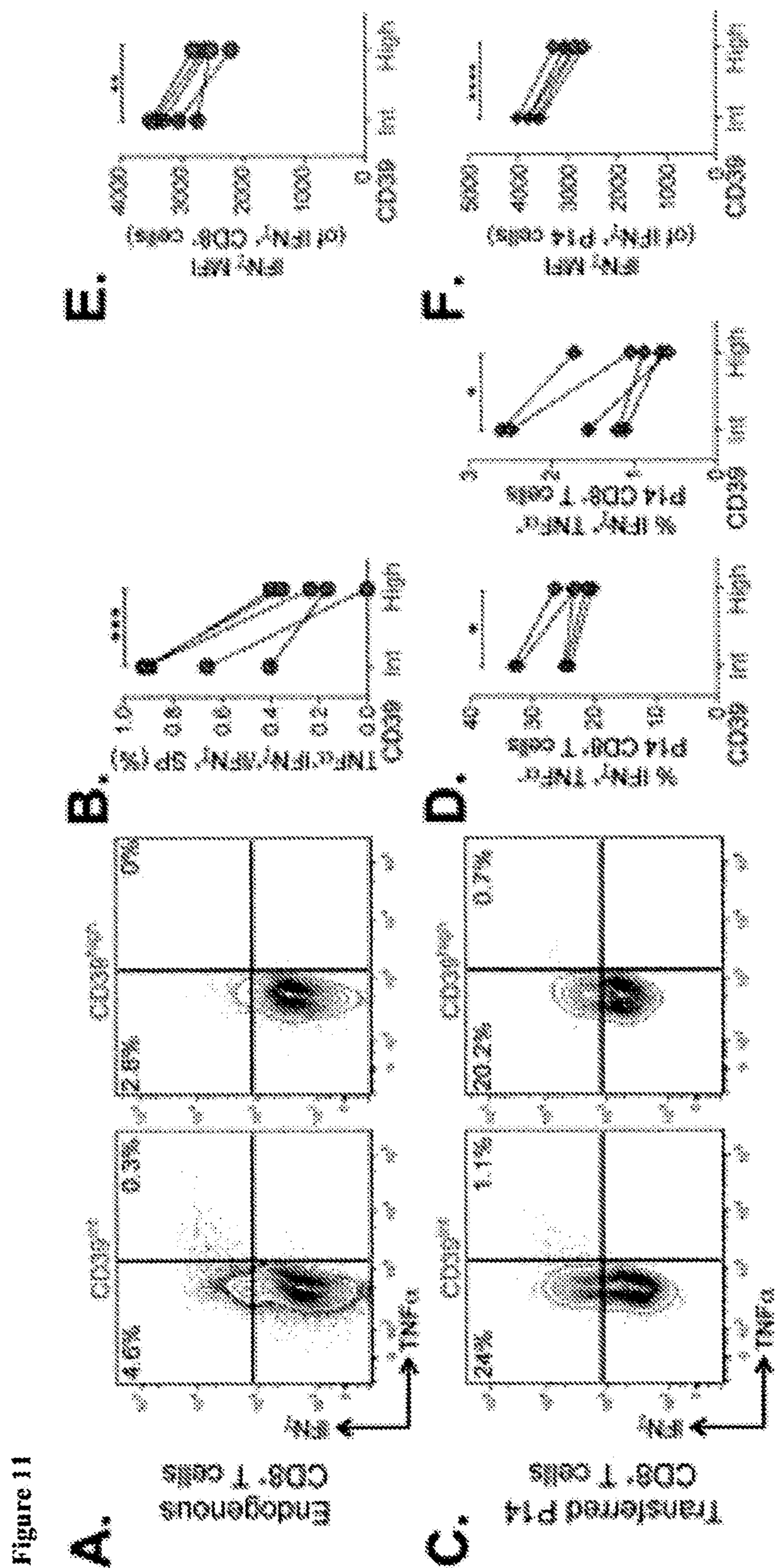


Figure 10

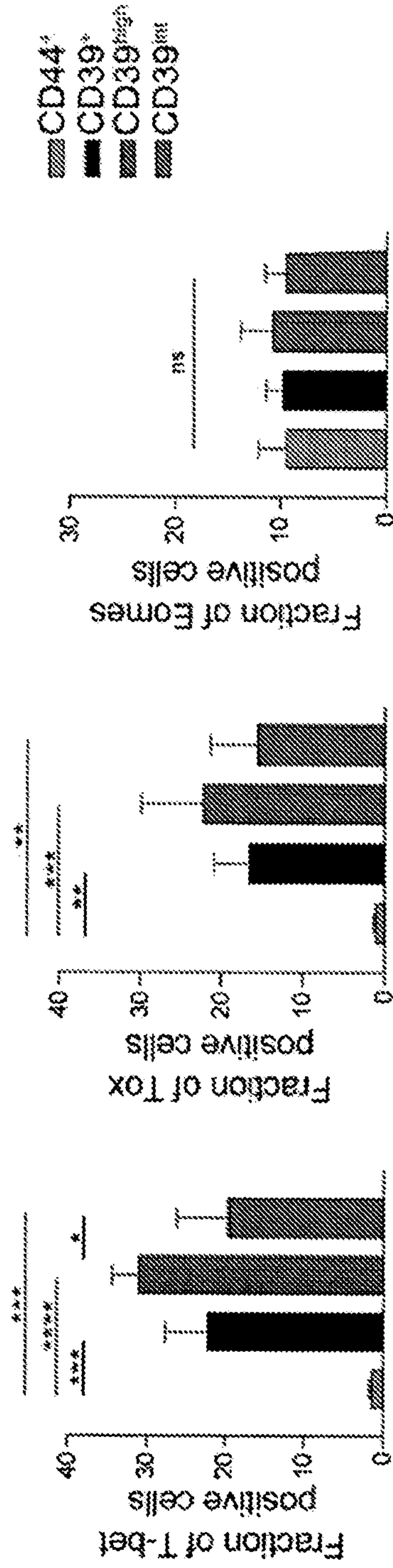
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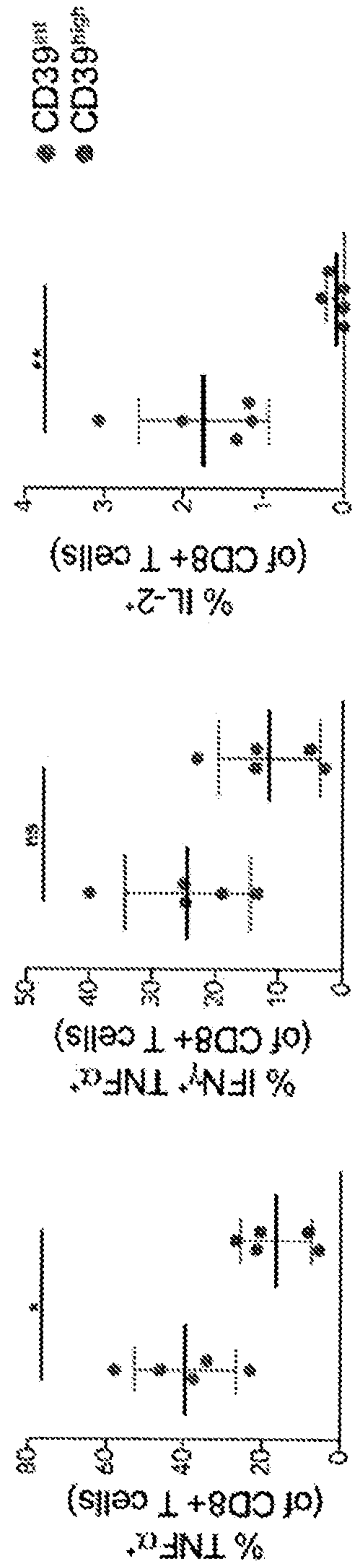
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Figure 12 (cont.)

D



E



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Figure 13

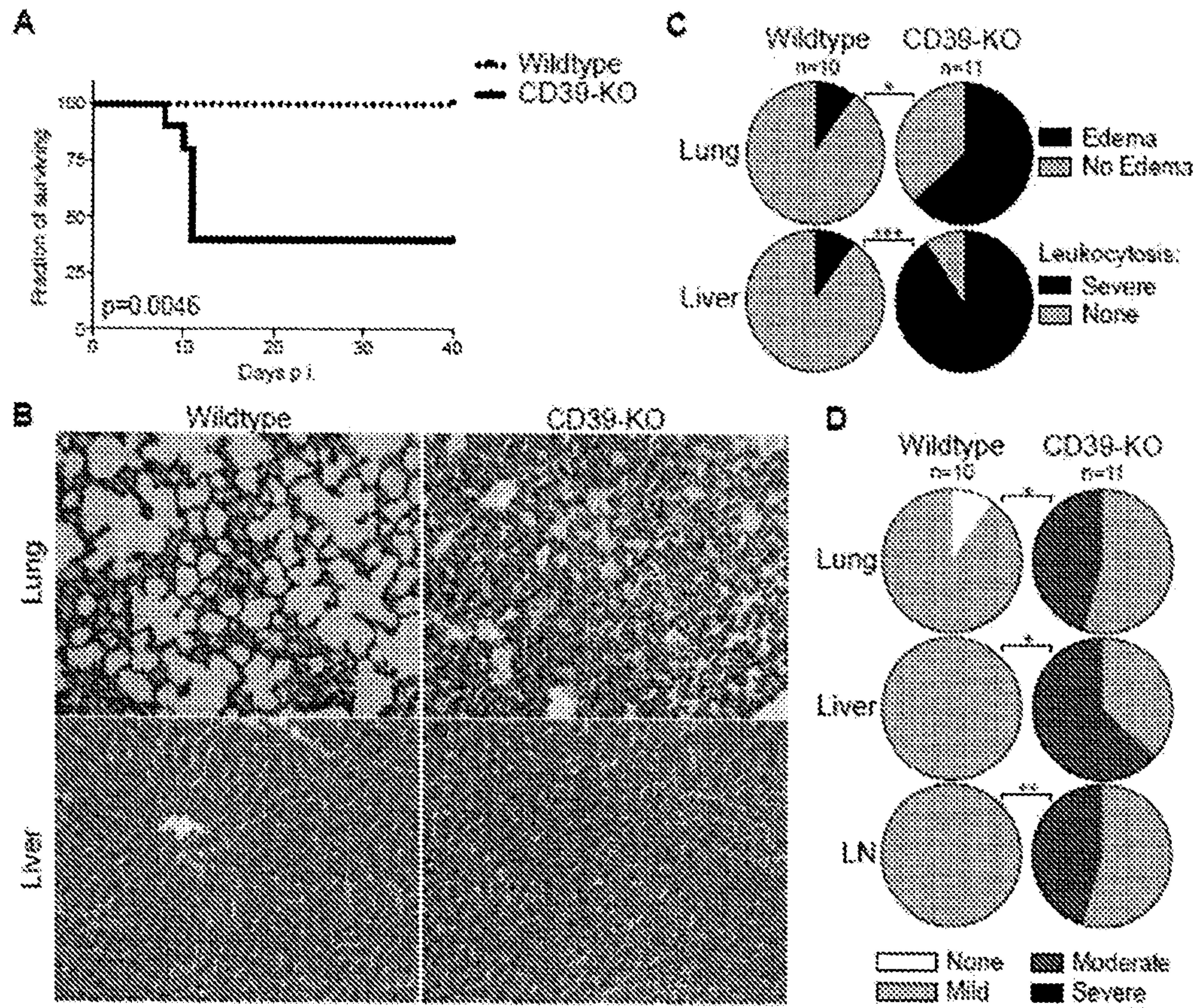


Figure 3

