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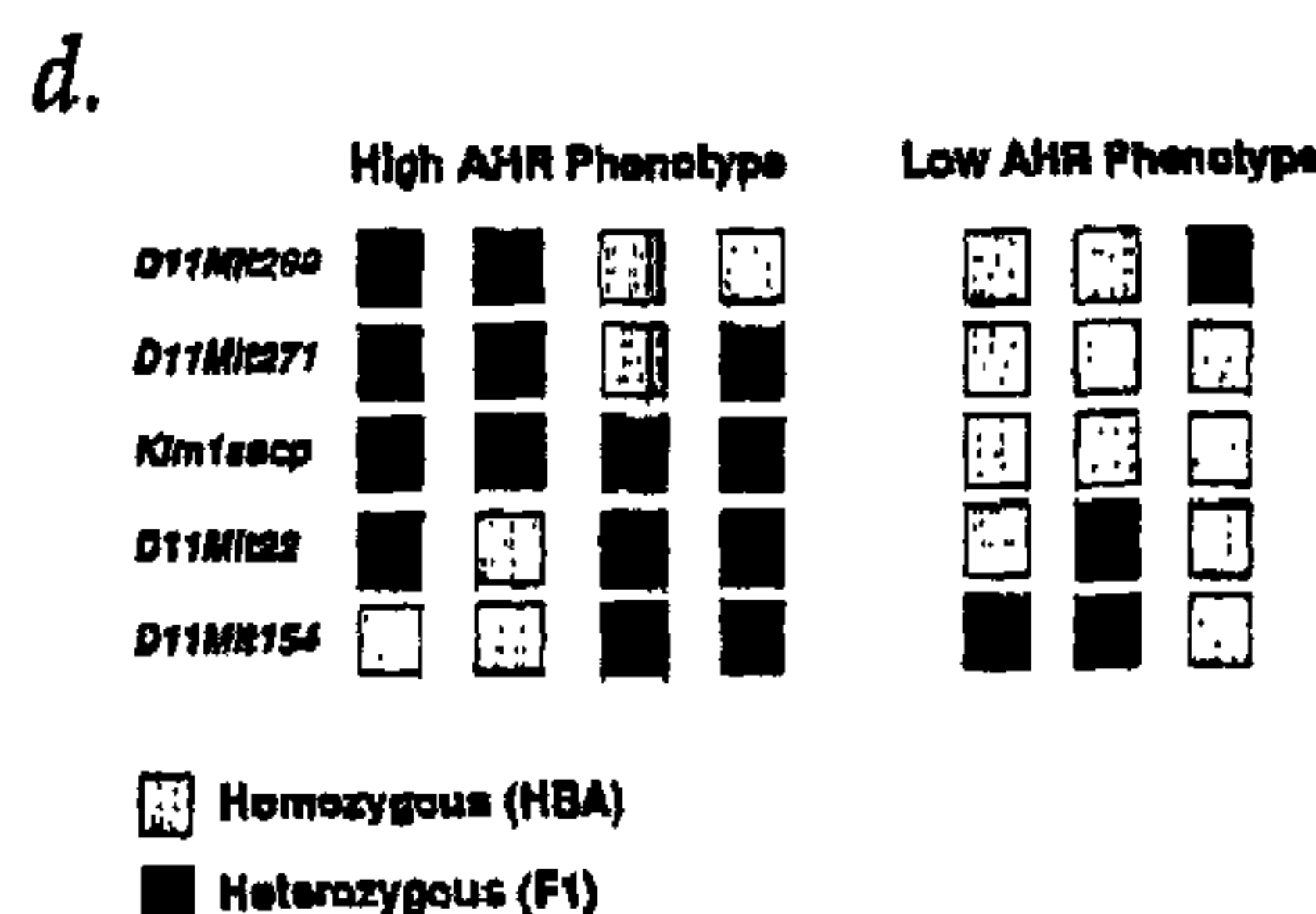
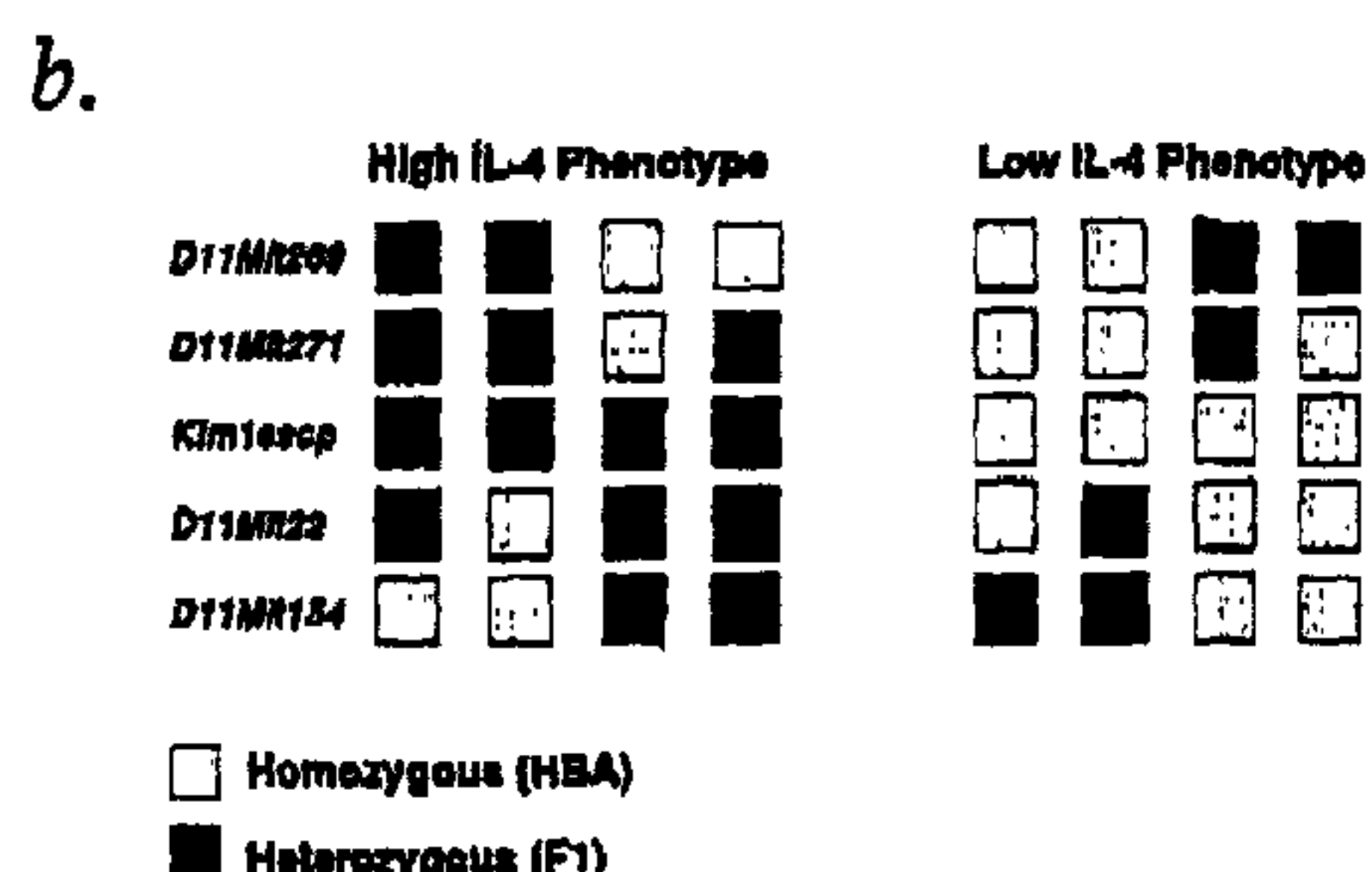
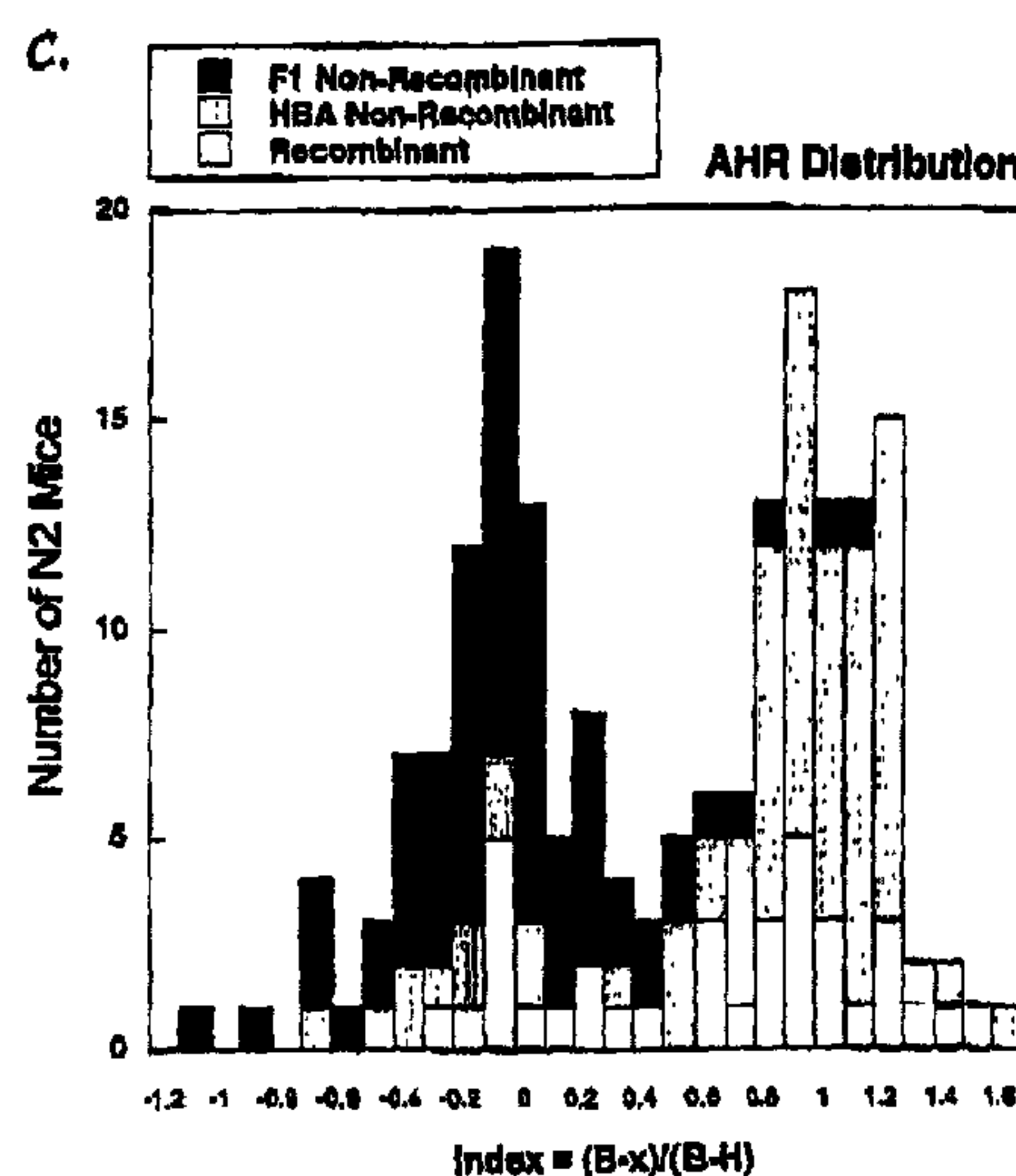
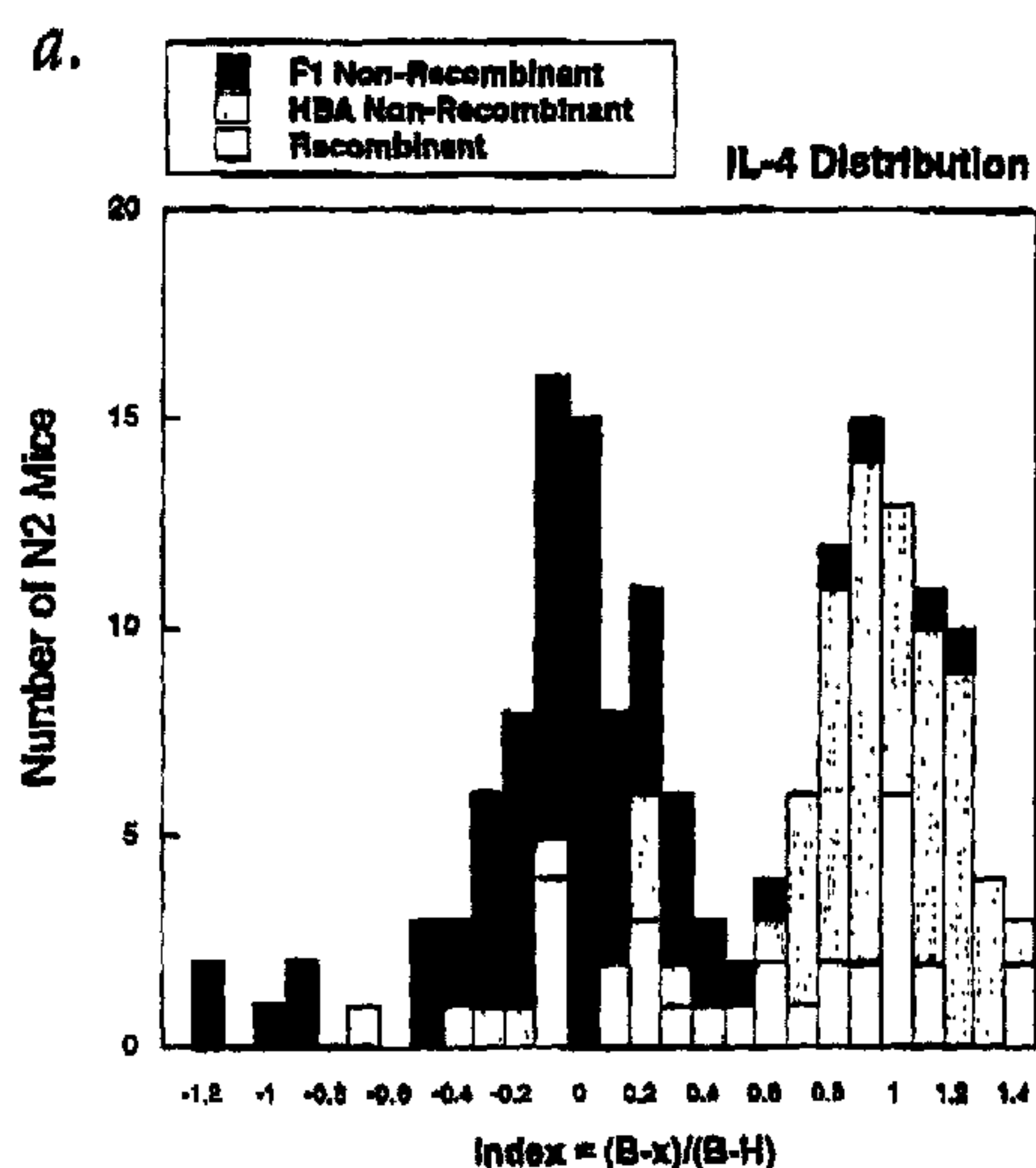
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(57) Abrégé/Abstract:

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region of human chromosome 5 that is commonly deleted in malignancies and myelodysplastic syndrome. Polymorphisms in the gene sequences are associated with the development of airway hyperreactivity and allergic inflammation, and T cell production of IL-4 and IL-13. The proteins include the human hepatitis A cellular receptor, hHAVcr-1.

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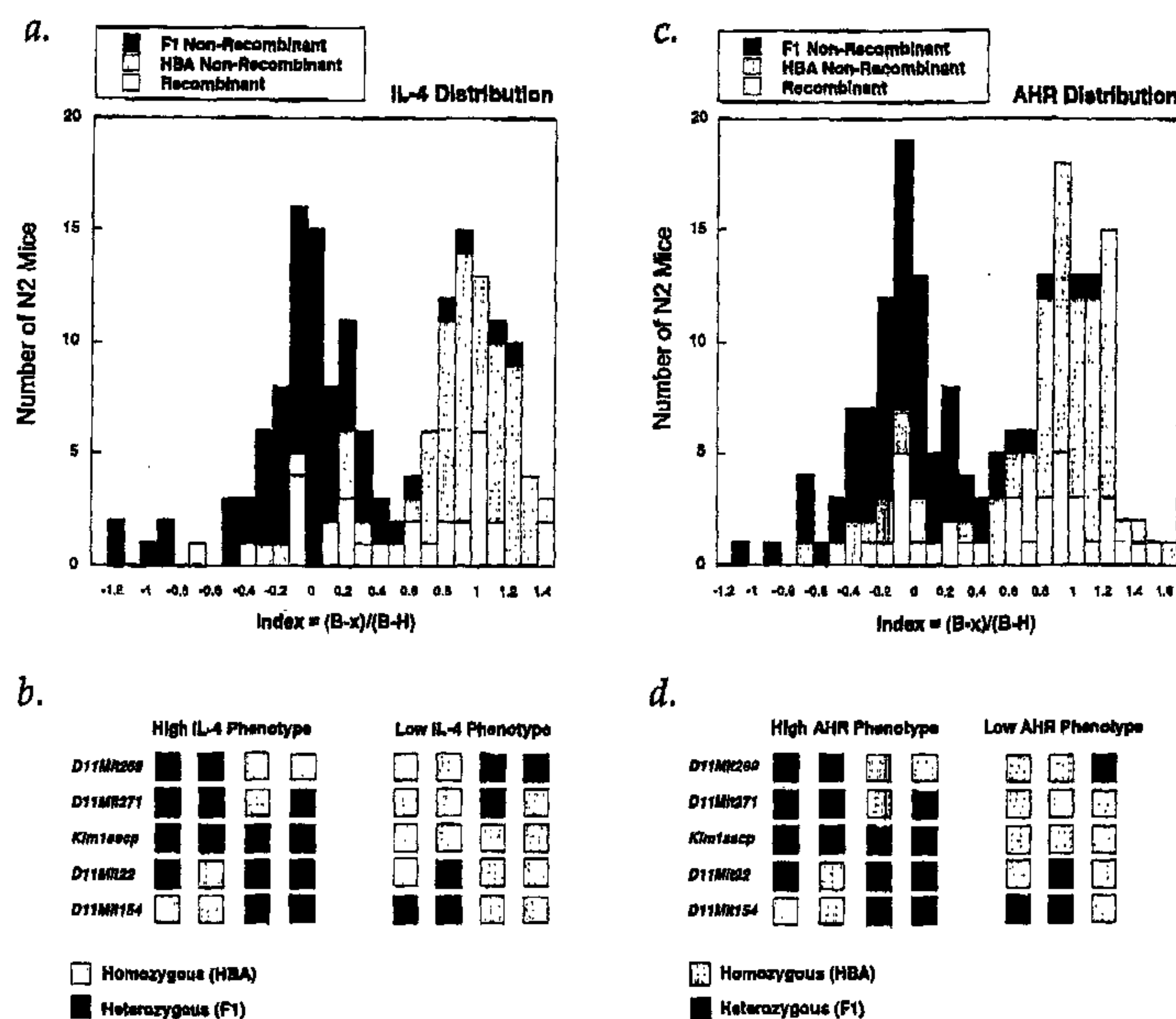
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(54) Title: T CELL REGULATORY GENES AND METHODS OF USE THEREOF

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T CELL REGULATORY GENES AND METHODS OF USE THEREOF

BACKGROUND OF THE INVENTION

The astonishing complexity of the immune system is its greatest strength. The 10^{12} - 10^{14} possible antibody specificities, the delicate interplay between the various regulatory and effector cells, the restriction of T cell responses according to MHC antigens; all these contribute to the ability of the host to effectively react against infectious agents and other antigens perceived as foreign. But this diversity has its drawbacks. Mistakes happen: the target of a response may turn out to be a normal self protein; inflammatory responses are misregulated; and normal responses are undesirably directed against grafts and transplanted cells. Under these circumstances, the complexity of the system makes diagnosis and therapy extremely difficult.

The profile of cytokines produced by $CD4^+$ T cells during an immune response determines the nature of effector functions which develop and regulates the outcome of an immune response. Production of IL-2 and IFN- γ during Th1-dominated responses is associated with vigorous cell-mediated immunity, the induction of IgG2a and inhibition of IgE synthesis, and with resistance to intracellular pathogens. In contrast, the production of IL-4, IL-5 and IL-10 during Th2-dominated responses is associated with humoral immunity and protection from autoimmune pathology. Overproduction of Th2-cytokines by allergen-specific $CD4^+$ T cells can result in the development of allergic disease and asthma, while Th1 cells have been associated with a variety of pro-inflammatory diseases.

One approach to immune associated diseases is immunotherapy. Immunotherapy has proven to be effective when used properly, and it is hoped that advances in immunologic intervention will further improve the efficacy. Alternative approaches have attempted to use cytokines to shift the immune response. IL-12, a heterodimeric cytokine produced by macrophages and dendritic cells, is potent in driving the development of Th1 cytokine synthesis in naive and memory $CD4^+$ T cells. Other cytokines, such as IL-13 and IL-4, have been associated with the differentiation of T cells to a Th2 type.

Atopy, which includes asthma, allergic rhinitis, and atopic dermatitis, is a complex trait that arises as a result of environmentally induced immune responses in genetically susceptible individuals. The prevalence of all atopic diseases has dramatically increased in industrialized countries over the past two decades. Asthma is the most common chronic disease of childhood and affects more than 15 million individuals in the United States, leading to direct treatment costs exceeding \$11 billion per annum. Epidemiological studies have suggested that the increase in asthma prevalence results

from changes in hygiene and from reduced frequency of infections (e.g., tuberculosis or hepatitis A) within industrialized society. However, the specific molecular pathways that result in the increased asthma prevalence, and the genetic polymorphisms that confer asthma susceptibility are poorly understood.

5 Expression of asthma is influenced by multiple environmental and genetic factors that interact with each other in non-additive ways, complicating the identification of asthma susceptibility genes. Asthma susceptibility has been linked to several chromosomal regions, but with resolution no better than 5-10 cM, in which there are usually hundreds of candidate genes. Moreover, because the effects of genetic variation in any single gene are
10 likely to have only modest effects in the overall pathogenesis of asthma, and because gene-gene and gene-environment interactions confound the analysis, the location of putative susceptibility genes to regions amenable to positional cloning has proven difficult to refine. Nevertheless, asthma susceptibility has been linked to chromosomes 5, 6, 11, 14, and 12. Of these, chromosome 5q23-35 has received the greatest attention because it
15 contains a large number of candidate genes(11, 12, 13, 14, 15, 16, 17, 18), including IL-9, IL-12p40, the β -adrenergic receptor, and the IL-4 cytokine cluster, which contains the genes for IL-4, IL-5, and IL-13. However, the large size of the linked region of 5q complicates its analysis, and a gene for asthma from this site has not yet been conclusively identified.

20 *Related Publications*

The genetic sequence of the human hepatitis virus A cellular receptor may be found in Genbank, accession number XM_011327. A related sequence is provided in Genbank, accession number BAB55044. Monney *et al.* (2002) Nature 415:436 describe
25 cell surface molecules expressed on Th1 cells. U.S. Patent nos. 5721351, US 6204371, US 6288218 relate to sequences corresponding to a mouse TIM-3 allele.

SUMMARY OF THE INVENTION

Genetic sequences of a gene family encoding polypeptides associated with
30 immune function and cell survival are provided. These genes encode cell surface molecules with conserved IgV and mucin domains, herein referred to as T cell Immunoglobulin domain and Mucin domain (TIM) proteins. The locus comprising the TIM family is genetically associated with immune dysfunction, including asthma. Furthermore, the TIM gene family is located within a region of human chromosome 5 that is commonly
35 deleted in malignancies and myelodysplastic syndrome. Polymorphisms are identified in TIM-1, TIM-3 and TIM-4, which can be associated with Th1/Th2 differentiation and airway hyperresponsiveness (AHR).

The nucleic acid compositions are used to produce the encoded proteins, which may be employed for functional studies, as a therapeutic, and in studying associated physiological pathways. TIM specific binding agents, including nucleic acids, antibodies, and the like, are useful as diagnostics for determining genetic susceptibility to atopy and asthma and as diagnostics for assessing tumor resistance to cancer therapy. TIM blocking agents find use as therapeutics in the treatment of immune dysfunction and disorders of cell survival, including malignancies.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1a, *HBA mice produce significantly less IL-4 than do BALB/c mice.* Lymph node cells of mice immunized with 150 μ g of KLH were harvested, B-cell depleted, and cultured in cDME with 10 μ g/ml KLH. Supernatants were harvested after 96 hours and assessed for IL-4 levels by ELISA. Shown is a box plot of IL-4 levels ($n=10$ in each group), representing the full range of data, with the boxes encompassing the upper and lower quartiles, with the median of the data set shown inside each box. IL-4 levels produced by BALB/c cells and by (BALB/c x HBA) F1 cells are significantly higher than HBA IL-4 levels $P<0.0001$ (student's t-test). *b, HBA mice produce significantly less IL-13 and IL-10 than do BALB/c mice.* Data shown are the average values of cytokines produced by lymph node cell cultures from ten individual mice in each experimental group, $\pm$ S.D. HBA IL-13 and IL-10 levels were lower than either the BALB/c or (BALB/c x HBA) F1 values, $P<0.0001$. HBA IL-5 versus BALB/c, $P<0.05$. HBA IFN- γ versus BALB/c, $P<0.001$. *c, Allergen-induced airway hyperreactivity is significantly greater in BALB/c than do HBA mice.* Pulmonary airflow obstruction was measured, and data shown represent peak enhanced pause (Penh) values averaged among sensitized mice in each group at various methacholine concentrations, $\pm$ S.E.M. (BALB x HBA) F1 demonstrate BALB/c phenotypes, while (BALB x DBA) F1 mice demonstrate DBA/2-like phenotypes.

Figure 2. Regions of HBA chromosome 11 were inherited from DBA/2. HBA chromosome 11 contains two regions derived from DBA between *hba- α 2* and *es-3*, as delineated by SSLP markers. The regions of HBA chromosome 11 with DBA/2 genotypes are highlighted (in blue) in the diagram to the left. The markers (left) provide 2-5 cM resolution distal to *D11Mit230*. Where the mouse chromosome 11 has regions of highly conserved synteny with 5q23-35, additional markers were identified with informative polymorphisms between BALB/c and DBA/2, to provide 0.01-2 cM resolution in this region (right column markers). Single-stranded confirmation polymorphisms (SSCP) markers are shown in green to distinguish them from the SSLP markers, and the positions of particular genes of interest, denoted in red, are also shown. Where the arrangement of our marker map differs from the Chromosome Committee Reports and the MIT linkage map, our map

concurs with previous linkage and physical maps.

Figure 3a. *IL-4 production by N2 mice is bimodal, with peaks corresponding to F1 and HBA phenotypes.* As a means of evaluating the relative phenotypes of recombinant N2 mice in multiple experiments, we utilized an indexing function that allowed us to consolidate data from multiple experiments. A histogram shows a bimodal distribution of IL-4 index values for N2 mice with (BALB x HBA) F1, HBA homozygous, and recombinant haplotypes indicated. Distributions associated with the F1 and HBA haplotypes are distinct ($P < 0.0001$, paired Student's t-test). *b. IL-4 regulation segregates with Kim1sscp.* Recombinant N2 haplotypes were sorted by IL-4 index values into groups associated with high IL-4 phenotypes (index < 0.35) and low IL-4 phenotypes (index > 0.65). Each column of boxes represents a recombinant haplotype. Alleles for these haplotypes at loci between D11Mit269 to D11Mit154 are shaded according to genotype (dark = F1; pale = HBA). High IL-4 production segregates with four haplotypes (left), and low IL-4 production segregates with four haplotypes (right). The IL-4 phenotype is linked to *Kim1sscp*. *c. AHR of N2 mice is bimodal, with peaks corresponding to F1 and HBA phenotypes.* Index values calculated from Penh values are shown. The histogram shows a bimodal distribution of AHR index values for N2 mice. (BALB x HBA) F1, HBA homozygous, and recombinant haplotypes are indicated. Distributions associated with the F1 and HBA haplotypes are distinct ($P < 0.0001$, paired student's t-test). *d. AHR Regulatory Locus cosegregates with the IL-4 Regulatory Locus between D11Mit22 and D11Mit271.* Recombinant N2 haplotypes were sorted by AHR index values into groups associated with high AHR phenotypes (index < 0.35) and low AHR phenotypes (index > 0.65). Each column of boxes represents a recombinant haplotype. Alleles for these haplotypes at loci between D11Mit269 to D11Mit154 are shaded according to genotype (dark = F1; pale = HBA). High AHR segregates with four haplotypes (left), and low IL-4 production segregates with three haplotypes (right). The AHR regulatory locus is linked to *Kim1sscp*, between *D11Mit271* and *D11Mit22*.

Figure 4 *Mouse chromosome 11 interval containing Tapr is highly homologous to 5q33.* In order to construct a composite map around the *Tapr* locus, we integrated available information from the mouse linkage, backcross, and radiation hybrid maps and identified a region of highly conserved synteny in current maps of the human genome (Human Genome Browser v3, UCSC, March 2001). ESTs located on a physical map of mouse chromosome 11 (left) are denoted by their accession numbers and aligned by homology to genes (center), which correspond to ESTs on human chromosome 5 (right). All known genes between *KIAA0171* and *Sgd* are shown.

Figure 5a, b, c. *Identification novel TIM gene family and major polymorphisms in TIM-1 and TIM-3.* Cloning of mouse TIM-1 and mouse TIM-2. Members of a gene family.

Sequences of the mouse TIM gene family members are shown. Shaded boxes illustrate identity between two of the mouse TIM genes. Total RNA from conA-stimulated splenocytes was reverse transcribed using Gibco Superscript II. PCR products of full length *Tim-3* cDNA were amplified, purified with Qiagen QIAquick PCR Purification reagents, and sequenced directly by Biotech Core (Mountain View, CA). PCR products for *Tim-1* and *Tim-2* cDNA were cloned into electrocompetent TOP10 cells with TOPO-XL cloning reagents (Invitrogen). Plasmids were purified with a standard alkaline lysis protocol. BALB/c and HBA plasmids were sequenced, as described. Homology of mouse TIM-1, rat KIM-1, and HAVcr-1. Identity with mouse TIM-1 is denoted by the shaded boxes. The approximate signal site is denoted by an open, inverted triangle and the Ig domain/mucin domain boundary is shown with a filled diamond. The predicted transmembrane domains are underlined. TIM-1 and TIM-3 sequences with major polymorphisms between BALB/c and HBA TIM-1 and TIM-3 shown.

Figure 6. *Tapr Regulates CD4 T cell IL-4 and IL-13 Responses.* T cells from BALB/c DO11.10 mice produce higher levels of IL-4 and IL-13 in response to antigen than do T cells from HBA DO11.10 mice. Splenic CD4⁺ cells were isolated by positive selection with anti-CD4 magnetic beads and then cocultured with bone marrow-derived DCs and OVA. After seven days, the cells were restimulated. Supernatants were harvested after 18-24 hours of the secondary culture. Data represent mean cytokine levels detected at increasing concentrations of OVA, $\pm$ S.D. Detection of expression of TIM-1 mRNA in purified CD 4 T cells during priming and differentiation.

Figure 7. Sequence alignment of Human and Mouse TIM protein sequences.

Figure 8. Polymorphisms in human TIM-1

Figure 9. SSCP polymorphism analysis of human TIM-1.

DETAILED DESCRIPTION OF THE EMBODIMENTS

Genetic sequences associated with immune function, including susceptibility to asthma, are provided. The sequences of murine Tim-1, Tim-2, Tim-3, and Tim-4, and the human counterpart sequences, are provided herein. The sequence of major polymorphisms are also provided. Genomic sequences demonstrate that these polymorphisms, including a deletion, are true polymorphisms, not splicing variants. Variants of the TIM-1 and TIM-3 sequences are associated with susceptibility to airway hyperreactivity and allergic T cell responses, and other variants associated with protection against these responses.

The extracellular domain of TIM gene family members contains two domains, an IgV domain and a mucin domain. This Ig/mucin structure is also found in

MAdCAM (mucosal addressin cell adhesion molecule), which contains two Ig domains and a mucin domain; however, there is only a low level of homology between TIMs and MAdCAM. A similar degree of homology is also present between TIM-1 and TOSO (NP_005440.1 GI:4885641), a protein which, like TIM-1 is expressed on activated T cells, and which protects T cells from Fas-mediated apoptosis.

T cells express the TIM family of genes, which critically regulates CD4 T cell differentiation. Th1 cells preferentially express the TIM-3 protein, while Th2 cells preferentially express the TIM-1 protein. TIM-1 has been linked to airway hyperreactivity and TIM-3 to autoimmune disease, therefore the expression pattern on differentiating lymphoid cells and the kinetics of expression of TIM-1 on lymphoid cells reflect the function of these molecules.

In another aspect of the invention, methods are provided for determining susceptibility of an individual to developing asthma and atopic diseases, by determining the genotype at the Tim locus. Screening may analyze, for example, polymorphisms in any one of the TIM-1, TIM-3 or TIM-4 alleles provided herein, or otherwise determined. Methods are provided for screening such polymorphisms, *e.g.* SSCP analysis, size polymorphisms, and the like.

In another aspect of the invention, a method of screening for biologically active agents that modulate Tim gene or polypeptide function is provided, where the method comprises combining a candidate biologically active agent with any one of: (a) a Tim polypeptide; (b) a cell comprising a nucleic acid encoding a Tim polypeptide; or (c) a non-human transgenic animal model for Tim gene function comprising one of: (i) a knockout of an *Tim* gene; (ii) an exogenous and stably transmitted *Tim* gene sequence; or (iii) a *Tim* promoter sequence operably linked to a reporter gene; and determining the effect of said agent on Tim function.

The activity of TIM polypeptides may be modulated in order to direct immune function. TIM-1 is preferentially expressed in Th2 cells, and agents that modulate TIM-1 activity find use in the treatment of Th2 related disorders, including allergies, asthma, and the like. TIM-3 is preferentially expressed in Th1 cells, and agents that modulate TIM-3 activity find use in the treatment of pro-inflammatory immune diseases, including autoimmune diseases, graft rejection and the like.

CONDITIONS OF INTEREST

Atopic diseases are complex genetic traits that develop as a result of environmentally induced immune responses in genetically predisposed individuals. Both atopic and non-atopic individuals are exposed to the same environmental factors, but genetic differences that distinguish atopic from non-atopic individuals result in atopic

disease in some individuals, manifested by allergic inflammation in the respiratory tract, skin or gastrointestinal tract, as well as by elevated serum IgE, eosinophilia and the symptoms of wheezing, sneezing or hives. In addition, allergic inflammatory responses are characterized by the presence of Th2 lymphocytes producing high levels of IL-4, IL-5, IL-9
 5 and IL-13, which enhance the growth, differentiation and/or recruitment of eosinophils, mast cells, basophils and B cells producing IgE.

Allergens of interest include antigens found in food, such as strawberries, peanuts, milk proteins, egg whites, *etc.* Other allergens of interest include various airborne antigens, such as grass pollens, animal danders, house mite feces, *etc.* Molecularly cloned
 10 allergens include *Dermatophagoides pteronyssinus* (Der P1); Lol pl-V from rye grass pollen; a number of insect venoms, including venom from jumper ant *Myrmecia pilosula*; *Apis mellifera* bee venom phospholipase A2 (PLA₂ and antigen 5S; phospholipases from the yellow jacket *Vespula maculifrons* and white faced hornet *Dolichovespula maculata*; a large number of pollen proteins, including birch pollen, ragweed pollen, *Parol* (the major
 15 allergen of *Parietaria officinalis*) and the cross-reactive allergen *Parj1* (from *Parietaria judaica*), and other atmospheric pollens including *Olea europaea*, *Artemisia sp.*, *gramineae*, *etc.* Other allergens of interest are those responsible for allergic dermatitis caused by blood sucking arthropods, *e.g. Diptera*, including mosquitos (*Anopheles sp.*, *Aedes sp.*, *Culiseta sp.*, *Culex sp.*); flies (*Phlebotomus sp.*, *Culicoides sp.*) particularly black flies, deer
 20 flies and biting midges; ticks (*Dermacenter sp.*, *Ornithodoros sp.*, *Otobius sp.*); fleas, *e.g.* the order *Siphonaptera*, including the genera *Xenopsylla*, *Pulex* and *Ctenocephalides felis felis*. The specific allergen may be a polysaccharide, fatty acid moiety, protein, *etc.*

Polymorphisms in a number of interacting/epistatic atopy genes are thought to result in enhanced susceptibility to allergic disorders. Genome wide scans have sought
 25 to identify the responsible genes by linking various parameters of allergy and asthma with polymorphic DNA markers of specific genes, usually repeat sequences of DNA (microsatellites that contain di- tri- and tetra-nucleotide repeats). These studies have identified several chromosomal regions as likely to be involved in the pathogenesis of atopy, but with resolution no better than 5-10 cM in which there are typically hundreds of
 30 candidate genes. Nevertheless, asthma susceptibility has been linked to chromosomes 5q23-31, chromosome 6p21, chromosome 11q13, and chromosome 12q (9-13) by two or more of these genome wide scanning studies.

Asthma, as defined herein, is reversible airflow limitation in an individual over a period of time. Asthma is characterized by the presence of cells such as eosinophils,
 35 mast cells, basophils, and CD25⁺ T lymphocytes in the airway walls. There is a close interaction between these cells, because of the activity of cytokines which have a variety of communication and biological effector properties. Chemokines attract cells to the site of

inflammation and cytokines activate them, resulting in inflammation and damage to the mucosa. With chronicity of the process, secondary changes occur, such as thickening of basement membranes and fibrosis. The disease is characterized by increased airway hyperresponsiveness to a variety of stimuli, and airway inflammation. A patient diagnosed as asthmatic will generally have multiple indications over time, including wheezing, asthmatic attacks, and a positive response to methacholine challenge, i.e., a PC20 on methacholine challenge of less than about 4 mg/ml. Guidelines for diagnosis may be found, for example, in the National Asthma Education Program Expert Panel Guidelines for Diagnosis and Management of Asthma, National Institutes of Health, 1991, Pub. No. 91-3042.

Asthma, allergic rhinitis (hay fever), atopic dermatitis (eczema) and food allergy are diseases that occur in the same families, implying common genetic mechanisms. These atopic diseases are exceedingly prevalent, affecting 20-40% of the general population and constitute a major public health problem. The economic costs for these disorders are enormous. For asthma alone, the estimated health care costs in 1996 were \$14 billion. In addition, the prevalence of all of the atopic diseases has increased dramatically in industrialized countries over the past two decades for reasons that are not yet clear. The prevalence of asthma in industrialized countries, for which the numbers are the most accurate, has doubled since 1982, and is projected to double again in prevalence by the year 2020.

Pro-inflammatory diseases associated with Th1 type T cells include autoimmune diseases such as multiple sclerosis, rheumatoid arthritis, type I diabetes mellitus, *etc.* (RA) is a chronic autoimmune inflammatory synovitis affecting 0.8% of the world population. Current therapy for RA utilizes therapeutic agents that non-specifically suppress or modulate immune function. Such therapeutics, including the recently developed TNF α antagonists, are not fundamentally curative, and disease activity rapidly returns following discontinuation of therapy. Tremendous clinical need exists for fundamentally curative therapies that do not cause systemic immune suppression or modulation.

A quantitative increase in myelin-autoreactive T cells with the capacity to secrete IFN-gamma is associated with the pathogenesis of MS and EAE, suggesting that autoimmune inducer/helper T lymphocytes in the peripheral blood of MS patients may initiate and/or regulate the demyelination process in patients with MS. The overt disease is associated with muscle weakness, loss of abdominal reflexes, visual defects and paresthesias. During the presymptomatic period there is infiltration of leukocytes into the cerebrospinal fluid, inflammation and demyelination.

IDDM is a cell-mediated autoimmune disorder leading to destruction of insulin-secreting beta cells and overt hyperglycemia. T lymphocytes invade the islets of Langerhans, and specifically destroy insulin-producing β -cells. The depletion of β cells results in an inability to regulate levels of glucose in the blood. The disease progression may be monitored in individuals diagnosed by family history and genetic analysis as being susceptible. The most important genetic effect is seen with genes of the major histocompatibility locus (*IDDM1*), although other loci, including the insulin gene region (*IDDM2*) also show linkage to the disease (see Davies *et al, supra* and Kennedy *et al.* (1995) Nature Genetics 9:293-298).

10

TIM GENE FAMILY

The provided TIM family genes and fragments thereof, encoded proteins, genomic regulatory regions, and specific antibodies are useful in the identification of individuals predisposed to development or resistance to asthma, and for the modulation of gene activity in vivo for prophylactic and therapeutic purposes. The encoded proteins are useful as an immunogen to raise specific antibodies, in drug screening for compositions that mimic or modulate activity or expression, including altered forms of the proteins, and as a therapeutic.

The TIM family genes are immediately adjacent to each other on human chromosome 5, in the order TIM-4, TIM-1, TIM-3, with no intervening genes. This segment of human chromosome 5 is commonly deleted in malignancies and dysplastic cell populations, as in myelodysplastic syndrome (see Boultonwood, *et al*, (1997) Genomics 45:88-96). There are TIM pseudogenes on chromosomes 5, 12, and 19. Each TIM protein, except TIM-4, contains a distinct predicted tyrosine signaling motif. The cytoplasmic region of TIM-1 contains two tyrosine residues and includes a highly conserved tyrosine kinase phosphorylation motif, RAEDNIY. The expanded region, SRAEDNIYIVEDRP, contains a predicted site for Itk phosphorylation and for EGF-receptor phosphorylation.

The mouse *Tim1* gene encodes a 305 amino acid membrane protein. The cytoplasmic region of TIM-1 contains two tyrosine residues and includes a highly conserved tyrosine kinase phosphorylation motif, RAEDNIY. The mucin domain of TIM-1 has multiple sites for O-linked glycosylation, and there two sites for N-linked glycosylation found in the immunoglobulin domain.

Mouse TIM-2, a similar 305 amino acid membrane protein, has 64% identity to mouse TIM-1, 60% identity to rat KIM-1, and 32% identity to hHAVcr-1. Like TIM-1, TIM-2 has two extracellular N-linked glycosylation sites and a serine, threonine- rich mucin domain with many O-linked glycosylation sites. TIM-2 also has an intracellular tyrosine

kinase phosphorylation motif, RTRCEDQVY.

Tim3 encodes a 281 amino acid membrane protein in mice, and a 301 amino acid protein in humans, that has a similar, integral membrane glycoprotein structure with multiple extracellular glycosylation sites and an intracellular tyrosine phosphorylation motif.

5 Although the mucin domain is not as prominent in TIM-3 as it is in TIM-1 and TIM-2, TIM-3 expressed on T cells interacts with a ligand on APCs and alters APC activation. TIM-3 has four sites for N-linked and five sites for O-linked glycosylation, suggesting that TIM-3, like TIM-1 and TIM-2, is heavily glycosylated and might interact with a ligand present on other cells, such as antigen presenting cells.

10 *Tim4* encodes a 344 amino acid protein in mice, and a 378 amino acid protein in humans. The predicted TIM-4 also shares the general membrane glycoprotein structural motifs of the other TIM proteins, a with an IgV-like domain with highly conserved cysteine residues, a threonine-rich mucin-like domain, and a short intracellular tail.

Polymorphisms in the murine sequences are provided in the sequence listing
15 for the BALB/c and HBA/DBA strains. In TIM-1, these polymorphisms encode three amino acid differences and a fifteen amino acid deletion in HBA/DBA. Seven predicted amino acid differences were identified in TIM-3. The polymorphisms in TIM-1 and TIM-4 are located in the signal and mucin-like domains, while the polymorphisms identified in TIM-3 are clustered in the Ig domain.

20 Variants in coding regions of human *Tim1* are provided in the seqlist and Figure 8. Variations include an insertion (labeled polymorphism 1), 157insMTTTVP, observed in 65% of the chromosomes, and a deletion (polymorphism 5), 187ΔThr, observed in 65% of the chromosomes. Other polymorphisms are T140A (polymorphism 7); V161A; (polymorphism 2); V167I (polymorphism 3); T172A (polymorphism 4); N258D
25 (polymorphism 6). Polymorphism 4 was observed in 40% of the chromosomes, and the other polymorphisms were each observed in ≤5% of the chromosomes. Most of these variations (2-6) are located within exon 3, the first mucin-encoding exon, and all of the variants occur at the genomic level and are not splice variants. The association between *Tim1* and asthma susceptibility is further supported by reports of significant linkage of mite-sensitive childhood asthma to D5S820 (mean LOD score = 4.8), a marker which is
30 approximately 0.5 megabases from *Tim1*.

In human tissues, a 4.4 kb TIM-1 mRNA is present in almost all tissues, though it is faint in most. A 5.5-kb band was observed in colon and liver. A 7.5-kb band was observed in spleen, thymus, and peripheral blood leukocytes, and smaller than 4.4-kb
35 bands were observed in some organs. TIM-1 mRNA is expressed with alternate 5' untranslated regions, in different cell populations. Hypoxia and ischemia induces TIM-1 expression in epithelial cells, and radiation induces expression of TIM gene family mRNA.

The TIM genes are expressed in tumor specimens. Human TIM-4 mRNA is expressed in glioblastoma tissue, and is also detected in mitogen stimulated or irradiated peripheral blood monocytes.

In one aspect, the invention provides for an isolated nucleic acid molecule other than a naturally occurring chromosome comprising a sequence encoding a TIM-1, TIM-2, TIM-3 or TIM-4 protein, or a homolog or variant thereof, which variant may be associated with susceptibility to airway hyperreactivity and allergic T cell responses. The nucleic acid may be operably linked to a vector and/or control sequences for expression in a homologous or heterologous host cell. Such a host cell can find use in the production of the encoded protein. In another aspect of the invention, a purified polypeptide is provided of TIM-1, TIM-2, TIM-3 or TIM-4 protein, or a homolog or variant thereof, which variant may be associated with susceptibility to airway hyperreactivity and allergic T cell responses. In another aspect, an antibody or other specific binding member that binds to the TIM-1, TIM-2, TIM-3 or TIM-4 polypeptide is provided.

Sequences of human and murine TIM sequences are provided in the sequence listing, as follows:

SEQ ID NO	Name	Length	Type
1	BALB/c TIM-1	305	Protein
2	BALB/c TIM-1	918	DNA
3	ES-HBA TIM-1	282	Protein
4	ES-HBA TIM-1	849	DNA
5	BALB/c TIM-2	305	Protein
6	BALB/c TIM-1	958	DNA
7	ES-HBA TIM-2	305	Protein
8	ES-HBA TIM-2	958	DNA
9	BALB/c TIM-3	281	Protein
10	BALB/c TIM-3	2725	DNA
11	ES-HBA TIM-3	281	Protein
12	ES-HBA TIM-3	862	DNA
13	BALB/c TIM-4	345	Protein
14	BALB/c TIM-4	1032	DNA
15	ES-HBA TIM-4	345	Protein
16	ES-HBA TIM-4	1032	DNA
17	hTIM-1 allele 1	359	Protein
18	hTIM-1 allele 1	1080	DNA
19	hTIM-1 allele 2	359	Protein
20	hTIM-1 allele 2	1080	DNA
21	hTIM-1 allele 3	365	Protein
22	hTIM-1 allele 3	1098	DNA
23	hTIM-1 allele 4	359	Protein
24	hTIM-1 allele 4	1079	DNA
25	hTIM-1 allele 5	364	Protein
26	hTIM-1 allele 5	1095	DNA
27	hTIM-1 allele 6	364	Protein
28	hTIM-1 allele 6	1099	DNA
29	hTIM-3 allele 1	301	Protein
30	hTIM-3 allele 1	1116	DNA

31	hTIM-3 allele 2	301	Protein
32	hTIM-3 allele 2	1116	DNA
33	hTIM-4 allele 1	378	Protein
34	hTIM-4 allele 1	1156	DNA
35	hTIM-4 allele 2	378	Protein
36	hTIM-4 allele 2	1156	DNA

The DNA sequence encoding Tim polypeptides may be cDNA or genomic DNA or a fragment thereof. Fragments of interest for probes, producing polypeptides, *etc.* may comprise one or more polymorphic residues. The term Tim gene shall be intended to mean the open reading frame encoding any one of the specific Tim polypeptides, introns, as well as adjacent 5' and 3' non-coding nucleotide sequences involved in the regulation of expression, up to about 1 kb beyond the coding region, but possibly further in either direction. The gene may be introduced into an appropriate vector for extrachromosomal maintenance or for integration into the host.

In some embodiments, the Tim gene sequence is other than human TIM-1 allele 1, as set forth in the sequence listing; and/or other than mouse TIM-3 DBA allele.

The term "cDNA" as used herein is intended to include all nucleic acids that share the arrangement of sequence elements found in native mature mRNA species, where sequence elements are exons and 3' and 5' non-coding regions. Normally mRNA species have contiguous exons, with the intervening introns removed by nuclear RNA splicing, to create a continuous open reading frame encoding a Tim protein.

A genomic sequence of interest comprises the nucleic acid present between the initiation codon and the stop codon, as defined in the listed sequences, including all of the introns that are normally present in a native chromosome. It may further include the 3' and 5' untranslated regions found in the mature mRNA. It may further include specific transcriptional and translational regulatory sequences, such as promoters, enhancers, *etc.*, including about 1 kb, but possibly more, of flanking genomic DNA at either the 5' or 3' end of the transcribed region. The genomic DNA may be isolated as a fragment of 100 kbp or smaller; and substantially free of flanking chromosomal sequence.

The sequence of the 5' region, and further 5' upstream sequences and 3' downstream sequences, may be utilized for promoter elements, including enhancer binding sites, that provide for expression in tissues where *Tim* genes are expressed. The tissue specific expression is useful for determining the pattern of expression, and for providing promoters that mimic the native pattern of expression. Naturally occurring polymorphisms in the promoter region are useful for determining natural variations in expression, particularly those that may be associated with disease. Alternatively, mutations may be introduced into the promoter region to determine the effect of altering expression in experimentally defined systems. Methods for the identification of specific DNA motifs

involved in the binding of transcriptional factors are known in the art, *e.g.* sequence similarity to known binding motifs, gel retardation studies, *etc.* For examples, see Blackwell *et al.* (1995) Mol Med **1**: 194-205; Mortlock *et al.* (1996) Genome Res. **6**: 327-33; and Joulin and Richard-Foy (1995) Eur J Biochem **232**: 620-626.

5 The regulatory sequences may be used to identify *cis* acting sequences required for transcriptional or translational regulation of TIM expression, especially in different tissues or stages of development, and to identify *cis* acting sequences and *trans* acting factors that regulate or mediate TIM expression. Such transcription or translational control regions may be operably linked to a TIM gene in order to promote expression of wild
10 type or altered TIM or other proteins of interest in cultured cells, or in embryonic, fetal or adult tissues, and for gene therapy.

 The nucleic acid compositions of the subject invention may encode all or a part of the subject polypeptides. Fragments may be obtained of the DNA sequence by chemically synthesizing oligonucleotides in accordance with conventional methods, by
15 restriction enzyme digestion, by PCR amplification, *etc.* For the most part, DNA fragments will be of at least 15 nt, usually at least 18 nt, more usually at least about 50 nt. Such small DNA fragments are useful as primers for PCR, hybridization screening, *etc.* Larger DNA fragments, *i.e.* greater than 100 nt are useful for production of the encoded polypeptide. For use in amplification reactions, such as PCR, a pair of primers will be used. The exact
20 composition of the primer sequences is not critical to the invention, but for most applications the primers will hybridize to the subject sequence under stringent conditions, as known in the art. It is preferable to choose a pair of primers that will generate an amplification product of at least about 50 nt, preferably at least about 100 nt. Algorithms for the selection of primer sequences are generally known, and are available in commercial
25 software packages. Amplification primers hybridize to complementary strands of DNA, and will prime towards each other.

 The *TIM* genes are isolated and obtained in substantial purity, generally as other than an intact mammalian chromosome. Usually, the DNA will be obtained substantially free of other nucleic acid sequences that do not include an *TIM* sequence or
30 fragment thereof, generally being at least about 50%, usually at least about 90% pure and are typically "recombinant", *i.e.* flanked by one or more nucleotides with which it is not normally associated on a naturally occurring chromosome.

 The DNA sequences are used in a variety of ways. They may be used as probes for identifying *TIM* related genes. Mammalian homologs have substantial sequence
35 similarity to the subject sequences, *i.e.* at least 75%, usually at least 90%, more usually at least 95% sequence identity with the nucleotide sequence of the subject DNA sequence. Sequence similarity is calculated based on a reference sequence, which may be a subset

of a larger sequence, such as a conserved motif, coding region, flanking region, *etc.* A reference sequence will usually be at least about 18 nt long, more usually at least about 30 nt long, and may extend to the complete sequence that is being compared. Algorithms for sequence analysis are known in the art, such as BLAST, described in Altschul *et al.* (1990)

5 J Mol Biol **215**:403-10.

Nucleic acids having sequence similarity are detected by hybridization under low stringency conditions, for example, at 50°C and 10XSSC (0.9 M saline/0.09 M sodium citrate) and remain bound when subjected to washing at 55°C in 1XSSC. Sequence identity may be determined by hybridization under stringent conditions, for example, at
10 50°C or higher and 0.1XSSC (9 mM saline/0.9 mM sodium citrate). By using probes, particularly labeled probes of DNA sequences, one can isolate homologous or related genes. The source of homologous genes may be any species, *e.g.* primate species, particularly human; rodents, such as rats and mice, canines, felines, bovines, ovines, equines, yeast, *Drosophila*, *Caenorhabditis*, *etc.*

15 The DNA may also be used to identify expression of the gene in a biological specimen. The manner in which one probes cells for the presence of particular nucleotide sequences, as genomic DNA or RNA, is well established in the literature and does not require elaboration here. mRNA is isolated from a cell sample. mRNA may be amplified by RT-PCR, using reverse transcriptase to form a complementary DNA strand, followed by
20 polymerase chain reaction amplification using primers specific for the subject DNA sequences. Alternatively, mRNA sample is separated by gel electrophoresis, transferred to a suitable support, *e.g.* nitrocellulose, nylon, *etc.*, and then probed with a fragment of the subject DNA as a probe. Other techniques, such as oligonucleotide ligation assays, *in situ* hybridizations, and hybridization to DNA probes arrayed on a solid chip may also find use.
25 Detection of mRNA hybridizing to the subject sequence is indicative of *TIM* gene expression in the sample.

The subject nucleic acid sequences may be modified for a number of purposes, particularly where they will be used intracellularly, for example, by being joined to a nucleic acid cleaving agent, *e.g.* a chelated metal ion, such as iron or chromium for
30 cleavage of the gene; or the like.

The sequence of the *TIM* locus, including flanking promoter regions and coding regions, may be mutated in various ways known in the art to generate targeted changes in promoter strength, sequence of the encoded protein, *etc.* The DNA sequence or product of such a mutation will be substantially similar to the sequences provided herein,
35 *i.e.* will differ by at least one nucleotide or amino acid, respectively, and may differ by at least two but not more than about ten nucleotides or amino acids. The sequence changes may be substitutions, insertions or deletions. Deletions may further include larger changes,

such as deletions of a domain or exon. Other modifications of interest include epitope tagging, *e.g.* with the FLAG system, HA, *etc.* For studies of subcellular localization, fusion proteins with green fluorescent proteins (GFP) may be used. Such mutated genes may be used to study structure-function relationships of TIM polypeptides, or to alter properties of the protein that affect its function or regulation. For example, constitutively active transcription factors, or a dominant negatively active protein that binds to the TIM DNA target site without activating transcription, may be created in this manner.

Techniques for *in vitro* mutagenesis of cloned genes are known. Examples of protocols for scanning mutations may be found in Gustin *et al.*, *Biotechniques* 14:22 (1993); Barany, *Gene* 37:111-23 (1985); Colicelli *et al.*, *Mol Gen Genet* 199:537-9 (1985); and Prentki *et al.*, *Gene* 29:303-13 (1984). Methods for site specific mutagenesis can be found in Sambrook *et al.*, *Molecular Cloning: A Laboratory Manual*, CSH Press 1989, pp. 15.3-15.108; Weiner *et al.*, *Gene* 126:35-41 (1993); Sayers *et al.*, *Biotechniques* 13:592-6 (1992); Jones and Winistorfer, *Biotechniques* 12:528-30 (1992); Barton *et al.*, *Nucleic Acids Res* 18:7349-55 (1990); Marotti and Tomich, *Gene Anal Tech* 6:67-70 (1989); and Zhu *Anal Biochem* 177:120-4 (1989).

Arrays provide a high throughput technique that can assay a large number of polynucleotides in a sample. In one aspect of the invention, an array is constructed comprising one or more of the TIM genes, proteins or antibodies, preferably comprising all of these sequences, which array may further comprise other sequences known to be up- or down-regulated in T cells, monocytes, and the like. This technology can be used as a tool to test for differential expression, or for genotyping. Arrays can be created by spotting polynucleotide probes onto a substrate (*e.g.*, glass, nitrocellulose, *etc.*) in a two-dimensional matrix or array having bound probes. The probes can be bound to the substrate by either covalent bonds or by non-specific interactions, such as hydrophobic interactions. Techniques for constructing arrays and methods of using these arrays are described in, for example, Schena *et al.* (1996) *Proc Natl Acad Sci U S A.* **93**(20):10614-9; Schena *et al.* (1995) *Science* **270**(5235):467-70; Shalon *et al.* (1996) *Genome Res.* **6**(7):639-45, USPN 5,807,522, EP 799 897; WO 97/29212; WO 97/27317; EP 785 280; WO 97/02357; USPN 5,593,839; USPN 5,578,832; EP 728 520; USPN 5,599,695; EP 721 016; USPN 5,556,752; WO 95/22058; and USPN 5,631,734.

The probes utilized in the arrays can be of varying types and can include, for example, synthesized probes of relatively short length (*e.g.*, a 20-mer or a 25-mer), cDNA (full length or fragments of gene), amplified DNA, fragments of DNA (generated by restriction enzymes, for example) and reverse transcribed DNA. Both custom and generic arrays can be utilized in detecting differential expression levels. Custom arrays can be prepared using probes that hybridize to particular preselected subsequences of mRNA

gene sequences or amplification products prepared from them.

Arrays can be used to, for example, examine differential expression of genes and can be used to determine gene function. For example, arrays can be used to detect differential expression, or expression of polymorphic sequences, in TIM genes. Exemplary
5 uses of arrays are further described in, for example, Pappalarado *et al.* (1998) Sem. Radiation Oncol. **8**:217; and Ramsay. (1998) Nature Biotechnol. **16**:40. Furthermore, many variations on methods of detection using arrays are well within the skill in the art and within the scope of the present invention. For example, rather than immobilizing the probe to a solid support, the test sample can be immobilized on a solid support which is then
10 contacted with the probe. Additional discussion regarding the use of microarrays in expression analysis can be found, for example, in Duggan, et al., Nature Genetics Supplement 21:10-14 (1999); Bowtell, Nature Genetics Supplement 21:25-32 (1999); Brown and Botstein, Nature Genetics Supplement 21:33-37 (1999); Cole et al., Nature Genetics Supplement 21:38-41 (1999); Debouck and Goodfellow, Nature Genetics
15 Supplement 21:48-50 (1999); Bassett, Jr., et al., Nature Genetics Supplement 21:51-55 (1999); and Chakravarti, Nature Genetics Supplement 21:56-60 (1999).

Pharmacogenetics is the linkage between an individual's genotype and that individual's ability to metabolize or react to a therapeutic agent. Differences in metabolism or target sensitivity can lead to severe toxicity or therapeutic failure by altering the relation
20 between bioactive dose and blood concentration of the drug. In the past few years, numerous studies have established good relationships between polymorphisms in metabolic enzymes or drug targets, and both response and toxicity. These relationships can be used to individualize therapeutic dose administration.

Genotyping of polymorphic alleles is used to evaluate whether an individual
25 will respond well to a particular therapeutic regimen. The polymorphic sequences are also used in drug screening assays, to determine the dose and specificity of a candidate therapeutic agent. A candidate TIM polymorphism is screened with a target therapy to determine whether there is an influence on the effectiveness in treating asthma. Drug screening assays are performed as described above. Typically two or more different
30 sequence polymorphisms are tested for response to a therapy.

The subject gene may be employed for synthesis of a complete TIM protein, or polypeptide fragments thereof, particularly fragments corresponding to functional domains; binding sites; *etc.*; and including fusions of the subject polypeptides to other proteins or parts thereof. For expression, an expression cassette may be employed,
35 providing for a transcriptional and translational initiation region, which may be inducible or constitutive, where the coding region is operably linked under the transcriptional control of the transcriptional initiation region, and a transcriptional and translational termination

region. Various transcriptional initiation regions may be employed that are functional in the expression host.

Polypeptides of particular interest that are fragments of the TIM polypeptides include specific domains of the TIM polypeptides, where a domain may comprise, for example, the extracellular domain, or the domains within the extracellular domain: the mucin domain and/or the Ig domain. Domains may also comprise the cytoplasmic domain, e.g. a fragment encompassing the tyrosine kinase phosphorylation motif, RAEDNIY, or the expanded region, SRAEDNIYIVEDRP. Polypeptides encoded by the soluble splice variants are also of interest. The sequence of the Ig domains are as follows: human TIM-1 Ig domain, SEQ ID NO: 17, 19, 21, 23, 25, 27, residues 21-126; human TIM-3 Ig domain, SEQ ID NO: 29 and 31, residues 22-131; human TIM-4 Ig domain, SEQ ID NO: 33 and 35, residues 25-133; mouse TIM-1 Ig domain, SEQ ID NO: 1 and 3, residues 21-129; mouse TIM-2 Ig domain, SEQ ID NO: 7, residues 22-128; mouse TIM-3 Ig domain, BALB/c allele, SEQ ID NO: 9, residues 22-132; mouse TIM-3 Ig domain, DBA/2 allele, SEQ ID No: 11, residues 22-132; mouse TIM-4 Ig domain, SEQ ID NO: 13 and 15, residues 25-135.

Functionally equivalent polypeptides may find use, where the equivalent polypeptide may contain deletions, additions or substitutions of amino acid residues that result in a silent change, thus producing a functionally equivalent differentially expressed on pathway gene product. Amino acid substitutions may be made on the basis of similarity in polarity, charge, solubility, hydrophobicity, hydrophilicity, and/or the amphipathic nature of the residues involved. "Functionally equivalent", as used herein, refers to a protein capable of exhibiting a substantially similar *in vivo* activity as the polypeptide encoded by a TIM gene.

The polypeptides may be expressed in prokaryotes or eukaryotes in accordance with conventional ways, depending upon the purpose for expression. For large scale production of the protein, a unicellular organism, such as *E. coli*, *B. subtilis*, *S. cerevisiae*, or cells of a higher organism such as vertebrates, particularly mammals, e.g. COS 7 cells, may be used as the expression host cells. In many situations, it may be desirable to express the TIM gene in mammalian cells, where the TIM gene will benefit from native folding and post-translational modifications. Small peptides can also be synthesized in the laboratory, including specific peptide epitopes, domains, and the like, where peptides will usually be at least about 8 amino acids in length, more usually at least about 20 amino acids in length, up to complete domains, and the full length protein. Peptides may comprise polymorphic regions of the protein. Also included are fusion proteins, where all or a fragment of the TIM protein is fused to a heterologous polypeptide, e.g. green fluorescent protein, antibody Fc regions, poly-histidine, and the like.

In mammalian host cells, a number of viral-based expression systems may

be used, including retrovirus, lentivirus, adenovirus, adeno-associated virus, and the like. In cases where an adenovirus is used as an expression vector, the coding sequence of interest can be ligated to an adenovirus transcription/translation control complex, *e.g.*, the late promoter and tripartite leader sequence. This chimeric gene may then be inserted in
5 the adenovirus genome by *in vitro* or *in vivo* recombination. Insertion in a non-essential region of the viral genome (*e.g.*, region E1 or E3) will result in a recombinant virus that is viable and capable of expressing differentially expressed or pathway gene protein in infected hosts.

Specific initiation signals may also be required for efficient translation of the
10 genes. These signals include the ATG initiation codon and adjacent sequences. In cases where a complete gene, including its own initiation codon and adjacent sequences, is inserted into the appropriate expression vector, no additional translational control signals may be needed. However, in cases where only a portion of the gene coding sequence is inserted, exogenous translational control signals must be provided. These exogenous
15 translational control signals and initiation codons can be of a variety of origins, both natural and synthetic. The efficiency of expression may be enhanced by the inclusion of appropriate transcription enhancer elements, transcription terminators, *etc.*

With the availability of the polypeptides in large amounts, by employing an expression host, the polypeptides may be isolated and purified in accordance with
20 conventional ways. A lysate may be prepared of the expression host and the lysate purified using HPLC, exclusion chromatography, gel electrophoresis, affinity chromatography, or other purification technique. The purified polypeptide will generally be at least about 80% pure, preferably at least about 90% pure, and may be up to and including 100% pure. Pure is intended to mean free of other proteins, as well as cellular debris.

The polypeptide may be labeled, either directly or indirectly. Any of a variety of suitable labeling systems may be used, including but not limited to, radioisotopes such as ¹²⁵I; enzyme labeling systems that generate a detectable colorimetric signal or light when exposed to substrate; and fluorescent labels. Indirect labeling involves the use of a protein, such as a labeled antibody, that specifically binds to the polypeptide of interest. Such
25 antibodies include but are not limited to polyclonal, monoclonal, chimeric, single chain, Fab fragments and fragments produced by a Fab expression library.
30

SPECIFIC BINDING MEMBERS

The term "specific binding member" or "binding member" as used herein
35 refers to a member of a specific binding pair, *i.e.* two molecules, usually two different molecules, where one of the molecules (*i.e.*, first specific binding member) through chemical or physical means specifically binds to the other molecule (*i.e.*, second specific

binding member). The complementary members of a specific binding pair are sometimes referred to as a ligand and receptor; or receptor and counter-receptor. For the purposes of the present invention, the two binding members may be known to associate with each other, for example where an assay is directed at detecting compounds that interfere with
5 the association of a known binding pair. Alternatively, candidate compounds suspected of being a binding partner to a compound of interest may be used.

Specific binding pairs of interest include carbohydrates and lectins; complementary nucleotide sequences; peptide ligands and receptor; effector and receptor molecules; hormones and hormone binding protein; enzyme cofactors and enzymes;
10 enzyme inhibitors and enzymes; lipid and lipid-binding protein; etc. The specific binding pairs may include analogs, derivatives and fragments of the original specific binding member. For example, a receptor and ligand pair may include peptide fragments, chemically synthesized peptidomimetics, labeled protein, derivatized protein, etc.

In a preferred embodiment, the specific binding member is an antibody. The
15 term "antibody" or "antibody moiety" is intended to include any polypeptide chain-containing molecular structure with a specific shape that fits to and recognizes an epitope, where one or more non-covalent binding interactions stabilize the complex between the molecular structure and the epitope. Antibodies that bind specifically to one of the TIM proteins are referred to as anti-TIM. The archetypal antibody molecule is the immunoglobulin, and all
20 types of immunoglobulins, IgG, IgM, IgA, IgE, IgD, etc., from all sources, e.g. human, rodent, rabbit, cow, sheep, pig, dog, other mammal, chicken, other avians, etc., are considered to be "antibodies." Antibodies utilized in the present invention may be polyclonal antibodies, although monoclonal antibodies are preferred because they may be reproduced by cell culture or recombinantly, and can be modified to reduce their
25 antigenicity.

Polyclonal antibodies can be raised by a standard protocol by injecting a production animal with an antigenic composition, which may be a polypeptide or a cDNA expressed *in vivo*. See, e.g., Harlow and Lane, *Antibodies: A Laboratory Manual*, Cold Spring Harbor Laboratory, 1988. When utilizing an entire protein, or a larger section of the
30 protein, antibodies may be raised by immunizing the production animal with the protein and a suitable adjuvant (e.g., Freund's, Freund's complete, oil-in-water emulsions, etc.) When a smaller peptide is utilized, it is advantageous to conjugate the peptide with a larger molecule to make an immunostimulatory conjugate. Commonly utilized conjugate proteins that are commercially available for such use include bovine serum albumin (BSA) and
35 keyhole limpet hemocyanin (KLH). In order to raise antibodies to particular epitopes, such as polymorphic residues, peptides derived from the full sequence may be utilized. The immunogen is injected into the animal host, preferably according to a predetermined

schedule incorporating one or more booster immunizations, and the animals are bled periodically. Polyclonal antibodies may then be purified from such antisera by, for example, affinity chromatography using the polypeptide coupled to a suitable solid support.

Alternatively, for monoclonal antibodies, hybridomas may be formed by
5 isolating the stimulated immune cells, such as those from the spleen of the inoculated animal. These cells are then fused to immortalized cells, such as myeloma cells or transformed cells, which are capable of replicating indefinitely in cell culture, thereby producing an immortal, immunoglobulin-secreting cell line. The immortal cell line utilized is preferably selected to be deficient in enzymes necessary for the utilization of certain
10 nutrients. Many such cell lines (such as myelomas) are known to those skilled in the art, and include, for example: thymidine kinase (TK) or hypoxanthine-guanine phosphoriboxyl transferase (HGPRT). These deficiencies allow selection for fused cells according to their ability to grow on, for example, hypoxanthine aminopterinthymidine medium (HAT).

Preferably, the immortal fusion partners utilized are derived from a line that
15 does not secrete immunoglobulin. The resulting fused cells, or hybridomas, are cultured under conditions that allow for the survival of fused, but not unfused, cells and the resulting colonies screened for the production of the desired monoclonal antibodies. Colonies producing such antibodies are cloned, expanded, and grown so as to produce large quantities of antibody, see Kohler and Milstein, 1975 Nature 256:495 (the disclosures of
20 which are hereby incorporated by reference).

Large quantities of monoclonal antibodies from the secreting hybridomas may then be produced by injecting the clones into the peritoneal cavity of mice and harvesting the ascites fluid therefrom. The mice, preferably primed with pristane, or some other tumor-promoter, and immunosuppressed chemically or by irradiation, may be any of
25 various suitable strains known to those in the art. The ascites fluid is harvested from the mice and the monoclonal antibody purified therefrom, for example, by CM Sepharose column or other chromatographic means. Alternatively, the hybridomas may be cultured *in vitro* or as suspension cultures. Batch, continuous culture, or other suitable culture processes may be utilized. Monoclonal antibodies are then recovered from the culture
30 medium or supernatant.

In addition, the antibodies or antigen binding fragments may be produced by genetic engineering. In this technique, as with the standard hybridoma procedure, antibody-producing cells are sensitized to the desired antigen or immunogen. The messenger RNA isolated from the immune spleen cells or hybridomas is used as a
35 template to make cDNA using PCR amplification. A library of vectors, each containing one heavy chain gene and one light chain gene retaining the initial antigen specificity, is produced by insertion of appropriate sections of the amplified immunoglobulin cDNA into

the expression vectors. A combinatorial library is constructed by combining the heavy chain gene library with the light chain gene library. This results in a library of clones which co-express a heavy and light chain (resembling the Fab fragment or antigen binding fragment of an antibody molecule). The vectors that carry these genes are co-transfected
5 into a host (e.g. bacteria, insect cells, mammalian cells, or other suitable protein production host cell.). When antibody gene synthesis is induced in the transfected host, the heavy and light chain proteins self-assemble to produce active antibodies that can be detected by screening with the antigen or immunogen.

Chimeric antibodies may be made by recombinant means by combining the
10 murine variable light and heavy chain regions (VK and VH), obtained from a murine (or other animal-derived) hybridoma clone, with the human constant light and heavy chain regions, in order to produce an antibody with predominantly human domains. The production of such chimeric antibodies is well known in the art, and may be achieved by standard means (as described, e.g., in U.S. Patent No. 5,624,659, incorporated fully herein
15 by reference). Humanized antibodies are engineered to contain even more human-like immunoglobulin domains, and incorporate only the complementarity-determining regions of the animal-derived antibody. This is accomplished by carefully examining the sequence of the hyper-variable loops of the variable regions of the monoclonal antibody, and fitting them to the structure of the human antibody chains. Although facially complex, the process
20 is straightforward in practice. See, e.g., U.S. Patent No. 6,187,287, incorporated fully herein by reference.

Alternatively, polyclonal or monoclonal antibodies may be produced from animals that have been genetically altered to produce human immunoglobulins. Techniques for generating such animals, and deriving antibodies therefrom, are described
25 in U.S. Patents No. 6,162,963 and 6,150,584, incorporated fully herein by reference.

Alternatively, single chain antibodies (Fv, as described below) can be produced from phage libraries containing human variable regions. See U.S. Patent No. 6,174,708. Intrathecal administration of single-chain immunotoxin, LMB-7 [B3(Fv)- PE38], has been shown to cure of carcinomatous meningitis in a rat model. *Proc Natl. Acad. Sci U*
30 *S A* 92, 2765-9, all of which are incorporated by reference fully herein.

In addition to entire immunoglobulins (or their recombinant counterparts), immunoglobulin fragments comprising the epitope binding site (e.g., Fab', F(ab')₂, or other fragments) are useful as antibody moieties in the present invention. Such antibody fragments may be generated from whole immunoglobulins by pepsin, papain, or other
35 protease cleavage. "Fragment," or minimal immunoglobulins may be designed utilizing recombinant immunoglobulin techniques. For instance "Fv" immunoglobulins for use in the present invention may be produced by linking a variable light chain region to a variable

heavy chain region via a peptide linker (e.g., poly-glycine or another sequence which does not form an alpha helix or beta sheet motif).

Fv fragments are heterodimers of the variable heavy chain domain (V_H) and the variable light chain domain (V_L). The heterodimers of heavy and light chain domains that occur in whole IgG, for example, are connected by a disulfide bond. Recombinant Fvs in which V_H and V_L are connected by a peptide linker are typically stable. These are single chain Fvs which have been found to retain specificity and affinity and have been shown to be useful for imaging tumors and to make recombinant immunotoxins for tumor therapy. However, researchers have found that some of the single chain Fvs have a reduced affinity for antigen and the peptide linker can interfere with binding. Improved Fv's have been also been made which comprise stabilizing disulfide bonds between the V_H and V_L regions, as described in U.S. Patent No. 6,147,203, incorporated fully herein by reference. Any of these minimal antibodies may be utilized in the present invention, and those which are humanized to avoid HAMA reactions are preferred for use in embodiments of the invention.

In addition, derivatized immunoglobulins with added chemical linkers, detectable moieties, such as fluorescent dyes, enzymes, substrates, chemiluminescent moieties and the like, or specific binding moieties, such as streptavidin, avidin, or biotin, and the like may be utilized in the methods and compositions of the present invention. For convenience, the term "antibody" or "antibody moiety" will be used throughout to generally refer to molecules which specifically bind to an epitope of the brain tumor protein targets, although the term will encompass all immunoglobulins, derivatives, fragments, recombinant or engineered immunoglobulins, and modified immunoglobulins, as described above.

Candidate antibodies can be tested for activity by any suitable standard means. As a first screen, the antibodies may be tested for binding against the immunogen. As a second screen, antibodies may be screened for cross-reactivity between alleles and between TIM family members, and tested for activity in inhibition of TIM function. For these screens, the candidate antibody may be labeled for detection. Antibodies that alter the biological activity of a TIM protein may be assayed in functional formats.

30

DIAGNOSIS

Diagnosis of asthma or atopy associated with Tim polymorphisms is performed by protein, DNA or RNA sequence and/or hybridization analysis of any convenient sample from a patient, e.g. biopsy material, blood sample, scrapings from cheek, etc. A nucleic acid sample from a patient having asthma that may be associated with *TIM*, is analyzed for the presence of a predisposing polymorphism in *TIM*. A typical patient genotype would have at least one predisposing mutation on at least one chromosome. The presence of a polymorphic *TIM* sequence that affects the activity or

expression of the gene product, and confers an increased susceptibility to asthma is considered a predisposing polymorphism. Individuals are screened by analyzing their DNA or mRNA for the presence of a predisposing polymorphism, as compared to an asthma neutral sequence. Specific sequences of interest include any polymorphism that leads to clinical bronchial hyperreactivity or is otherwise associated with asthma, including, but not limited to, insertions, substitutions and deletions in the coding region sequence, intron sequences that affect splicing, or promoter or enhancer sequences that affect the activity and expression of the protein. Examples of specific *TIM* polymorphisms are provided in the Examples.

Screening may also be based on the functional or antigenic characteristics of the protein. Immunoassays designed to detect predisposing polymorphisms in *TIM* proteins may be used in screening. Where many diverse mutations lead to a particular disease phenotype, functional protein assays have proven to be effective screening tools.

Biochemical studies may be performed to determine whether a candidate sequence polymorphism in the *TIM* coding region or control regions is associated with disease. For example, a change in the promoter or enhancer sequence that affects expression of *TIM* may result in predisposition to asthma. Expression levels of a candidate variant allele are compared to expression levels of the normal allele by various methods known in the art. Methods for determining promoter or enhancer strength include quantitation of the expressed natural protein; insertion of the variant control element into a vector with a reporter gene such as β -galactosidase, luciferase, chloramphenicol acetyltransferase, *etc.* that provides for convenient quantitation; and the like. The activity of the encoded *TIM* protein may be determined by comparison with the wild-type protein.

A number of methods are available for analyzing nucleic acids for the presence of a specific sequence. Where large amounts of DNA are available, genomic DNA is used directly. Alternatively, the region of interest is cloned into a suitable vector and grown in sufficient quantity for analysis. Cells that express *TIM* genes, such as trachea cells, may be used as a source of mRNA, which may be assayed directly or reverse transcribed into cDNA for analysis. The nucleic acid may be amplified by conventional techniques, such as the polymerase chain reaction (PCR), to provide sufficient amounts for analysis. The use of the polymerase chain reaction is described in Saiki, *et al.* (1985) Science **239**:487, and a review of current techniques may be found in Sambrook, *et al.* Molecular Cloning: A Laboratory Manual, CSH Press 1989, pp.14.2-14.33. Amplification may also be used to determine whether a polymorphism is present, by using a primer that is specific for the polymorphism. Alternatively, various methods are known in the art that utilize oligonucleotide ligation as a means of detecting polymorphisms, for examples see Riley *et al.* (1990) N.A.R. **18**:2887-2890; and Delahunty *et al.* (1996) Am. J. Hum. Genet.

58:1239-1246.

A detectable label may be included in an amplification reaction. Suitable labels include fluorochromes, e.g. fluorescein isothiocyanate (FITC), rhodamine, Texas Red, phycoerythrin, allophycocyanin, 6-carboxyfluorescein (6-FAM), 2',7'-dimethoxy-4',5'-
5 dichloro-6-carboxyfluorescein (JOE), 6-carboxy-X-rhodamine (ROX), 6-carboxy-2',4',7',4,7-hexachlorofluorescein (HEX), 5-carboxyfluorescein (5-FAM) or N,N,N',N'-tetramethyl-6-carboxyrhodamine (TAMRA), radioactive labels, e.g. ^{32}P , ^{35}S , ^3H ; *etc.* The label may be a two stage system, where the amplified DNA is conjugated to biotin, haptens, *etc.* having a high affinity binding partner, e.g. avidin, specific antibodies, *etc.*, where the binding partner
10 is conjugated to a detectable label. The label may be conjugated to one or both of the primers. Alternatively, the pool of nucleotides used in the amplification is labeled, so as to incorporate the label into the amplification product.

The sample nucleic acid, e.g. amplified or cloned fragment, is analyzed by one of a number of methods known in the art. The nucleic acid may be sequenced by
15 dideoxy or other methods, and the sequence of bases compared to a neutral *TIM* sequence. Hybridization with the variant sequence may also be used to determine its presence, by Southern blots, dot blots, *etc.* The hybridization pattern of a control and variant sequence to an array of oligonucleotide probes immobilised on a solid support, as described in US 5,445,934, or in WO95/35505, may also be used as a means of detecting
20 the presence of variant sequences. Single strand conformational polymorphism (SSCP) analysis, denaturing gradient gel electrophoresis (DGGE), mismatch cleavage detection, and heteroduplex analysis in gel matrices are used to detect conformational changes created by DNA sequence variation as alterations in electrophoretic mobility. Alternatively, where a polymorphism creates or destroys a recognition site for a restriction endonuclease
25 (restriction fragment length polymorphism, RFLP), the sample is digested with that endonuclease, and the products size fractionated to determine whether the fragment was digested. Fractionation is performed by gel or capillary electrophoresis, particularly acrylamide or agarose gels.

The hybridization pattern of a control and variant sequence to an array of
30 oligonucleotide probes immobilised on a solid support, as described in US 5,445,934, or in WO95/35505, may be used as a means of detecting the presence of variant sequences. In one embodiment of the invention, an array of oligonucleotides are provided, where discrete positions on the array are complementary to at least a portion of mRNA or genomic DNA of the *TIM* locus. Such an array may comprise a series of oligonucleotides, each of which can
35 specifically hybridize to a nucleic acid, e.g. mRNA, cDNA, genomic DNA, *etc.* from the *TIM* locus.

Antibodies specific for TIM polymorphisms may be used in screening

immunoassays. A reduction or increase in neutral TIM and/or presence of asthma associated polymorphisms is indicative that asthma is TIM-associated. A sample is taken from a patient suspected of having TIM-associated asthma. Samples, as used herein, include biological fluids such as tracheal lavage, blood, cerebrospinal fluid, tears, saliva, lymph, dialysis fluid and the like; organ or tissue culture derived fluids; and fluids extracted from physiological tissues. Also included in the term are derivatives and fractions of such fluids. Biopsy samples are of particular interest, *e.g.* trachea scrapings, *etc.* The number of cells in a sample will generally be at least about 10^3 , usually at least 10^4 more usually at least about 10^5 . The cells may be dissociated, in the case of solid tissues, or tissue sections may be analyzed. Alternatively a lysate of the cells may be prepared.

Diagnosis may be performed by a number of methods. The different methods all determine the absence or presence or altered amounts of normal or abnormal TIM in patient cells suspected of having a predisposing polymorphism in TIM. For example, detection may utilize staining of cells or histological sections, performed in accordance with conventional methods. The antibodies of interest are added to the cell sample, and incubated for a period of time sufficient to allow binding to the epitope, usually at least about 10 minutes. The antibody may be labeled with radioisotopes, enzymes, fluorescers, chemiluminescers, or other labels for direct detection. Alternatively, a second stage antibody or reagent is used to amplify the signal. Such reagents are well known in the art. For example, the primary antibody may be conjugated to biotin, with horseradish peroxidase-conjugated avidin added as a second stage reagent. Final detection uses a substrate that undergoes a color change in the presence of the peroxidase. The absence or presence of antibody binding may be determined by various methods, including flow cytometry of dissociated cells, microscopy, radiography, scintillation counting, *etc.*

An alternative method for diagnosis depends on the *in vitro* detection of binding between antibodies and TIM in a lysate. Measuring the concentration of TIM binding in a sample or fraction thereof may be accomplished by a variety of specific assays. A conventional sandwich type assay may be used. For example, a sandwich assay may first attach TIM-specific antibodies to an insoluble surface or support. The particular manner of binding is not crucial so long as it is compatible with the reagents and overall methods of the invention. They may be bound to the plates covalently or non-covalently, preferably non-covalently.

Other immunoassays are known in the art and may find use as diagnostics. Ouchterlony plates provide a simple determination of antibody binding. Western blots may be performed on protein gels or protein spots on filters, using a detection system specific for TIM as desired, conveniently using a labeling method as described for the sandwich assay.

The *TIM* genes are useful for analysis of TIM expression, *e.g.* in determining developmental and tissue specific patterns of expression, and for modulating expression *in vitro* and *in vivo*. Vectors useful for introduction of the gene include plasmids and viral
5 vectors. Of particular interest are retroviral-based vectors, *e.g.* Moloney murine leukemia virus and modified human immunodeficiency virus; adenovirus vectors, *etc.* that are maintained transiently or stably in mammalian cells. A wide variety of vectors can be employed for transfection and/or integration of the gene into the genome of the cells. Alternatively, micro-injection may be employed, fusion, or the like for introduction of genes
10 into a suitable host cell. See, for example, Dhawan *et al.* (1991) Science **254**:1509-1512 and Smith *et al.* (1990) Molecular and Cellular Biology 3268-3271.

The expression vector will have a transcriptional initiation region oriented to produce functional mRNA. The native transcriptional initiation region or an exogenous transcriptional initiation region may be employed. The promoter may be introduced by
15 recombinant methods *in vitro*, or as the result of homologous integration of the sequence into a chromosome. Many strong promoters are known in the art, including the β -actin promoter, SV40 early and late promoters, human cytomegalovirus promoter, retroviral LTRs, methallothionein responsive element (MRE), tetracycline-inducible promoter constructs, *etc.*

20 Expression vectors generally have convenient restriction sites located near the promoter sequence to provide for the insertion of nucleic acid sequences. Transcription cassettes may be prepared comprising a transcription initiation region, the target gene or fragment thereof, and a transcriptional termination region. The transcription cassettes may be introduced into a variety of vectors, *e.g.* plasmid; retrovirus, *e.g.* lentivirus; adenovirus;
25 and the like, where the vectors are able to transiently or stably be maintained in the cells, usually for a period of at least about one day, more usually for a period of at least about several days to several weeks.

Antisense molecules are used to down-regulate expression of *TIM* in cells. The anti-sense reagent may be antisense oligonucleotides (ODN), particularly synthetic
30 ODN having chemical modifications from native nucleic acids, or nucleic acid constructs that express such anti-sense molecules as RNA. The antisense sequence is complementary to the mRNA of the targeted gene, and inhibits expression of the targeted gene products. Antisense molecules inhibit gene expression through various mechanisms, *e.g.* by reducing the amount of mRNA available for translation, through activation of RNase
35 H, or steric hindrance. One or a combination of antisense molecules may be administered, where a combination may comprise multiple different sequences.

Antisense molecules may be produced by expression of all or a part of the

target gene sequence in an appropriate vector, where the transcriptional initiation is oriented such that an antisense strand is produced as an RNA molecule. Alternatively, the antisense molecule is a synthetic oligonucleotide. Antisense oligonucleotides will generally be at least about 7, usually at least about 12, more usually at least about 20 nucleotides in length, and not more than about 500, usually not more than about 50, more usually not more than about 35 nucleotides in length, where the length is governed by efficiency of inhibition, specificity, including absence of cross-reactivity, and the like. It has been found that short oligonucleotides, of from 7 to 8 bases in length, can be strong and selective inhibitors of gene expression (see Wagner *et al.* (1996) Nature Biotechnology 14:840-844).

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TRANSGENIC ANIMALS

The subject nucleic acids can be used to generate genetically modified non-human animals or site specific gene modifications in cell lines. The term "transgenic" is intended to encompass genetically modified animals having a deletion or other knock-out of *TIM* gene activity, having an exogenous *TIM* gene that is stably transmitted in the host cells, or having an exogenous *TIM* promoter operably linked to a reporter gene. Transgenic animals may be made through homologous recombination, where the *TIM* locus is altered. Alternatively, a nucleic acid construct is randomly integrated into the genome. Vectors for stable integration include plasmids, retroviruses and other animal viruses, YACs, and the like. Of interest are transgenic mammals, *e.g.* cows, pigs, goats, horses, *etc.*, and particularly rodents, *e.g.* rats, mice, *etc.*

A "knock-out" animal is genetically manipulated to substantially reduce, or eliminate endogenous *TIM* function. Different approaches may be used to achieve the "knock-out". A chromosomal deletion of all or part of the native *TIM* homolog may be induced. Deletions of the non-coding regions, particularly the promoter region, 3' regulatory sequences, enhancers, or deletions of gene that activate expression of *TIM* genes. A functional knock-out may also be achieved by the introduction of an anti-sense construct that blocks expression of the native *TIM* genes (for example, see Li and Cohen (1996) *Cell* 85:319-329).

Transgenic animals may be made having exogenous *TIM* genes. The exogenous gene is usually either from a different species than the animal host, or is otherwise altered in its coding or non-coding sequence. The introduced gene may be a wild-type gene, naturally occurring polymorphism, or a genetically manipulated sequence, for example those previously described with deletions, substitutions or insertions in the coding or non-coding regions. The introduced sequence may encode an *TIM* polypeptide, or may utilize the *TIM* promoter operably linked to a reporter gene. Where the introduced gene is a coding sequence, it usually operably linked to a promoter, which may be

constitutive or inducible, and other regulatory sequences required for expression in the host animal.

Specific constructs of interest, but are not limited to, include anti-sense *TIM*, which will block *TIM* expression, expression of dominant negative *TIM* mutations, and
5 over-expression of a *TIM* gene. A detectable marker, such as *lac Z* may be introduced into the *TIM* locus, where upregulation of *TIM* expression will result in an easily detected change in phenotype.

The modified cells or animals are useful in the study of *TIM* function and regulation. Animals may be used in functional studies, drug screening, *etc.*, *e.g.* to
10 determine the effect of a candidate drug on asthma. A series of small deletions and/or substitutions may be made in the *TIM* gene to determine the role of different exons in DNA binding, transcriptional regulation, *etc.* By providing expression of *TIM* protein in cells in which it is otherwise not normally produced, one can induce changes in cell behavior. These animals are also useful for exploring models of inheritance of asthma, *e.g.* dominant
15 *v.* recessive; relative effects of different alleles and synergistic effects between *TIM* and other asthma genes elsewhere in the genome.

DNA constructs for homologous recombination will comprise at least a portion of the *TIM* gene with the desired genetic modification, and will include regions of homology to the target locus. DNA constructs for random integration need not include
20 regions of homology to mediate recombination. Conveniently, markers for positive and negative selection are included. Methods for generating cells having targeted gene modifications through homologous recombination are known in the art. For various techniques for transfecting mammalian cells, see Keown *et al.* (1990) Methods in Enzymology **185**:527-537.

25 Drug screening may be performed in combination with the subject animal models. Many mammalian genes have homologs in yeast and lower animals. The study of such homologs' physiological role and interactions with other proteins can facilitate understanding of biological function. In addition to model systems based on genetic complementation, yeast has been shown to be a powerful tool for studying protein-protein
30 interactions through the two hybrid system described in Chien *et al.* (1991) P.N.A.S. **88**:9578-9582. Two-hybrid system analysis is of particular interest for exploring transcriptional activation by *TIM* proteins.

COMPOUND SCREENING

35 One can identify ligands or substrates that bind to, modulate or mimic the action of *TIM*. Areas of investigation are the development of treatments for immune disorders, asthma, cancer, ischemia-reperfusion injury, and other diseases that are

associated with cellular responses to stress. Drug screening identifies agents that provide an inhibition, replacement, or enhancement for TIM function in affected cells. For example, agents that reverse or inhibit TIM function may reduce bronchial reactivity in asthma by reducing levels of Th2 cytokines, and TIM inhibitors may enhance tumor sensitivity to cancer therapy, by potentiating the effects of radiation and chemotherapeutic treatments that induce apoptosis. Of particular interest are screening assays for agents that have a low toxicity for human cells. A wide variety of assays may be used for this purpose, including labeled *in vitro* protein-protein binding assays, protein-DNA binding assays, electrophoretic mobility shift assays, immunoassays for protein binding, and the like. The purified protein may also be used for determination of three-dimensional crystal structure, which can be used for modeling intermolecular interactions, transcriptional regulation, *etc.*

The term "agent" as used herein describes any molecule, *e.g.* protein or pharmaceutical, with the capability of altering or mimicking the physiological function of TIM, such as a signal tyrosine kinase inhibitor, or a peptide inhibitor of an integrin binding site. Generally a plurality of assay mixtures are run in parallel with different agent concentrations to obtain a differential response to the various concentrations. Typically, one of these concentrations serves as a negative control, *i.e.* at zero concentration or below the level of detection.

Candidate agents encompass numerous chemical classes, though typically they are organic molecules, preferably small organic compounds having a molecular weight of more than 50 and less than about 2,500 daltons. Candidate agents comprise functional groups necessary for structural interaction with proteins, particularly hydrogen bonding, and typically include at least an amine, carbonyl, hydroxyl or carboxyl group, preferably at least two of the functional chemical groups. The candidate agents often comprise cyclical carbon or heterocyclic structures and/or aromatic or polyaromatic structures substituted with one or more of the above functional groups. Candidate agents are also found among biomolecules including, but not limited to: peptides, saccharides, fatty acids, steroids, purines, pyrimidines, derivatives, structural analogs or combinations thereof.

Candidate agents are obtained from a wide variety of sources including libraries of synthetic or natural compounds. For example, numerous means are available for random and directed synthesis of a wide variety of organic compounds and biomolecules, including expression of randomized oligonucleotides and oligopeptides. Alternatively, libraries of natural compounds in the form of bacterial, fungal, plant and animal extracts are available or readily produced. Additionally, natural or synthetically produced libraries and compounds are readily modified through conventional chemical, physical and biochemical means, and may be used to produce combinatorial libraries. Known pharmacological agents may be subjected to directed or random chemical

modifications, such as acylation, alkylation, esterification, amidification, *etc.* to produce structural analogs.

Where the screening assay is a binding assay, one or more of the molecules may be joined to a label, where the label can directly or indirectly provide a detectable
5 signal. Various labels include radioisotopes, fluorescers, chemilumescers, enzymes, specific binding molecules, particles, *e.g.* magnetic particles, and the like. Specific binding molecules include pairs, such as biotin and streptavidin, digoxin and antidigoxin *etc.* For the specific binding members, the complementary member would normally be labeled with a molecule that provides for detection, in accordance with known procedures.

10 A variety of other reagents may be included in the screening assay. These include reagents like salts, neutral proteins, *e.g.* albumin, detergents, *etc.* that are used to facilitate optimal protein-protein binding and/or reduce non-specific or background interactions. Reagents that improve the efficiency of the assay, such as protease inhibitors, nuclease inhibitors, anti-microbial agents, *etc.* may be used. The mixture of
15 components are added in any order that provides for the requisite binding. Incubations are performed at any suitable temperature, typically between 4 and 40°C. Incubation periods are selected for optimum activity, but may also be optimized to facilitate rapid high-throughput screening. Typically between 0.1 and 1 hours will be sufficient.

Other assays of interest detect agents that mimic TIM function. For
20 example, candidate agents are added to a cell that lacks functional TIM, and screened for the ability to reproduce TIM in a functional assay.

THERAPEUTIC METHODS

Agents that modulate activity of TIM genes or proteins provide a point of
25 therapeutic or prophylactic intervention, particularly agents that inhibit or upregulate activity of the polypeptide, or expression of the gene. Numerous agents are useful in modulating this activity, including agents that directly modulate expression, *e.g.* expression vectors, antisense specific for the targeted polypeptide; and agents that act on the protein, *e.g.* specific antibodies and analogs thereof, small organic molecules that block catalytic
30 activity, *etc.*

Methods can be designed to selectively deliver nucleic acids to certain cells. Examples of such cells include T cells, *etc.* Certain treatment methods are designed to selectively express an expression vector to cells of interest. One technique for achieving selective expression in nerve cells is to operably link the coding sequence to a promoter
35 that is primarily active in immune system cells, *e.g.* IL-2 promoter, T cell antigen receptor promoter, and the like. Alternatively, or in addition, the nucleic acid can be administered with an agent that targets the nucleic acid to the cells of interest. For instance, the nucleic

acid can be administered with an antibody that specifically binds to a cell-surface antigen. When liposomes are utilized, substrates that bind to a cell-surface membrane protein associated with endocytosis can be attached to the liposome to target the liposome to nerve cells and to facilitate uptake.

5 Antisense molecules can be used to down-regulate expression in cells. The antisense reagent may be antisense oligonucleotides (ODN), particularly synthetic ODN having chemical modifications from native nucleic acids, or nucleic acid constructs that express such antisense molecules as RNA. The antisense sequence is complementary to the mRNA of the targeted gene, and inhibits expression of the targeted gene products.

10 Antisense molecules inhibit gene expression through various mechanisms, e.g. by reducing the amount of mRNA available for translation, through activation of RNase H, or steric hindrance. One or a combination of antisense molecules may be administered, where a combination may comprise multiple different sequences.

 Antisense molecules may be produced by expression of all or a part of the

15 target gene sequence in an appropriate vector, where the transcriptional initiation is oriented such that an antisense strand is produced as an RNA molecule. Alternatively, the antisense molecule is a synthetic oligonucleotide. Antisense oligonucleotides will generally be at least about 7, usually at least about 12, more usually at least about 20 nucleotides in length, and not more than about 500, usually not more than about 50, more usually not

20 more than about 35 nucleotides in length, where the length is governed by efficiency of inhibition, specificity, including absence of cross-reactivity, and the like. It has been found that short oligonucleotides, of from 7 to 8 bases in length, can be strong and selective inhibitors of gene expression (see Wagner *et al.* (1996) Nature Biotechnology 14:840-844).

 A specific region or regions of the endogenous sense strand mRNA

25 sequence is chosen to be complemented by the antisense sequence. Selection of a specific sequence for the oligonucleotide may use an empirical method, where several candidate sequences are assayed for inhibition of expression of the target gene *in vitro* or in an animal model. A combination of sequences may also be used, where several regions of the mRNA sequence are selected for antisense complementation.

30 Antisense oligonucleotides may be chemically synthesized by methods known in the art (see Wagner *et al.* (1993) *supra.* and Milligan *et al.*, *supra.*) Preferred oligonucleotides are chemically modified from the native phosphodiester structure, in order to increase their intracellular stability and binding affinity. A number of such modifications have been described in the literature, which alter the chemistry of the backbone, sugars or

35 heterocyclic bases.

 Among useful changes in the backbone chemistry are phosphorothioates; phosphorodithioates, where both of the non-bridging oxygens are substituted with sulfur;

phosphoroamidites; alkyl phosphotriesters and boranophosphates. Achiral phosphate derivatives include 3'-O'-5'-S-phosphorothioate, 3'-S-5'-O-phosphorothioate, 3'-CH₂-5'-O-phosphonate and 3'-NH-5'-O-phosphoroamidate. Peptide nucleic acids replace the entire ribose phosphodiester backbone with a peptide linkage. Sugar modifications are also used to enhance stability and affinity. The alpha.-anomer of deoxyribose may be used, where the base is inverted with respect to the natural .beta.-anomer. The 2'-OH of the ribose sugar may be altered to form 2'-O-methyl or 2'-O-allyl sugars, which provides resistance to degradation without comprising affinity. Modification of the heterocyclic bases must maintain proper base pairing. Some useful substitutions include deoxyuridine for deoxythymidine; 5-methyl-2'-deoxycytidine and 5-bromo-2'-deoxycytidine for deoxycytidine. 5-propynyl-2'-deoxyuridine and 5-propynyl-2'-deoxycytidine have been shown to increase affinity and biological activity when substituted for deoxythymidine and deoxycytidine, respectively.

The compounds having the desired pharmacological activity may be administered in a physiologically acceptable carrier to a host for treatment of asthma attributable to a defect in TIM function. The compounds may also be used to enhance TIM function. The therapeutic agents may be administered in a variety of ways, orally, topically, parenterally *e.g.* subcutaneously, intraperitoneally, by viral infection, intravascularly, *etc.* Inhaled treatments are of particular interest. Depending upon the manner of introduction, the compounds may be formulated in a variety of ways. The concentration of therapeutically active compound in the formulation may vary from about 0.1-100 wt.%.

The pharmaceutical compositions can be prepared in various forms, such as granules, tablets, pills, suppositories, capsules, suspensions, salves, lotions and the like. Pharmaceutical grade organic or inorganic carriers and/or diluents suitable for oral and topical use can be used to make up compositions containing the therapeutically-active compounds. Diluents known to the art include aqueous media, vegetable and animal oils and fats. Stabilizing agents, wetting and emulsifying agents, salts for varying the osmotic pressure or buffers for securing an adequate pH value, and skin penetration enhancers can be used as auxiliary agents.

30

It is to be understood that this invention is not limited to the particular methodology, protocols, cell lines, animal species or genera, and reagents described, as such may vary. It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to limit the scope of the present invention which will be limited only by the appended claims.

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As used herein the singular forms "a", "and", and "the" include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to "a

cell" includes a plurality of such cells and reference to "the array" includes reference to one or more arrays and equivalents thereof known to those skilled in the art, and so forth. All technical and scientific terms used herein have the same meaning as commonly understood to one of ordinary skill in the art to which this invention belongs unless clearly
5 indicated otherwise.

All publications mentioned herein are incorporated herein by reference for the purpose of describing and disclosing, for example, the cell lines, constructs, and methodologies that are described in the publications which might be used in connection with the presently described invention. The publications discussed above and throughout
10 the text are provided solely for their disclosure prior to the filing date of the present application. Nothing herein is to be construed as an admission that the inventors are not entitled to antedate such disclosure by virtue of prior invention.

The following examples are put forth so as to provide those of ordinary skill in the art with a complete disclosure and description of how to make and use the subject
15 invention, and are not intended to limit the scope of what is regarded as the invention. Efforts have been made to ensure accuracy with respect to the numbers used (*e.g.* amounts, temperature, concentrations, *etc.*) but some experimental errors and deviations should be allowed for. Unless otherwise indicated, parts are parts by weight, molecular weight is average molecular weight, temperature is in degrees centigrade; and pressure is
20 at or near atmospheric.

EXPERIMENTAL

To analyze the human 5q23-35 region for asthma susceptibility genes, we utilized a mouse model, which offers several potential advantages. Environmental variation
25 can be controlled, multiple phenotypes can be tested simultaneously, and inbred strains can be sensitized with allergen to develop airway hyperreactivity (AHR), a cardinal feature of human asthma. We utilized congenic inbred mouse strains that differed only by a small chromosomal region homologous to human chromosome 5q, thereby allowing this region to be studied in the absence of genetic variation outside the region. Positional cloning
30 revealed a novel gene family encoding T cell membrane proteins (*Tim*), TIM-1, TIM-2, TIM-3, TIM-4, TIM-5, TIM-6, and TIM-7, in which major sequence variants of TIM-1, TIM-3, and TIM-4, cosegregate completely with *Tapr*.

IL-4 production and airway hyperreactivity are reduced in HBA mice. We
35 examined congenic mice produced on a BALB/c genomic background with discrete genomic intervals inherited from individual DBA/2 chromosomes. BALB/c mice develop Th2 biased, atopy-resembling immune responses with enhanced AHR, while DBA/2 mice

develop reduced IL-4 responses that protect against the development of AHR. By screening several of these congenic strains for reduced Th2 responsiveness, we identified one congenic line, C.D2 Es-Hba (HBA), which contained a segment of chromosome 11 inherited from DBA/2 mice, homologous to human 5q23-35. Fig. 1a shows that lymph node
5 cells from immunized control BALB/c mice, as expected, produced high levels of IL-4, confirming the proclivity of BALB/c mice to develop Th2-biased immune responses. In contrast, lymph node cells from HBA mice produced significantly lower levels of IL-4, similar to that observed in DBA/2 mice. In addition, HBA mice produced significantly less IL-13 and IL-10, and somewhat lower levels of IL-5 compared to BALB/c mice, whereas
10 production of IFN- γ was increased, as shown in Fig. 1b. These results indicated that the DBA/2-derived region of HBA chromosome 11, which has large regions of conserved synteny with human 5q23-35, contains a gene that reduces antigen-specific IL-4, IL-13, and IL-10 production, enhances IFN- γ production, and converts the BALB/c cytokine phenotype into a DBA/2 cytokine phenotype.

15 The HBA mice were examined for the capacity to develop antigen-induced airway hyperreactivity (AHR), which is associated with Th2-biased immune responses. Upon sensitization and challenge with allergen, control BALB/c mice developed high AHR, whereas similarly immunized HBA congenic mice, like DBA/2 mice, expressed normal airway reactivity in response to methacholine (Fig. 1c). Collectively, these results strongly
20 suggested that genetic variation in a single locus on chromosome 11 regulated both Th2 cytokine production and AHR; therefore, we tentatively refer to the relevant genetic determinant(s) in HBA mice as a single locus, *T cell and Airway Phenotype Regulator (Tapr)*.

We also examined (BALB/c x HBA) F1 mice, which like the BALB/c mice,
25 produced high levels of IL-4, IL-13, and IL-10 (Fig. 1a and 1b) and developed elevated antigen-induced AHR (Fig. 1c). These results indicate that a DBA/2 allele on chromosome 11, in isolation of other genes that regulate IL-4 synthesis, reduced IL-4 production and AHR in a recessive manner. In contrast, (BALB/c x DBA/2) F1 mice produced low levels of IL-4 and had normal airway responsiveness on immunization (Fig. 1), indicating that loci
30 from other regions of the DBA genome also modulated IL-4 production and antigen-induced AHR, and that the DBA/2 alleles, in aggregate, functioned in a dominant manner to limit IL-4 production and AHR. These results underscore the multigenic, complex nature of atopic traits and demonstrate the potential advantages of using a congenic strain to isolate and characterize a single locus without interference from multiple epistatic genes that also
35 influence the asthmatic phenotype.

Genetic Mapping of Tapr, the locus which controls AHR and IL-4 responsiveness. Previously, the congenic region in the HBA mice was delineated with 36

genome-wide markers, including two chromosome 11 markers, hemoglobin- $\alpha 2$ (*hba- $\alpha 2$*) and esterase-3 (*es-3*) loci. The HBA genome, outside of chromosome 11, was inherited from BALB/c. A more precise analysis with 25 simple sequence length polymorphism (SSLP) markers known to be polymorphic between DBA/2 and BALB/c mice showed that

5 HBA mice inherited two segments of chromosome 11 from DBA/2 (Fig. 2, left column). The proximal region contained a 20 cM segment with homology to chromosome 5q23-35, which afforded the possibility that a genetic locus implicated in human asthma linkage studies could be identified in a mouse model of asthma.

To map at higher resolution the T_H2-AHR controlling locus, *Tapr*, (BALB/c x

10 HBA) F1 mice were backcrossed to HBA mice to produce N2 animals. With this backcross approach, the set of alleles contributed by the HBA parent is pre-determined, and the set of alleles contributed by the F1 parent can be assessed by genotyping. Thus, recombination events that produce informative haplotypes within the congenic region can be detected in the N2 mice and used to assess the linkage of *Tapr* to loci in the congenic interval.

15 Because of the recessive nature of *Tapr*, we tested N2 mice from these backcrosses to identify the minimum homozygous region of HBA-derived genes sufficient to confer the HBA *Tapr* phenotype. More than 2,000 N2 animals were generated and genotyped. Using SSLP markers, we selected those N2 mice with informative recombination events, and the N2 mice were phenotyped for the capacity to produce IL-4 in response to immunization with

20 keyhole limpet hemocyanin (KLH). In this primary analysis, we determined that the relevant locus resided within the proximal congenic region, between *D11Mit135* and *D11Mit260*. In order to map *Tapr* at higher resolution, 22 additional markers were identified and utilized to provide 0.1-1 cM resolution in the area of interest.

To accurately compare the results of IL-4 cytokine analyses performed over several

25 months time, an IL-4 index for each experiment was generated for each N2 mouse, $\left(\frac{B - x}{B - H} \right)$, where B=IL-4 production by cells from BALB/c mice, H=IL-4 production by cells from HBA mice, and x=IL-4 production by cells from the N2 mouse being assessed. High concentrations of IL-4 (BALB/c-like) are represented by index values near 0, and low concentrations of IL-4 (HBA-like) are represented by index values near 1.0. The "B and "H" values were established with 3-5 control mice for each group of 3-6 N2 mice carrying

30 informative recombinations that we tested. The index values fall within a bimodal distribution (Fig. 3a), in which the phenotype index associated with N2 mice that had nonrecombinant HBA genotypes was significantly higher ($P < 0.0001$, in a paired Student's t-test) than the phenotype index associated with N2 mice that had nonrecombinant (BALB/c x

35 HBA)F1 genotypes.

For the mice with unique genotypes, we used several methods to ensure the

adequacy of single measurements of cytokine production and AHR, since this is critical in linkage analysis. First, at the same time that we tested each of the N2 mice carrying recombinations of interest, we also tested “non-recombinant” siblings of each “recombinant N2” that were strictly HBA or F1 (BALB x HBA) in genotype. Furthermore, we bred additional N3 mice by crossing some of the N2 mice carrying recombinations of interest back to HBA mice, in order to have more individual mice with that particular N2 genotype. All values were the average of the values for the individual mice tested with a given genotype. In this way, we are confident of the measures of cytokine production and AHR, and that we have overcome assay variations due to variables inherent in biological systems.

Because the IL-4 values associated with the N2 mice that inherited recombinant haplotypes segregated in a bimodal distribution (Fig. 3a), were able to demonstrate that the genetic locus that controls high IL-4 responses is located between markers *D11Mit271* and *D11Mit22* (Fig. 3b). Moreover, high levels of IL-4 production were observed in all mice with a BALB/c allele present at *Kim1sscp*, and low levels of IL-4 production were observed in all mice with homozygous HBA genotypes at *Kim1sscp*. Thus, *Tapr* was nonrecombinant with *Kim1sscp*, an intronic marker within a mouse homologue of *Rattus norvegicus* Kidney Injury Molecule (*Kim-1*). In contrast, *Tapr* segregated from all other markers with at least one recombination. The fact that *Tapr* and *Kim1sscp* segregated together, indicated that the *Tapr* locus is located very close to or is indistinguishable from *Kim1sscp*. Based on the frequency recombinant haplotypes between *D11Mit271* and *D11Mit22*, we calculate a recombination frequency, 0.0039, which indicates that the *Tapr* locus maps to a small, 0.3-0.5 cM, region. We also calculated a recombination frequency of 0.08 between *Tapr* and IL-4. Therefore, *Tapr* is located 5-10 cM away from the IL-4 cytokine cluster but is within the a region of the mouse genome that has highly conserved synteny with the 5q23-35 region that has been linked to human atopy and asthma.

Using an analogous approach, we examined the segregation of allergen-induced AHR phenotypes in mice with informative recombinant haplotypes. With indexed AHR values, N2 mice clearly exhibit parental phenotypes, which produced a bimodal distribution in a histogram of AHR index values in a group of sensitized N2 mice (Fig. 3c). By analyzing the segregation of AHR phenotypes associated with more than 1,000 N2 mice, we demonstrated that the genetic locus which controls AHR responses is also located between markers *D11Mit271* and *D11Mit22* (Fig. 3d) and that the AHR phenotype was nonrecombinant with *Kim1sscp*. Thus, we demonstrate that both IL-4 responsiveness and AHR cosegregate with the *Tapr* locus, which suggests that the same locus regulates both IL-4 expression and AHR (Fig. 3).

These findings further demonstrate that the *Tapr* locus is more than 5 cM centromeric to the IL-4 cytokine cluster and the cytokine genes in the cluster previously thought to be 'candidate' atopy or asthma susceptibility genes. Our mapping results also establish that *Tapr* is genetically separable from both the IL-12p40 gene and the region of mouse chromosome 11 that includes the T_H1-IL12 regulatory locus, *Tpm*.

Mouse and human homologues anchor Tapr to human 5q33. In order to construct a composite map around the *Tapr* locus, we integrated available information from the Mouse Genome Database (MGD) linkage, backcross, and radiation hybrid maps and identified a region of conserved synteny in maps of the human genome. Current radiation hybrid maps place the markers that are near *D11Mit271* and *D11Mit22*, including several expressed sequence tags (ESTs) that have extensive homology to known genes or unigene clusters, onto a physical map of the mouse genome. We further examined these markers and their associated ESTs for previously unidentified similarity to known gene clusters. We assembled these markers onto a scaffold for comparison to the human genome. Using this approach, we found significant similarity between particular radiation hybrid markers and the following human genes: *KIAA0171*, *Adam-19*, *Sox-30*, *Pir-121*, *Crsp9* (*Crsp33*), and *hHAVcr-1* (*hHAVcr-1*). Fig. 4 demonstrates that once we anchored these genes to a physical map of the mouse genome between our flanking markers, we were able to locate those genes in the Human Genome Browser.

The high degree of conservation between the mouse and human genomes in this region indicates linkage of the *Tapr* locus to human 5q33.2. As shown Fig. 4, we identified all known genes and ESTs in this region of the human map. Genes of particular interest near human *hHAV-cr* and the mouse homologue of *Kim-1*, include IL-2 inducible T cell kinase (*Itk*) and a coregulator of the SP-1 transcription factor (*Crsp9*), both known to be involved in T cell differentiation. We sequenced coding regions from these candidate genes and found no polymorphisms in either ITK or CRSP-9.

Localization of a Family of Novel T cell Surface Proteins to the Tapr Region. Because the mouse homolog of rat *Kim1* is located within the 0.4 cM region and is tightly linked with *Tapr*, we examined publicly available databases and found clusters of ESTs with some sequence similarity that provided only partial coverage and contained large segments of variation. The closest human homolog of *Kim-1* is the human hepatitis A virus cellular receptor, *hHAV-cr*, and tBLAST searches of the human genome suggested that two additional homologs of *Kim-1*, perhaps members of a gene family, also are located on human chromosome 5 and mouse chromosome 11.

Using cDNA from conA-stimulated splenocytes, we identified and cloned two

mouse orthologues of *Kim1*, which we term *Tim1* and *Tim2*, that map to the *Tapr* region, as shown in Fig. 5A. TIM-3 is a third, more distantly related, orthologue of KIM-1.

All three members of this gene family are expressed by stimulated T cells, and all three forms map to the *Tapr* region of mouse chromosome 11/ human chromosome 5 where they encode cell surface glycoproteins with common structural motifs, including an immunoglobulin (Ig) domain, mucin domain, and intracellular tail with phosphorylation sites. Because the cellular functions of these proteins is unknown, we refer to the genes as members of a *T cell, Immunoglobulin domain, Mucin domain (Tim)* gene family. Mouse *Tim1* is the mouse homologue of rat *Kim1* and the *HAVcr-1* identified in African green monkeys and humans. *Tim2* is a previously unknown gene that had not been identified in any organism prior to this study.

The mouse *Tim1* gene encodes a 305 amino acid membrane protein, that has 78% overall identity with rat KIM-1 and 35% identity with human HAVcr-1. A gapped multiple sequence alignment with mouse TIM-1, rat KIM-1, human HAVcr-1 and African green monkey HAVcr-1, shown in Fig. 5B, demonstrates the degree of homology between the TIM-1/KIM-1/HAVcr-1 proteins in these species. The cytoplasmic region of TIM-1 contains two tyrosine residues and includes a highly conserved tyrosine kinase phosphorylation motif, RAEDNIY, which is integral to the predicted Itk and EGFR kinase site of TIM-1, SRAEDNIYIVEDRP. The mucin domain of TIM-1 has multiple sites for O-linked glycosylation, and there two sites for N-linked glycosylation found in the immunoglobulin domain.

TIM-2, a similar 305 amino acid membrane protein, has 64% identity to mouse TIM-1, 60% identity to rat KIM-1, and 32% identity to hHAVcr-1 (Figure 5A, B). Like TIM-1, TIM-2 has two extracellular N-linked glycosylation sites and a serine, threonine-rich mucin domain with many O-linked glycosylation sites. TIM-2 also has an intracellular tyrosine kinase phosphorylation motif, RTRCEDQVY.

Tim3 encodes a 281 amino acid membrane protein that has a similar, integral membrane glycoprotein structure with multiple extracellular glycosylation sites and an intracellular tyrosine phosphorylation motif. Although the mucin domain is not as prominent in TIM-3 as it is in TIM-1 and TIM-2 (Figure 5A), TIM-3 expressed on T cells likely interacts with a ligand on APCs and alters APC activation. TIM-3 does have four sites for N-linked and five sites for O-linked glycosylation, suggesting that TIM-3, like TIM-1 and TIM-2, is heavily glycosylated and might interact with a ligand present on other cells, such as antigen presenting cells.

Tim4 encodes a 344 amino acid protein in mice, and a 378 amino acid protein in humans. The predicted TIM-4 also shares the general membrane glycoprotein structural motifs of the other TIM proteins, a with an IgV-like domain with highly conserved

cysteine residues, a threonine-rich mucin-like domain, and a short intracellular tail. However, TIM-4 lacks the phosphotyrosine motif present in the other TIM proteins, and therefore may modulate the function of the other TIM proteins.

Each of the TIM Ig domain shares an predicted integrin-binding motif that is similar to the SVVYGLR motif found in osteopontin, an transmembrane protein like the TIMs that is implicated in the regulation of cell adhesion, survival, and oncogenesis, as well as in the regulation of helper T cell differentiation. This integrin binding motif demonstrates alpha(9) and alpha(4) specificity.

Comparison of the sequences of the BALB/c and HBA/DBA coding regions for the three *Tim* genes revealed major polymorphisms in TIM-1, TIM-3, and TIM-4, but not TIM-2. In TIM-1, these polymorphisms encode three amino acid differences and a fifteen amino acid deletion in HBA/DBA. Seven predicted amino acid differences were identified in TIM-3 (Fig. 5c). Genomic sequences confirm that these polymorphisms, including the deletion, are true polymorphisms, not splicing variants. By further sequencing genomic segments of TIM-1 and TIM-3 in other mouse strains, we found that C57/BL6, a strain similar to DBA/2 with respect to its tendency to develop reduced T_H2 and AHR responses, also has the HBA/DBA allele of *Tim1* and *Tim3*. The polymorphisms in TIM-1 and TIM-4 are located in the signal and mucin-like domains, while the polymorphisms identified in TIM-3 are clustered in the Ig domain (Fig. 5c). In glycoproteins with Ig and mucin domains, variants in either domain may affect receptor-ligand interactions, as shown for MAdCAM-1. Although the predicted cleavage sites of TIM-1 and TIM-4 are unaltered by the polymorphism in the signal sequence, it is possible that the polymorphism may affect the efficiency of cleavage and/or trafficking of the receptor to the cell surface. These *Tim* sequences and polymorphisms are important for immune responses, and for HAV viral pathogenesis in humans.

Analysis of genomic DNA samples from our N2 backcross (Fig. 3) demonstrated that the TIM-1 and TIM-3 polymorphisms cosegregate completely with *Tapr*. While these observations do not distinguish the extent to which changes in TIM-1, TIM-3, or both, are responsible for changes in AHR and T_H2 -mediated inflammation, we suggest that polymorphisms in human TIM-1(hHAVcr-1) and/or TIM-3 underlie the strong association between asthma susceptibility and human chromosome 5q. This idea is supported by the fact that major variants in coding regions of human *Tim1* are evident on examination of human genome and EST databases. Comparison of these human cDNA variants with the previously described variants of monkey HAVcr-1 and the mouse variants identified here demonstrates that there is extensive variation in the predicted protein sequences of TIM-1 (Fig 5b,c). This high degree of variation distinguishes TIM-1 and its family members from

many other candidate genes, such as the cytokines and the cytokine receptors that have been most closely studied as asthma susceptibility candidate genes. In addition, the association between *Tim1* and asthma susceptibility is further supported by reports of significant linkage of mite-sensitive childhood asthma to D5S820 (mean LOD score = 4.8),
5 a marker which is approximately 0.5 megabases from *Tim1* and *Tim3* (Fig. 4).

In addition to the above genetic polymorphisms, there are several expression polymorphisms in the TIM genes that arise due to alternate splicing. Alternate splicing of TIM-1, TIM-2 and TIM-4 mRNA produces several TIM variants, some of which are secreted, soluble forms of the TIM receptors. These splice variants, along with TIM splice
10 variants that have alternate 5' untranslated regions, may contribute to the cell-specific and condition-specific expression patterns of the TIM proteins.

T cells confer the Tapr effect. To better understand the function of the *Tapr* locus we determined whether allelic variation of *Tapr* affected the function of T cells or of
15 antigen presenting cells (APC). For these experiments, we generated ovalbumin (OVA)-specific T cell receptor (TCR) transgenic mice (Tg) with the HBA background (HBA DO11.10), which we compared to TCR-Tg mice with the BALB/c background (BALB/c DO11.10). Purified CD4⁺ T cells from either of these strains were cocultured with OVA and dendritic cells (DCs) derived from either BALB/c or HBA bone marrow, and the cytokines
20 produced were evaluated. Irradiated spleen cells were not used as APCs for this experiment, because it was found that irradiated spleen cells and other tissues express high levels of the TIM genes.

BALB/c DO11.10 T cells produced higher levels of IL-4 and IL-13 than did HBA DO11.10 T cells, in a manner that was independent of the source of the antigen
25 presenting cells (Fig. 6A). In addition, the source of the CD4 T cells determined the amount of IL-4/IL-13 produced at each antigen concentration, regardless of the source of the APC during either the primary or secondary stimulation. Equivalent levels of IL-12 were detected in culture supernatants for each combination of cell types, further demonstrating that BALB/c and HBA DC function were comparable. Furthermore, BALB DO11.10 and
30 HBA DO11.10 T cells produced equivalent levels of IL-2 and demonstrated comparable levels of proliferation in response to OVA during the secondary cultures, indicating that HBA and BALB/c T cells are similarly activated, although the levels of Th2 cytokines they produce are quite distinct.

We show in Figure 6B that within the first twelve hours of primary culture in
35 our DO11.10/DC system, we find that mRNA for TIM-1 is expressed by both BALB/c and HBA CD4⁺ T cells. Within four days of primary stimulation, we find significant levels of IL-13 in supernatants of the BALB/c DO11.10 and detect none in the HBA DO11.10

supernatants. This differentiation is detectable in mRNA levels at 36 hours (Fig. 6B). Between twelve and thirty six hours, expression of IL-13 mRNA is reduced in HBA CD4 T cells, while IL-13 expression is maintained in the BALB/c CD4 T cells. Thus, during the primary response to antigen, BALB/c CD4 T cells develop a stronger Th2 response than do HBA CD4 T cells. Our findings demonstrate that *Tapr* regulates helper T cell differentiation during primary antigen specific responses, and we detect TIM-1 expression in CD4 T cells during the earliest stages of these responses.

Following differentiation into mature Th1 and Th2 subsets, helper T cells demonstrate committed TIM expression by RT-PCR, such that Th1 cells express TIM-3, while Th2 cells preferentially express TIM-1. All T cell populations demonstrate weak TIM-4 expression. While the Itk signal through TIM-1 is likely to promote Th2 differentiation, the EGFR signal through the TIM proteins is likely to enhance cell survival in effector and especially memory T cell populations. Since Itk is expressed only in T cell and mast cells, the Itk kinase activity on TIM-1 is restricted to immune cells, particularly those involved in asthma and allergy. However, other protein tyrosine kinases, such as EGFR, are involved in the function of TIM proteins expressed by other tissues, including ischemic epithelial cells, irradiated spleen cells, and tumor cells.

In these studies, we mapped *Tapr*, a locus that regulates the development of Th2 cytokine production and antigen-induced AHR, a cardinal feature of asthma. We localized *Tapr* using an interval specific congenic mouse (HBA) that carried a chromosomal segment homologous to human chromosome 5q, a region of the human genome that has been repeatedly linked to atopy and asthma. This region has also been repeatedly linked to 5q- syndrome associated with myelodysplasia and neoplastic cytogenetic abnormalities. Using this congenic mouse strategy that converted a complex trait into a simpler, possibly single gene, trait, we narrowed the interval of *Tapr* to 0.4 cM interval, sequenced several candidate genes in this region, and positionally cloned the TIM gene family.

The TIM gene family has not been previously described. We identified and cloned the full cDNA sequence and discovered significant polymorphisms in the TIM-1 proteins of BALB/c compared to HBA mice. We found that the BALB/c sequences for TIM-1 and TIM-3 are associated with susceptibility to AHR and allergic T cell responses, whereas the HBA sequences are associated with protection against these responses. TIM-3 is preferentially expressed by differentiated T_H1. The association of polymorphic *Tim3* variants with *Tapr* suggests that TIM-3 might regulate T_H1 and T_H2 cell function. However, the variations in *Tim3* might also be attributed to a haplotype tightly linked to *Tim4* or *Tim1*.

We believe that TIM-1 plays a very important role in the regulation of the immune system (particularly with respect to asthma and allergic disease) and in the the

regulation of epithelial and hematopoietic cell survival in response to stress (hypoxia, nutritional deficiency, irradiation, chemotherapy, etc.) for several reasons. First, *Tim1*, like *Tim3*, is expressed in CD4 T cells during primary antigen stimulation, when it is most likely that the *Tapr* effect occurs. T cells play a critical role in the development of AHR and in the pathogenesis of asthma, our results suggest that *Tapr* affects asthma by enhancing early CD4 commitment to Th2 responses by controlling the production of IL-13 and subsequent T cell differentiation. Second, HAV infection in humans during infancy or childhood is inversely associated with the development of asthma and allergy. We suggest that the HAV interaction with TIM-1/HAVcr-1 may alter the T cell cytokine production may able to reverse or prevent the biased Th1/Th2 balance in individuals otherwise prone to atopy and asthma. SLAM, a measles virus receptor, is an example of another T cell surface glycoprotein that regulates the Th1/Th2 balance in a manner that may be altered by viral interaction. Because some viral receptors, such as SLAM for the measles virus or CD4, CCR5, and CXCR4 for HIV, are receptors of the host's own immune system, even when an infection does not succeed, virus-receptor mediated signal transduction can lead to the release of cytokines and the development of disease.

Third, the polymorphisms in TIM-1 are associated with the different types of helper T cell responses that we observe. Therefore, the variants of TIM-1 may themselves contribute to the genetic Th1/Th2 predisposition that occurs in the absence of any known environmental cause of immune deviation. The HAV receptor in primates is known to be highly variable, and we propose that polymorphic alleles of human TIM-1/hHAVcr-1, like those we have identified in mice, may be associated with variations in Th2 bias and asthma susceptibility. Mutations in the genes for cell surface molecules that serve as viral receptors and that alter susceptibility to infection are not uncommon, and therefore significant genetic variation in TIM-1 and other members of the TIM gene family is far more likely to be observed than variation in other genes such as those for cytokines. It is unclear why asthma susceptibility alleles might be prevalent in the human gene pool, but the association of *Tapr* with HAVcr provides an interesting explanation for the persistence of asthma susceptibility alleles. During human evolution certain alleles of the *Tim* gene family may have conferred resistance to atopic diseases and other immune disorders, but selection of those resistance alleles may have been counterbalanced by selection of alternate alleles that confer resistance to viral pathogenesis.

In summary, our studies represent the first successful utilization of a congenic mouse strategy to locate a strong candidate asthma susceptibility gene and overcome the inherent difficulties in the examination of this complex genetic trait. We identified a previously unknown gene family that exists in a region homologous to human

chromosome 5q, and which plays a major role in Th cell development and in asthma susceptibility. While prior studies in humans identified several candidate genes on human chromosome 5q, the *Tim1* gene product identified in our study also provides an explanation for the inverse relationship between HAV infection and reduced asthma susceptibility.

5 Subpopulations of CD4⁺ T cells (Th) produce distinct patterns of cytokines, and this has led to the concept of functional heterogeneity among Th cells. Type 1 Th cells (Th1) produce interleukin 2 (IL-2) and/or interferon γ , elicit delayed type hypersensitivity (DTH) responses and activate macrophages. Type 2 Th cells (Th2), on the other hand, produce IL-4, IL-5 and IL-10 and are especially important for IgE production and
10 eosinophilic inflammation, and may suppress cell mediated immunity. Th2 cells are believed to play a pivotal role in the pathogenesis of atopy. Several factors determine whether a T helper cell will differentiate into Th1 versus Th2 during a particular immune response. These include, but are not necessarily restricted to, the cytokine milieu, the strength of the TCR signal and/or antigen density, and the costimulatory pathways. CD4⁺ T
15 helper cell differentiation into Th1 or Th2 subsets has profound effects on the outcome of atopy, autoimmune diseases, infectious diseases, and graft rejection.

The specific features of immune responses that protect nonatopic individuals from the development of allergic diseases and which could inhibit allergic responses in atopic individuals are poorly understood. Because Th1 cells cross regulate Th2 cells in
20 some systems, allergen-specific Th1 cells have been assumed to regulate allergic disease and asthma. Th1 cells inhibit the development and proliferation of Th2 cells, and IgE production is reciprocally regulated by IL-4 and IFN- γ . This suggests that protection from allergy is due to the development of inhibitory allergen-specific Th1 cells. Allergen-specific T cell clones derived from the peripheral blood of nonallergic individuals have been shown
25 to produce Th1 cytokines. These observations have also supported the hygiene hypothesis of asthma, which suggests that the prevalence of infections, particularly those that induce Th1 responses, are reduced in westernized societies by improved public health measures and the use of vaccines and antibiotics. As a result, Th2 responses and atopy develop more intensely and rapidly in the absence of Th1 mediated responses.

30 The TIM genes identified herein are also candidate oncogenes. Transfection of cell lines with TIM genes confers resistance to cell death, and the predicted EGFR kinase motif described in TIM-1 provides a probable mechanism by which this cell survival is controlled. Furthermore, TIM-1 demonstrates a significant degree of sequence identity (approximately 20%) and structural similarity (a transmembrane glycoprotein with
35 an IgV domain, mucin/syndecan domain, transmembrane domain, and intracellular domain with similar phosphotyrosine motifs) with TOSO, a protein that protects cells from Fas-mediated apoptosis. Like the TIM genes, TOSO is a likely oncogene, which maps to a

region of the genome with frequent changes in hematologic malignancies and solid tumors.

METHODS

Animals. Congenic lines, including C.D2 Es-HBA were generated by introgressively backcrossing DBA/2N onto a BALB/cAnPt background. BALB/cBy, DBA/2J, and (BALB/c x DBA/2) F1 mice (CByD2F1/J) were obtained from the Jackson Laboratory (Bar Harbor, ME), while BALB/cAn and DBA/2N were obtained from Taconic Labs. (BALB/c x HBA) F1 mice were produced with a cross between BALB/cByJ and HBA. N2 mice were generated by backcrossing (BALB/c x HBA) F1 to HBA. In our analysis of recombinant N2 animals, recombinant mice were tested along with non-recombinant siblings, whenever possible. In order to examine individual N2 genotypes in multiple assays, we preserved selected recombinant haplotypes by backcrossing selected N2 mice to HBA to generate N3 mice, which were genotyped to chose mice carrying the recombinant N2 haplotype. DO11.10 mice, which are transgenic for TCR recognizing OVA peptide 323-339 (pOVA³²³⁻³³⁹) and backcrossed to BALB/c(43), were kindly provided by Dr. Dennis Loh and were bred in our facilities. HBA DO11.10 mice were produced by backcrossing DO11.10 to HBA. DO11.10 mice were selected by FACS analysis for the TCR-Tg and genotyped to select for HBA alleles between *D11Mit135* and *D11Mit168*. The Stanford University Committee on Animal Welfare approved all animal protocols.

Genotyping. Additional markers around the *Tapr* locus were identified by testing all available "D11Mit-" markers present between *D11Mit140* and *D11Mit269* and all radiation hybrid markers near *D11Mit271* and *D11Mit22* for any polymorphisms between DBA/2 and BALB/c. MIT MapPair primers were obtained from Research Genetics (Huntsville, AL), and all other primers were synthesized in the Protein and Nucleic Acid Facility (Stanford, CA). PCR was performed as previously described, and SSLP polymorphisms were resolved with 4-5% Metaphor agarose (BioWhittaker, Walkersville, MD). Products analyzed for SSCP were amplified with ³³P-dCTP and separated on denaturing acrylamide gels at 40W and 4°C, with a Sequi-Gen GT System (Bio-Rad, Hercules, CA).

Immunization protocols. Mice studied in cytokine production assays were primed with KLH (Calbiochem, La Jolla, CA) in complete Freund's adjuvant (CFA) (DeKruyff et al. *J Immunol* **149**, 3468-76 (1992)). For measurement of airway hyperreactivity, mice were immunized with OVA intraperitoneally (i.p., 50 µg) complexed with aluminum potassium sulfate (alum) on day 0, and intranasally (i.n. 50 µg OVA in 50 µl of PBS) after light anesthesia on days 7, 8 and 9. Control mice received i.p. injections of alum alone and intranasal PBS. Airway hyperreactivity to inhaled methacholine was measured 24 hours after the last intranasal dose of OVA (day 10).

Measurement of Airway Responsiveness. Airway responses were assessed by methacholine-induced airflow obstruction from conscious mice placed in a whole body plethysmograph (Buxco Electronics Inc., Troy, NY), as described previously (Hansen et al. *J Clin Invest* **103**, 175-83 (1999)).

5 *Cell Culture.* Lymph node cells from mice primed with KLH were prepared as described previously (Yeung et al. *J Immunol* **161**, 4146-52 (1998)). Transgenic DO11.10 CD4 T cells were positively selected using MACS columns following incubation with anti-CD4 magnetic beads (Miltenyi Biotech, Germany). 2×10^4 cells/well were cocultured in 96-well round bottom plates with 250 μ g/ml OVA and 1×10^4 bone marrow-
10 derived dendritic cells/well. After seven days, the DO11.10 T cells were washed and restimulated with fresh antigen presenting cells and antigen at the concentration indicated. Antigen concentration for the primary DO11.10 cultures was titrated during the restimulation. Bone marrow-derived dendritic cells were generated as previously described with some modifications; 5×10^6 bone marrow cells were cultured in 9-cm diameter tissue
15 culture dishes with 10 ml culture medium containing 20-25 U/ml GM-CSF. Loosely adherent cells were transferred onto a second dish on the sixth day of culture; within four days, these transferred cells were used as a source of dendritic cells.

Cytokine ELISA. ELISAs were performed as previously described in Macaulay et al. *J Immunol* **160**, 1694-700 (1998); and Macaulay et al. *J Immunol* **158**,
20 4171-9 (1997).

Monoclonal Antibodies. Monoclonal antibodies for ELISA and FACS analysis were purified from ascites fluid by ammonium sulfate precipitation and ion-exchange chromatography. Anti-clonotypic antibody KJ1-26.1, was generously provided by Dr. Philippa Marrack, National Jewish Medical Center, and the antibody was FITC-
25 conjugated according to standard protocols prior to FACS.

Example 2

Identification of Human Tim Sequences

30 The positional cloning of the TIM gene family within a locus that confers protection against the development of Th2 responses and allergen-induced airway hyperreactivity provides an opportunity to greatly improve our understanding of the regulation of Th2 driven responses and atopic diseases. In addition, TIM-3 is specifically expressed on murine Th1 cells and anti-TIM-3 mAb leads to increased severity of experimental autoimmune encephalomyelitis (EAE). This emphasizes the importance of
35 the gene family in T helper subset regulation.

 The human Tim cDNAs, which are the orthologues of murine Tim-3 and Tim-4 were cloned by PCR. The human orthologue of TIM-1 was cloned as HAVcr-1, the

cellular receptor for hepatitis A virus. The TIM family genes are immediately adjacent to each other on human chromosome 5, in the order TIM-4, TIM-1, TIM-3, with no intervening genes. There are TIM pseudogenes on chromosomes 12 and 19. The gene family members are only moderately related. The protein sequences and relationship among the
5 Tim gene family are shown in Figure 7.

The cytoplasmic domains of TIM gene family members are the most conserved domain between mouse and human orthologues, e.g., 77% identity between the human and mouse TIM-3 cytoplasmic domains. In contrast, the whole TIM-3 is only 63% identical between human and mouse. Each TIM gene contains a distinct predicted tyrosine
10 signaling motif. The cytoplasmic region of TIM-1 contains two tyrosine residues and includes a highly conserved tyrosine kinase phosphorylation motif, RAEDNIY. The expanded region, SRAEDNIYIVEDRP, contains a predicted site for Itk and EGF receptor phosphorylation. Itk is known to phosphorylate phospholipase C- γ (PLC- γ), and thereby trigger a cascade of signaling events that are involved in T cell activation and helper T cell
15 differentiation. Furthermore, Itk signaling affects Th1/Th2 differentiation, and Itk^{-/-} mice do not develop strong Th2 responses. EGF receptor kinase activity is associated with cell survival and resistance to cell death. Similarly, TIM-3 contains distinct, conserved tyrosine phosphorylation and SH2 binding motifs in the cytoplasmic domain. This suggests that the interaction of a TIM with its ligand will engage an intracellular signaling pathway and that
20 each TIM will be distinct in this signaling.

The extracellular IgV domain of the TIM proteins also contains a predicted integrin-binding motif that is similar to the SVVYGLR motif of osteopontin that is involved in adhesion via alpha(9)beta(1), alpha(4)beta(1), and alpha(4)beta(7) integrins. TIM-1 transfected pre-B cells of the 300.19 line demonstrate a high degree of adhesion and
25 increased survival in cell culture, as compared to non-transfected 300.19 cells. TIM-1 and TIM-2 transfected CHO cells also demonstrate enhanced survival compared to untransfected CHO cells. These results demonstrate that the TIM proteins regulate cell adhesion and death

Genetic polymorphisms in the human Tim1 and Tim3 genes. SNPs or
30 nucleotide polymorphisms and deletions/insertions present in the human *Tim1* gene are identified. Because SNPs are extremely common in the genome, occurring every 300-600 base pairs, only the coding region of *Tim1* was analyzed. Moreover, genetic variations that are common are also likely to be important. Initially cDNA is sequenced from T cells taken from 30-40 individuals (60-80 chromosomes). Power calculations show that surveying
35 target sequences in coding regions of 60 chromosomes will easily detect SNPs with a population frequency of greater than 1%, and having a more than 90% chance of detecting alleles with a population frequency of 5% or greater. Therefore, screening 30-40

individuals for sequence variations captures most of the common, functionally relevant, non-conservative, DNA variation present in a population.

Since DNA variants/SNPs in close physical proximity often show strong dependency relationships (i.e., linkage disequilibrium), it is determined if a group of DNA variants (SNP haplotypes) are inherited together, and determined if screening for only a portion of these SNPs will be sufficient for identifying the haplotype. Analysis of large regions of various chromosomes indicate that discrete haplotype blocks (of tens to hundreds of kilobases) are generally present, each with limited diversity punctuated by apparent sites of recombination. To find haplotypes, cDNA is sequenced and searched for combinations of sequence variations that are seen repeatedly in multiple individuals.

Peripheral blood mononuclear cells (PBMC) were from 38 donors, and were stimulated *in vitro* with PHA (7.5 μ g/ml) for 24 and 72 hours, or with Concavalin A (2 μ g/ml) for 24 hours. PMA (20ng/ml) and Ionomycin (1 μ M) were added during the last six hours of stimulation. The cells were then harvested and the total RNA was extracted using Trizol reagent(Invitrogen). To obtain cDNA templates for sequencing, RNA was reverse transcribed using Superscript II reverse transcriptase (Invitrogen), according to the manufacturer's protocol. The cDNA were used to PCR amplify the full length of *Tim* cDNA using Herculase Hot Starttm high fidelity polymerase (Stratagene). The PCR primers were: (SEQ ID NO:37) GTGTCTGACAGTGGCGTA (forward), (SEQ ID NO:38) TTTGCCCAGGCAGAACCA (forward), CCACCCAAGGTCACGACT (reverse), (SEQ ID NO:39) ATGCCACGGACTAAGACC (reverse). The PCR products were purified with Qiagen QIAquick gel extraction reagents, and sequenced using four internal sequencing primers for *Tim1* and two internal sequencing primers for *Tim3*.

The full length *Tim1* RT-PCR product was cloned in these individuals by taking total RNA from activated T cells and transcribing it with Superscript II and oligo dT. *Tim1* cDNA was amplified with Expand high fidelity polymerase (Roche) to generate a 1 kb product spanning the *Tim1* coding region, which was purified with a PCR Purification kit (Invitrogen). This purified product was then cloned into the TOPO pEF6 vector (Invitrogen), followed by transformation of TOP10 competent bacteria. Bacterial colonies were grown on LB plates with ampicillin selection. Single colonies were picked and plasmid preps generated using Qiagen mini prep kits. Restriction mapping using Hind III digestion was used to select plasmids containing inserts in the correct orientation. These plasmids were then sequenced with three different primers, forward (T7), internal and reverse (BGH), and the sequences aligned in SeqMan program with NCBI human TIM reference sequence.

After sequencing *Tim1* from the chromosomes from 35 individuals (70 chromosomes) several polymorphisms in *Tim1* were identified, which are shown in Figure 8. These polymorphisms are numbered 1-7 (left column). The full sequence of human

TIM-1, which is listed in the NCBI database (NM_012206), is provided in Figure 8 as a reference point. This sequence is present in less than 20% of the chromosomes that were sequenced, due to the existence of multiple, prevalent sequence polymorphisms in the coding region. 6 additional sequence variations were identified, shown in Figure 8, and all of the polymorphisms were observed in the mucin, extracellular domain, as was true for mice, although the specific variations were distinct from those seen in mice. Importantly, there is a limited degree of association between these variants, in various combinations. The most pronounced variations are the insertion labeled polymorphism 1, 157insMTTTVP, which was observed in 65% of the chromosomes, and the deletion in polymorphism 5, 187 Δ Thr, was observed in 65% of the chromosomes. Polymorphism 4 was observed in 40% of the chromosomes, and the other polymorphisms were each observed in $\leq$ 5% of the chromosomes. Notably, most of these variations (2-6) are located within exon 3, the first mucin-encoding exon, and all of the variants occur at the genomic level and are not splice variants.

Based on this sequence analysis of mRNA, a more rapid method for analyzing the genomic DNA from the larger number of patients/controls has been developed. To screen individuals for the variations seen in sequences shown in Figure 8, the DNA is initially tested for simple sequence length polymorphisms (SSLP) in a 150 PCR product, which can detect the major insertion, polymorphism 1, and the deletion, polymorphism 5.

In addition, to genotype the other polymorphisms (2-4, 6, and 7) and identify novel polymorphisms, a relatively simple assay using single strand conformational polymorphism (SSCP) analysis of PCR products has been developed. Under well-optimized conditions, SSCP analysis detects more than 90% of single nucleotide substitutions and all length polymorphisms. For this analysis, PCR primers have been identified that amplify each exon of the *Tim* genes, and variants can be distinguished using standard non-denaturing SSCP gel electrophoresis methods (Figure 9). Non-denaturing polyacrylamide gel electrophoresis is used with an ABI 377 DNA sequence for high resolution SSCP analysis of each exon. Fluorescent end-labeled primers are synthesized and purified. Novel SSCP patterns that are detected during the high-throughput genotyping process will identify novel variants. Using this method, the genotype of patients and controls is rapidly analyzed.

The *Tim3* gene was analyzed using essentially the same methodologies. mRNA from activated T cells is sequenced to identify *Tim3* polymorphisms, as well as long range haplotypes between the *Tim1* and *Tim3*. After sequencing *Tim3* cDNA representing 60 chromosomes, it has been found that *Tim3* is polymorphic, as it is in the mouse genome. However, only one polymorphism, Leu140Arg, is prevalent, found in

approximately 12% of the chromosomes represented.

Example 3

Expression of Tim Sequences

5 Murine TIM-3 protein is expressed on Th1 clones but not on naive T cells or Th2 cells. Using TCR transgenic T cells, TIM-3 protein was not expressed on Th1 cells after one or two rounds of Th1-directed differentiation but was expressed after the third and further rounds of Th1 stimulation. TIM-3 mRNA expression was detected somewhat earlier. In order to determine if TIM-3 gene expression was the same in human, TIM-3 and TIM-1
10 mRNA expression in human Th1 cells was examined using tetanus toxoid specific T cells generated by stimulation with antigen in the presence of IL-12 and anti IL-4 mAb. Given the association of TIM-1 with asthma, TIM-1 and TIM-3 mRNA expression in human Th2 cells was examined. Th2 cell lines were generated from allergic donors by *in vitro* stimulation with allergen, IL-4, and anti IL-12 mAb. RNA was analyzed by PCR for TIM
15 gene expression.

TIM-3 was generally expressed after Th1 differentiation whereas TIM-1 was lost. Conversely, TIM-3 was not expressed in any of the Th2 but TIM-1 was expressed in all Th2 cells. Both TIM-1 and TIM-3 are expressed in monocyte-depleted, unstimulated peripheral blood mononuclear cells from the donors used to derive the Th1 and Th2 cell
20 lines, presumably because this mixed population contains both Th1 and Th2 memory cells. These results suggest a reciprocal relationship with TIM-1 being expressed in Th2 and TIM-3 in Th1. This reciprocal relationship between TIM-1 and TIM-3 has also been observed in the mouse.

In human tissues, a 4.4 kb TIM-1 mRNA was very strongly expressed in
25 kidney and testis. The 4.4-kb mRNA was present in almost all tissues, though it was faint in most. A 5.5-kb band was observed in colon and liver. A 7.5-kb band was observed in spleen, thymus, and peripheral blood leukocytes, and smaller than 4.4-kb bands were observed in some organs. These results suggest that hTIM-1 is expressed at some level in most human tissues and that a message of 7.5-kb may code for hTIM-1 in tissues of
30 immunological interest. However, expression of Kim-1 (Kidney Injury Molecule-1), the rat homologue of TIM-1, increases in kidney upon ischemic injury. Since the MTN blots used in the expression analysis were prepared from mRNA extracted from cadavers, the increased expression of TIM-1 in kidney was re-analyzed. TIM-1 was not found to be overexpressed in kidney RNA obtained from normal kidney biopsies. Therefore, it is likely
35 that the high levels of expression of TIM-1 observed in kidney and testis were due to an up-regulation in the expression of TIM-1 resulting from tissue injury. The injured kidney may express proteins that direct incoming inflammatory cells towards a more protective Th2

response rather than a destructive Th1 response.

Example 4

TIM Ligands and Antibodies

5 *Generation of Antibodies.* Generation of monoclonal antibodies against mouse TIM-1 allows examination of the cell surface expression of TIM-1 in different tissues, cell lines and mouse strains. Both alleles of mouse TIM-1 have been cloned into a vector for high protein expression (Invitrogen, pEF6-TOPO). Rats have been immunized and boosted with both Tim1 cDNA constructs to rapidly generate antibodies against cell surface
10 molecules. This method with cDNA vaccination favors the production of mAb against cell surface epitopes since the Tim1 cDNA will be taken up by APC, which will express the TIM-1 as a cell surface molecule. In order to generate mAb that would bind equally well to both the BALB/c and the HBA TIM-1 (by binding to conserved domains of TIM-1 such as the Immunoglobulin domain of TIM-1), both the BALB/c and HBA Tim1 cDNA (pEF6-mTIMbalb and pEF6-mTIMhba) were injected into each rat.
15

Further boosting of the Tim1 cDNA-immunized rats was done with CHO cells stably transfected with the pEF6-mTIM-1-GFP expression constructs. CHO transfectants expressing high levels of mouse TIM-1 were sorted by FACS, and injected into the rats. Another mTIM-1 expressing cell was generated by stably transfecting the pre-B cell line
20 300.19 with the pEF6-mTIM-1 expression constructs. This line is used to screen the rat serum and the hybridomas following fusion for anti-TIM-1 antibody by flow cytometry. Rats have been generated which have high polyclonal titers against anti-TIM-1, as detected by the binding of rat serum (and a secondary FITC-goat anti-rat Ig) to stable pEF6-mTIM1-transfected 300.19 cells, as compared with control serum from unimmunized rats. This
25 staining is specific for TIM-1 since there is no reactivity with nontransfected cells or cells transfected with TIM-2.

The rat spleen is removed and the splenocytes fused with a myeloma cell line (SP/2) to produce hybridomas. Hybridoma supernatants are screened using the TIM-1 transfected 300.19 cell lines to identify hybridoma clones that produce monoclonal anti-
30 TIM-1. Specificity of the mAb for TIM-1 (and not other TIM proteins) is confirmed using TIM-2 transfected cells and mTIM-3 transfected cells or TIM-3 Ig fusion protein.

Antibody Staining. Th1 and Th2 cell lines were generated from both BALB/c and HBA DO11.10 spleen cells. RT-PCR for TIM-1 mRNA expression demonstrated that
35 TIM-1 is expressed in Th2 lines, but not in Th1 lines, following two rounds of restimulation with antigen under standard polarizing conditions. DO11.10 T cells following two rounds of stimulation with antigen/APC under Th2 polarizing conditions were stained with the

polyclonal rat anti-TIM-1 antiserum. These Th2 cells expressed high levels of TIM-1.

These experiments showing preferential expression of TIM-1 in Th2 lines are quantified and confirmed using anti-Tim-1 mAbs and Northern blots. DO11.10 cells from BALB and HBA are cultured with antigen and APC, and restimulated for 1, 2, and 3 weeks under standard polarizing conditions (anti-IL-12 plus IL-4 or anti-IL-4 plus IL-12). After each week of stimulation, cells are stained with anti-TIM-1 mAb. By harvesting stimulated cells at various time points the kinetics of TIM-1 expression on T cells undergoing differentiation to Th1 or Th2 subset is determined. To determine if Tim-1 surface expression changes following T cell activation, we will also compare TIM-1 expression on resting and activated T cells one week after each round of antigen stimulation, by stimulating some cells with PMA and ionomycin. Activated cells are stained for intracellular cytokine expression to verify the Th subset differentiation of the T cells. Alternatively, quantitative RT-PCR or northern blots using mRNA harvested from T cells activated with PMA plus ionomycin, following each round of stimulation, are used to determine relative levels of mRNA production.

TIM-1-Ig fusion proteins BALB/c TIM-1-mIgG2a has been prepared, which is a fusion protein between the TIM-1 polypeptide and the Fc region of mouse immunoglobulin. The vector has been engineered to contain a mutation in murine IgG2a Fc that minimizes binding to Fc receptors. The TIM-1 fusion protein is utilized in characterization of TIM-1 function. The TIM-1 Ig fusion protein is expected to block TIM-1 function by binding to the TIM-1 ligand and interrupt TIM-1/TIM-1-ligand interactions.

Purified D1muc-Fc fusion protein containing the cys-rich immunoglobulin domain and 2/3 of the mucin-like region of TIM-1 fused to the hinge and Fc fragment of human IgG1 (IgVmuc-hlg) was run on a gel. This protein was expressed in CHO cells, and the IgVmuc-hlg protein was purified from CHO supernatants with protein-A agarose columns. Purified IgVmuc-hlg fusion protein neutralizes about 2 logs of HAV infectivity. In addition, treatment of HAV with IgVmuc-hlg produced a major shift in the sedimentation of the HAV particles, indicating that IgVmuc-hlg induced uncoating of the viral genome, whereas a fusion protein containing only the Ig-like region without the mucin domain (IgV-hlg) did not. This HAV neutralization system and the IgVmuc-hlg fusion protein will be used to analyze the function of TIM-1/HAV receptor alleles.

Based upon the *in vivo* effect of anti-TIM-3 mAb on macrophage expansion and activation, it was hypothesized that the TIM-3 ligand would be expressed on cells of the myeloid lineage. Dendritic cells (DC) were prepared from blood monocytes according to established protocols with 1000 U/ml IL-4 and 800 U/ml GM-CSF. DC were matured by replating the cells for 2 days in IL-4 (1000 U/ml) and GM-CSF (800 U/ml) supplemented

with IL-1 β (10 ng/ml), TNF- α (10 ng/ml), IL-6 (1000 U/ml), and PGE₂ (1 μ g/ml). Mature DCs stained positively with hTIM-3-Ig, though there was variability among donors, suggesting that mature DC express a ligand for the IgV domain of TIM-3. Bone marrow derived endothelial cells stained very weakly and B cell lines did not stain with TIM-3-Ig.

5

Although the intracytoplasmic tail of Tim1/huhavcr-1 is relatively short, it contains a sequence that is highly conserved between mouse, rat, human and monkey (RAEDNIYI), and which may be phosphorylated, and signal through interaction with other signal transduction molecules. The most likely candidate molecule that can bind the RAEDNIYI motif in T cells is the tyrosine kinase Itk. The interleukin-2 inducible tyrosine kinase, Itk is a nonreceptor protein tyrosine kinase of the Tec family that participates in the intracellular signaling events leading to T cell activation. Tec family members contain the conserved SH3, SH2, and catalytic domains common to many kinase families, but they are distinguished by unique sequences outside of this region. It is known that Itk phosphorylate phospholipase C- γ (PLC- γ), and triggers a cascade of signaling events that are involved in T cell activation and helper T cell differentiation. In the absence of Itk signaling, Th2 cells do not develop. These results suggest that TIM-1/huhavcr-1 may signal through Itk, thereby altering the cytokine development in CD4 T cells.

20

Example 5

TIM Knockout Mice

A knockout construct is used in the generation of a *Tim1* deficient mouse, which enables analysis of development of immune responses in the absence of TIM-1 molecules. In another approach, TIM-1-Ig fusion proteins or anti-TIM-1 monoclonal antibody are used to block the function of TIM-1 in *Tim1*^{+/+} (wild type) mice. The *Tim1* knockout mice and the anti-TIM-1 mAb approaches are complementary for the evaluation of the role of TIM-1 in T cell differentiation and in asthma pathogenesis.

The HBA mouse genomic sequence of *Tim1* has a deletion of exon 4, compared to the BALB/c sequence, due to an integrated L1 retroviral element at exon 4. If truncation of one exon reduces TIM-1 function, then total deletion of TIM-1 function by generation of *Tim1* knockout mice, should severely limit the capacity of such mice to generate Th2 responses. TIM-1 KO mice are generated by deleting the TIM-1 exons 1 and 2, using cre-lox technology and BALB/c ES cells, which should eliminate cell surface expression of TIM-1, thereby demonstrating the importance of TIM-1 function in the development of Th2 cells and AHR.

35

To create an appropriate targeting construct, specific BACs containing members of the TIM gene family were identified by screening a C57/Bl6 BAC library (RPCI-

23) using high density filter sets. These BAC clones were used to build a 500 kB contig and physical map that covers the approximately 350 kb genomic region encompassing the *Tim* gene family. One specific BAC, RPCI-23-222F8, that contains the complete *Tim1* gene was chosen to generate a TIM targeting construct. The targeting construct deletes a 4 kb region encompassing the promotor region, signal exon, and IgV exon (exons 1 and 2), via homologous recombination with 5' and 3' arms flanking this region. This targeting vector can be used in either C57Bl/6 or BALB/c ES cells, since the homologous arms of the targeting construct are homologous to both BALB/c and HBA (C57Bl/6) DNA. The construct is introduced into ES cells, which are screened for the targeted allele by PCR and by Southern blots.

The targeting vector, pLOX, contains three loxP sites, and by expressing cre recombinase in the targeted ES cells, recombination will generate three forms of the targeted region, of which two alleles, A and B, are used to create *Tim1* KO mice. Selected ES cell clones are introduced into blastocysts to generate chimeric mice and bred for germline transmission of the knockout. Tail DNAs are analyzed for transmission of the knockout. Allele A is used initially, in which cre/lox recombination has used the outermost loxP sites to delete the TK and neomycin selection cassettes in addition to TIM-1 exons 1 and 2. The removal of the entire neo and TK cassette from the TIM-1 genomic targeting region prevents confounding artifacts that can arise secondary to the transcription of neo in close proximity to other genes of the same family. Alternatively, if allele A produces a lethal or confounding phenotype, mice are generated with targeted allele B, in which the neo and TK cassette has been deleted and the TIM-1 region is flanked by lox-p sites. Use of this conditional targeting approach should allow T cell-specific deletion of Tim-1 in mice expressing cre-recombinase under the control of a T cell specific promoter.

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Glu	Ala	Thr	Thr	Phe	Tyr	Pro	Asp	Gln	Thr	Thr	Ala	Glu	Val	Thr	Glu
			180					185					190		
Thr	Leu	Pro	Ser	Thr	Pro	Ala	Asp	Trp	His	Asn	Thr	Val	Thr	Ser	Ser
		195					200					205			
Asp	Asp	Pro	Trp	Asp	Asp	Asn	Thr	Glu	Val	Ile	Pro	Pro	Gln	Lys	Pro
	210					215					220				
Gln	Lys	Asn	Leu	Asn	Lys	Gly	Phe	Tyr	Val	Gly	Ile	Ser	Ile	Ala	Ala
225					230					235					240
Leu	Leu	Ile	Leu	Met	Leu	Leu	Ser	Thr	Met	Val	Ile	Thr	Arg	Tyr	Val
				245					250					255	
Val	Met	Lys	Arg	Lys	Ser	Glu	Ser	Leu	Ser	Phe	Val	Ala	Phe	Pro	Ile
			260					265					270		
Ser	Lys	Ile	Gly	Ala	Ser	Pro	Lys	Lys	Val	Val	Glu	Arg	Thr	Arg	Cys
		275					280				285				
Glu	Asp	Gln	Val	Tyr	Ile	Ile	Glu	Asp	Thr	Pro	Tyr	Pro	Glu	Glu	Glu
	290					295					300				
Ser															
305															

<210> 6

<211> 958

<212> DNA

<213> Mus musculus

<400> 6

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tcaccctgtc acacttccat gtattttatt gacacacctt ggtggaatcg ttcctatgtg 180
ttggggccta ggggaatgcc gccattctta ttgtatacgg tcaacttatct ggaccaatgg 240
atatacggtc acacatcaga ggaacagtcg ataccagcta aagggaataa tttcagaagg 300
aaatgtgtcc ttgaccatag agaacactgt tgtgggtgat ggtgggtccct attgctgtgt 360
agtggagata cctggagcgt tccattttgt ggactatatg ttggaagtta aaccagaaat 420
ttccacgagt ccaccaacaa ggcccacagc tacaggaaga cccacaacta tttcaacaag 480
atccacacat gtaccaacat caaccagagt ctctacctct acttctccaa caccagcaca 540
cacagagacc tacaaccag aggccactac attttatcca gatcagacta cagctgaggt 600
gacagaaacc ttaccctcta ctctgcaga ctggcataac actgtgacat cctcagatga 660
cccttgggat gataacactg aagtaatccc tccacagaag ccacagaaaa acctgaataa 720
gggcttctat gttggcatct ccattgcagc cctgctgata ttgatgcttc tgagcaccat 780
ggttatcacc aggtacgtgg ttatgaaaag gaagtcagaa tctctgagct ttgttgctct 840
ccctatctct aagattggag cttcccccaa aaaagtgggt gaacggacca gatgtgaaga 900
ccaggtctac attattgaag acactcctta ccctgaagaa gagtcctagt gcctctac 958

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<210> 7

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<211> 305

<212> PRT

<213> Mus musculus

<220>

<221> VARIANT

<222> (1)...(305)

<223> TIM-2, C.D2 ES-HBA and DBA/2J allele

<400> 7

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Met Asn Gln Ile Gln Val Phe Ile Ser Gly Leu Ile Leu Leu Leu Pro
 1           5           10           15
Gly Ala Val Glu Ser His Thr Ala Val Gln Gly Leu Ala Gly His Pro
          20           25           30
Val Thr Leu Pro Cys Ile Tyr Ser Thr His Leu Gly Gly Ile Val Pro
          35           40           45
Met Cys Trp Gly Leu Gly Glu Cys Arg His Ser Tyr Cys Ile Arg Ser
          50           55           60
Leu Ile Trp Thr Asn Gly Tyr Thr Val Thr His Gln Arg Asn Ser Arg
65           70           75           80
Tyr Gln Leu Lys Gly Asn Ile Ser Glu Gly Asn Val Ser Leu Thr Ile
          85           90           95
Glu Asn Thr Val Val Gly Asp Gly Gly Pro Tyr Cys Cys Val Val Glu
          100          105          110
Ile Pro Gly Ala Phe His Phe Val Asp Tyr Met Leu Glu Val Lys Pro
          115          120          125
Glu Ile Ser Thr Ser Pro Pro Thr Arg Pro Thr Ala Thr Gly Arg Pro
          130          135          140
Thr Thr Ile Ser Thr Arg Ser Thr His Val Pro Thr Ser Thr Arg Val
145          150          155          160
Ser Thr Ser Thr Ser Pro Thr Pro Ala His Thr Glu Thr Tyr Lys Pro
          165          170          175
Glu Ala Thr Thr Phe Tyr Pro Asp Gln Thr Thr Ala Glu Val Thr Glu
          180          185          190
Thr Leu Pro Ser Thr Pro Ala Asp Trp His Asn Thr Val Thr Ser Ser
          195          200          205
Asp Asp Pro Trp Asp Asp Asn Thr Glu Val Ile Pro Pro Gln Lys Pro
          210          215          220
Gln Lys Asn Leu Asn Lys Gly Phe Tyr Val Gly Ile Ser Ile Ala Ala
225          230          235          240
Leu Leu Ile Leu Met Leu Leu Ser Thr Met Val Ile Thr Arg Tyr Val
          245          250          255
Val Met Lys Arg Lys Ser Glu Ser Leu Ser Phe Val Ala Phe Pro Ile
          260          265          270
Ser Lys Ile Gly Ala Ser Pro Lys Lys Val Val Glu Arg Thr Arg Cys
          275          280          285
Glu Asp Gln Val Tyr Ile Ile Glu Asp Thr Pro Tyr Pro Glu Glu Glu
          290          295          300
Ser
305

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<210> 8

<211> 958

<212> DNA

<213> Mus musculus

<400> 8

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tcaccctgtc acacttccat gtatttattc gacacacctt ggtggaatcg ttcctatgtg 180
ttggggccta ggggaatgcc gccattctta ttgtatacgg tcacttatct ggaccaatgg 240

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atatacgggtc acacatcaga ggaacagtcg ataccagcta aaggggaata tttcagaagg 300
aaatgtgtcc ttgaccatag agaacactgt tgtgggtgat ggtgggtccct attgctgtgt 360
agtggagata cctggagcgt tccattttgt ggactatatg ttggaagtta aaccagaaat 420
ttccacgagt ccaccaacaa ggcccacagc tacaggaaga cccacaacta tttcaacaag 480
atccacacat gtaccaacat caaccagagt ctctacctct acttctccaa caccagcaca 540
cacagagacc taaaaccag aggccactac attttatcca gatcagacta cagctgaggt 600
gacagaaacc ttaccctcta ctctgcaga ctggcataac actgtgacat cctcagatga 660
cccttgggat gataacactg aagtaatccc tccacagaag ccacagaaaa acctgaataa 720
gggcttctat gttggcatct ccattgcagc cctgctgata ttgatgcttc tgagcaccat 780
ggttatcacc aggtacgtgg ttatgaaaag gaagtcagaa tctctgagct tcgttgcctt 840
ccctatctct aagattggag cttcccccaa aaaagtggtc gaacggacca gatgtgaaga 900
ccaggtctac attattgaag acactcctta ccccgaagaa gagtcctagt gcctctac 958

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<210> 9

<211> 281

<212> PRT

<213> Mus musculus

<220>

<221> VARIANT

<222> (1)...(281)

<223> TIM-3 BALB/c allele

<400> 9

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Met Phe Ser Gly Leu Thr Leu Asn Cys Val Leu Leu Leu Leu Gln Leu
 1          5          10          15
Leu Leu Ala Arg Ser Leu Glu Asp Gly Tyr Lys Val Glu Val Gly Lys
 20          25          30
Asn Ala Tyr Leu Pro Cys Ser Tyr Thr Leu Pro Thr Ser Gly Thr Leu
 35          40          45
Val Pro Met Cys Trp Gly Lys Gly Phe Cys Pro Trp Ser Gln Cys Thr
 50          55          60
Asn Glu Leu Leu Arg Thr Asp Glu Arg Asn Val Thr Tyr Gln Lys Ser
 65          70          75          80
Ser Arg Tyr Gln Leu Lys Gly Asp Leu Asn Lys Gly Asp Val Ser Leu
 85          90          95
Ile Ile Lys Asn Val Thr Leu Asp Asp His Gly Thr Tyr Cys Cys Arg
 100          105          110
Ile Gln Phe Pro Gly Leu Met Asn Asp Lys Lys Leu Glu Leu Lys Leu
 115          120          125
Asp Ile Lys Ala Ala Lys Val Thr Pro Ala Gln Thr Ala His Gly Asp
 130          135          140
Ser Thr Thr Ala Ser Pro Arg Thr Leu Thr Thr Glu Arg Asn Gly Ser
 145          150          155          160
Glu Thr Gln Thr Leu Val Thr Leu His Asn Asn Asn Gly Thr Lys Ile
 165          170          175
Ser Thr Trp Ala Asp Glu Ile Lys Asp Ser Gly Glu Thr Ile Arg Thr
 180          185          190
Ala Ile His Ile Gly Val Gly Val Ser Ala Gly Leu Thr Leu Ala Leu
 195          200          205
Ile Ile Gly Val Leu Ile Leu Lys Trp Tyr Ser Cys Lys Lys Lys Lys
 210          215          220
Leu Ser Ser Leu Ser Leu Ile Thr Leu Ala Asn Leu Pro Pro Gly Gly
 225          230          235          240
Leu Ala Asn Ala Gly Ala Val Arg Ile Arg Ser Glu Glu Asn Ile Tyr
 245          250          255
Thr Ile Glu Glu Asn Val Tyr Glu Val Glu Asn Ser Asn Glu Tyr Tyr
 260          265          270
Cys Tyr Val Asn Ser Gln Gln Pro Ser
 275          280

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<210> 10
 <211> 2725
 <212> DNA
 <213> Mus musculus

<400> 10
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 gcaaggatcat tggaagatgg ttataagggt gaggttggtta aaaatgccta tctgccctgc 180
 agttacactc tacctacatc tgggacactt gtgcctatgt gctggggcaa gggatttctgt 240
 ccttgggtcac agtgtaccaa tgagttgctc agaactgatg aaagaaatgt gacatatcag 300
 aaatccagca gataccagct aaagggcgat ctcaacaaaag gagatgtgtc tctgatcata 360
 aagaatgtga ctctggatga ccatgggacc tactgctgca ggatacagtt ccctgggtctt 420
 atgaatgata aaaaattaga actgaaatta gacatcaaag cagccaagggt cactccagct 480
 cagactgccc atggggactc tactacagct tctccaagaa ccctaaccac ggagagaaat 540
 ggttcagaga cacagacact ggtgaccctc cataataaca atggaacaaa aatttccaca 600
 tgggctgatg aaattaagga ctctggagaa acgatcagaa ctgctatcca cattggagtg 660
 ggagtctctg ctgggttgac cctggcactt atcattggtg tcttaatcct taaatggtat 720
 tcctgtaaga aaaagaagtt atcgagtttg agccttatta cactggccaa cttgcctcca 780
 ggaggggttg caaatgcagg agcagtcagg attcgctctg aggaaaatat ctacaccatc 840
 gaggagaacg tatatgaagt ggagaattca aatgagtact actgctacgt caacagccag 900
 cagccatcct gaccgcctct ggactgccac ttttaaaggc tcgccttcat ttctgacttt 960
 ggtatttccc tttttgaaaa ctatgtgata tgtcacttgg caacctcatt ggaggttctg 1020
 accacagcca ctgagaaaag agttccagtt ttctggggat aattaactca caaggggatt 1080
 cgactgtaac tcatgctaca ttgaaatgct ccattttatc cctgagtttc agggatcggg 1140
 tctccactc cagagacttc aatcatgcgt gttgaagctc actcgtgctt tcatacatta 1200
 ggaatggtta gtgtgatgtc tttgagacat agaggtttgt ggtatatccg caaagctcct 1260
 gaacaggtag ggggaataaaa gggctaagat aggaagggtgc ggttctttgt tgatgttgaa 1320
 aatctaaaga agttggtagc ttttctagag atttctgacc ttgaaagatt aagaaaaagc 1380
 caggtggcat atgcttaaca cgatataact tgggaacctt aggcaggagg gtgataagtt 1440
 caaggtcagc cagggctatg ctggtaagac tgtctcaaaa tccaaagacg aaaataaaca 1500
 tagagacagc aggaggctgg agatgaggct cggacagtga ggtgcatttt gtacaagcac 1560
 gaggaatcta tatttgatcg tagacccac atgaaaaagc taggcctggt agagcatgct 1620
 tgtagactca agagatggag aggtaaaggc acaacagatc cccggggctt gcgtgcagtc 1680
 agcttagcct aggtgctgag ttccaagtcc acaagagtc ctgtctcaaa gtaagatgga 1740
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 gaacctgcac acacacacac acacacacac acacacacac acacacacac acacatgaaa 1860
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 tgcctctgtt aagacatgag tgggagcatg gcagagcagt ccagtaatta attccagcac 1980
 tcagaaggct ggagcagaag cgtggagagt tcaggagcac tgtgcccaac actgccagac 2040
 tcttcttaca caagaaaaag gttacccgca agcagcctgc tgtctgtaaa aggaaaccct 2100
 gcgaaaggca aactttgact gttgtgtgct caaggggaac tgactcagac aacttctcca 2160
 ttcctggagg aaactggagc tgtttctgac agaagaacaa ccggtgactg ggacatacga 2220
 aggcagagct cttgcagcaa tctatatagt cagcaaaata ttctttggga ggacagtcgt 2280
 caccaaattg atttccaagc cgggtggacct cagtttcatc tggcttacag ctgcctgcc 2340
 agtgccttg atctgtgctg gctcccatct ataacagaat caaattaaat agaccccgag 2400
 tgaaaaatatt aagtgagcag aaaggtagct ttgttcaaag atttttttgc attggggagc 2460
 aactgtgtac atcagaggac atctgttagt gaggacacca aaacctgtgg taccgttttt 2520
 tcatgtatga attttgttgt ttaggttgct tctagctagc tgtggaggtc ctggctttct 2580
 taggtgggta tggaaggag accatctaac aaaatccatt agagataaca gctctcatgc 2640
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<210> 11
 <211> 281
 <212> PRT
 <213> Mus musculus

<220>
 <221> VARIANT
 <222> (1)...(281)
 <223> TIM-3, C.D2 ES-HBA and DBA/2J allele

<400> 11

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Met Phe Ser Gly Leu Thr Leu Asn Cys Val Leu Leu Leu Leu Gln Leu
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Leu Leu Ala Arg Ser Leu Glu Asn Ala Tyr Val Phe Glu Val Gly Lys
          20          25          30
Asn Ala Tyr Leu Pro Cys Ser Tyr Thr Leu Ser Thr Pro Gly Ala Leu
          35          40          45
Val Pro Met Cys Trp Gly Lys Gly Phe Cys Pro Trp Ser Gln Cys Thr
          50          55          60
Asn Glu Leu Leu Arg Thr Asp Glu Arg Asn Val Thr Tyr Gln Lys Ser
65          70          75          80
Ser Arg Tyr Gln Leu Lys Gly Asp Leu Asn Lys Gly Asp Val Ser Leu
          85          90          95
Ile Ile Lys Asn Val Thr Leu Asp Asp His Gly Thr Tyr Cys Cys Arg
          100          105          110
Ile Gln Phe Pro Gly Leu Met Asn Asp Lys Lys Leu Glu Leu Lys Leu
          115          120          125
Asp Ile Lys Ala Ala Lys Val Thr Pro Ala Gln Thr Ala His Gly Asp
          130          135          140
Ser Thr Thr Ala Ser Pro Arg Thr Leu Thr Thr Glu Arg Asn Gly Ser
145          150          155          160
Glu Thr Gln Thr Leu Val Thr Leu His Asn Asn Asn Gly Thr Lys Ile
          165          170          175
Ser Thr Trp Ala Asp Glu Ile Lys Asp Ser Gly Glu Thr Ile Arg Thr
          180          185          190
Ala Ile His Ile Gly Val Gly Val Ser Ala Gly Leu Thr Leu Ala Leu
          195          200          205
Ile Ile Gly Val Leu Ile Leu Lys Trp Tyr Ser Cys Lys Lys Lys Lys
          210          215          220
Leu Ser Ser Leu Ser Leu Ile Thr Leu Ala Asn Leu Pro Pro Gly Gly
225          230          235          240
Leu Ala Asn Ala Gly Ala Val Arg Ile Arg Ser Glu Glu Asn Ile Tyr
          245          250          255
Thr Ile Glu Glu Asn Val Tyr Glu Val Glu Asn Ser Asn Glu Tyr Tyr
          260          265          270
Cys Tyr Val Asn Ser Gln Gln Pro Ser
          275          280

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<210> 12

<211> 862

<212> DNA

<213> Mus musculus

<400> 12

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tctgccctgc agttacactc tatctacacc tggggcactt gtgcctatgt gctggggcaa 180
gggattctgt ccttggtcac agtgtaccaa cgagttgctc agaactgatg aaagaaatgt 240
gacatatcag aaatccagca gataccagct aaagggcgat ctcaacaaag gagacgtgtc 300
tctgatcata aagaatgtga ctctggatga ccatgggacc tactgctgca ggatacagtt 360
ccctgggtctt atgaatgata aaaaattaga actgaaatta gacatcaaag cagccaaggt 420
cactccagct cagactgccc atggggactc tactacagct tctccaagaa ccctaaccac 480
ggagagaaat gggttcagaga cacagacact ggtgaccctc cataataaca atggaacaaa 540
aatttccaca tgggctgatg aaattaagga ctctggagaa acgatcagaa ctgctatcca 600
cattggagtg ggagtctctg ctgggttgac cctggcactt atcattggtg tcttaatcct 660
taaattggtat tcctgtaaga aaaagaagtt atcgagtttg agccttatta cactggccaa 720
cttgccctca ggagggttg ccaatgcagg agcagtcagg attcgctctg aggaaaatat 780
ctacaccatc gaggagaacg tatatgaagt ggagaattca aatgagtact actgctacgt 840
caacagccag cagccatcct ga 862

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<210> 13
 <211> 345
 <212> PRT
 <213> Mus musculus

<220>
 <221> VARIANT
 <222> (1)...(345)
 <223> TIM-4, BALB/c allele

<400> 13
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 1 5 10 15
 Leu Tyr Leu Ser Lys Ser Pro Ala Ala Ser Glu Asp Thr Ile Ile Gly
 20 25 30
 Phe Leu Gly Gln Pro Val Thr Leu Pro Cys His Tyr Leu Ser Trp Ser
 35 40 45
 Gln Ser Arg Asn Ser Met Cys Trp Gly Lys Gly Ser Cys Pro Asn Ser
 50 55 60
 Lys Cys Asn Ala Glu Leu Leu Arg Thr Asp Gly Thr Arg Ile Ile Ser
 65 70 75 80
 Arg Lys Ser Thr Lys Tyr Thr Leu Leu Gly Lys Val Gln Phe Gly Glu
 85 90 95
 Val Ser Leu Thr Ile Ser Asn Thr Asn Arg Gly Asp Ser Gly Val Tyr
 100 105 110
 Cys Cys Arg Ile Glu Val Pro Gly Trp Phe Asn Asp Val Lys Lys Asn
 115 120 125
 Val Arg Leu Glu Leu Arg Arg Ala Thr Thr Thr Lys Lys Pro Thr Thr
 130 135 140
 Thr Thr Arg Pro Thr Thr Thr Pro Tyr Val Thr Thr Thr Thr Pro Glu
 145 150 155 160
 Leu Leu Pro Thr Thr Val Met Thr Thr Ser Val Leu Pro Thr Thr Thr
 165 170 175
 Pro Pro Gln Thr Leu Ala Thr Thr Ala Phe Ser Thr Ala Val Thr Thr
 180 185 190
 Cys Pro Ser Thr Thr Pro Gly Ser Phe Ser Gln Glu Thr Thr Lys Gly
 195 200 205
 Ser Ala Ile Thr Thr Glu Ser Glu Thr Leu Pro Ala Ser Asn His Ser
 210 215 220
 Gln Arg Ser Met Met Thr Ile Ser Thr Asp Ile Ala Val Leu Arg Pro
 225 230 235 240
 Thr Gly Ser Asn Pro Gly Ile Leu Pro Ser Thr Ser Gln Leu Thr Thr
 245 250 255
 Gln Lys Thr Thr Leu Thr Thr Ser Glu Ser Leu Gln Lys Thr Thr Lys
 260 265 270
 Ser His Gln Ile Asn Ser Arg Gln Thr Ile Leu Ile Ile Ala Cys Cys
 275 280 285
 Val Gly Phe Val Leu Met Val Leu Leu Phe Leu Ala Phe Leu Leu Arg
 290 295 300
 Gly Lys Val Thr Gly Ala Asn Cys Leu Gln Arg His Lys Arg Pro Asp
 305 310 315 320
 Asn Thr Glu Val Ser Asp Ser Phe Leu Asn Asp Ile Ser His Gly Arg
 325 330 335
 Asp Asp Glu Asp Gly Ile Phe Thr Leu
 340 345

<210> 14
 <211> 1032
 <212> DNA
 <213> Mus musculus

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<400> 14

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cattacctct cgtgggtccca gagccgcaac agtatgtgct ggggcaaagg ttcatgtccc 180
aattccaagt gcaatgcaga gcttctccgt acagatggaa caagaatcat ctccaggaag 240
tcaacaaaat atacactttt ggggaaggtc cagtttgggtg aagtgtcctt gaccatctca 300
aacaccaatc gaggtgacag tgggggtgtac tgctgccgta tagaggtgcc tggctgggtc 360
aatgatgtca agaagaatgt gcgcttggag ctgaggagag ccacaacaac caaaaaacca 420
acaacaacca cccggccaac caccaccctt tatgtaacca ccaccacccc agagctgctt 480
ccaacaacag tcatgaccac atctgttctt ccaaccacca caccaccca gacactagcc 540
accactgcct tcagtacagc agtgaccacg tgcccctcaa caacacctgg ctcttctca 600
caagaaacca caaaagggtc cgccatcact acagaatcag aaactctgcc tgcattcaat 660
cactctcaaa gaagcatgat gaccatatct acagacatag ccgtactcag gccacaggc 720
tctaaccctg ggattctccc atccacttca cagctgacga cacagaaaac aacattaaca 780
acaagtgagt ctttgcagaa gacaactaaa tcacatcaga tcaacagcag acagaccatc 840
ttgatcattg cctgctgtgt gggatttgtg ctaatgggtg tattgtttct ggcgtttctc 900
cttcgaggga aagtcacagg agccaactgt ttgcagagac acaagaggcc agacaacact 960
gaagatagtg acagcgtcct caatgacatg tcacacggga gggatgatga agacgggatc 1020
ttcactctct ga 1032

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<210> 15

<211> 345

<212> PRT

<213> Mus musculus

<220>

<221> VARIANT

<222> (1)...(345)

<223> C.D2 ES-HBA and DBA/2J allele

<400> 15

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Met Ser Lys Gly Leu Leu Leu Leu Trp Leu Val Met Glu Leu Trp Trp
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Leu Tyr Leu Ser Lys Ser Pro Ala Ala Ser Glu Asp Thr Ile Ile Gly
          20          25          30
Phe Leu Gly Gln Pro Val Thr Leu Pro Cys His Tyr Leu Ser Trp Ser
          35          40          45
Gln Ser Arg Asn Ser Met Cys Trp Gly Lys Gly Ser Cys Pro Asn Ser
          50          55          60
Lys Cys Asn Ala Glu Leu Leu Arg Thr Asp Gly Thr Arg Ile Ile Ser
65          70          75          80
Arg Lys Ser Thr Lys Tyr Thr Leu Leu Gly Lys Val Gln Phe Gly Glu
          85          90          95
Val Ser Leu Thr Ile Ser Asn Thr Asn Arg Gly Asp Ser Gly Val Tyr
          100          105          110
Cys Cys Arg Ile Glu Val Pro Gly Trp Phe Asn Asp Val Lys Lys Asn
          115          120          125
Val Arg Leu Glu Leu Arg Arg Ala Thr Thr Thr Lys Lys Pro Thr Thr
          130          135          140
Thr Thr Arg Pro Thr Thr Thr Pro Tyr Val Thr Thr Thr Thr Pro Glu
145          150          155          160
Leu Leu Pro Thr Thr Val Met Thr Thr Ser Val Leu Pro Thr Thr Thr
          165          170          175
Pro Pro Gln Thr Leu Ala Thr Thr Ala Phe Ser Thr Ala Val Thr Thr
          180          185          190
Cys Pro Ser Thr Thr Pro Gly Ser Phe Ser Gln Glu Thr Thr Lys Gly
          195          200          205
Ser Ala Phe Thr Thr Glu Ser Glu Thr Leu Pro Ala Ser Asn His Ser
          210          215          220
Gln Arg Ser Met Met Thr Ile Ser Thr Asp Ile Ala Val Leu Arg Pro
225          230          235          240
Thr Gly Ser Asn Pro Gly Ile Leu Pro Ser Thr Ser Gln Leu Thr Thr

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				245					250						255				
Gln	Lys	Thr	Thr	Leu	Thr	Thr	Ser	Glu	Ser	Leu	Gln	Lys	Thr	Thr	Lys				
				260				265						270					
Ser	His	Gln	Ile	Asn	Ser	Arg	Gln	Thr	Ile	Leu	Ile	Ile	Ala	Cys	Cys				
		275					280					285							
Val	Gly	Phe	Val	Leu	Met	Val	Leu	Leu	Phe	Leu	Ala	Phe	Leu	Leu	Arg				
	290					295				300									
Gly	Lys	Val	Thr	Gly	Ala	Asn	Cys	Leu	Gln	Arg	His	Lys	Arg	Pro	Asp				
305					310					315					320				
Asn	Thr	Glu	Val	Ser	Asp	Ser	Phe	Leu	Asn	Asp	Ile	Ser	His	Gly	Arg				
				325				330						335					
Asp	Asp	Glu	Asp	Gly	Ile	Phe	Thr	Leu											
			340					345											

<210> 16
 <211> 1032
 <212> DNA
 <213> Mus musculus

<400> 16
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 cattacctct cgtgggtccca gagccgcaac agtatgtgct ggggcaaagg ttcatgtccc 180
 aattccaagt gcaatgcaga gcttctccgt acagatggaa caagaatcat ctccaggaag 240
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 aacaccaatc gaggtgacag tgggggtgtac tgctgccgta tagaggtgcc tggctgggttc 360
 aatgatgtca agaagaatgt gcgcttggag ctgaggagag ccacaacaac caaaaaacca 420
 acaacaacca cccggccaac caccaccctt tatgtaacca ccaccacccc agagctgctt 480
 ccaacaacag tcatgaccac atctgttctt ccaaccacca caccaccccac gacactagcc 540
 accactgcct tcagtacagc agtgaccacg tgcccctcaa caacacctgg ctctttctca 600
 caagaaacca caaaaggggtc cgccttcaact acagaatcag aaactctgcc tgcattccaat 660
 cactctcaaa gaagcatgat gaccatatct acagacatag ccgtactcag gccacacaggc 720
 tctaaccctg ggattctccc atccacttca cagctgacga cacagaaaac aacattaaca 780
 acaagtgagt ctttgcagaa gacaactaaa tcacatcaga tcaacagcag acagaccatc 840
 ttgatcattg cctgctgtgt gggatttgtg ctaatggtgt tattgtttct ggcgtttctc 900
 ctctcagagg aagtcacagg agccaactgt ttgcagagac acaagaggcc agacaacact 960
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<210> 17
 <211> 359
 <212> PRT
 <213> H. sapiens

<220>
 <221> VARIANT
 <222> (1)...(360)
 <223> TIM-1 allele 1

<400> 17
 Met His Pro Gln Val Val Ile Leu Ser Leu Ile Leu His Leu Ala Asp
 1 5 10 15
 Ser Val Ala Gly Ser Val Lys Val Gly Gly Glu Ala Gly Pro Ser Val
 20 25 30
 Thr Leu Pro Cys His Tyr Ser Gly Ala Val Thr Ser Met Cys Trp Asn
 35 40 45
 Arg Gly Ser Cys Ser Leu Phe Thr Cys Gln Asn Gly Ile Val Trp Thr
 50 55 60
 Asn Gly Thr His Val Thr Tyr Arg Lys Asp Thr Arg Tyr Lys Leu Leu
 65 70 75 80
 Gly Asp Leu Ser Arg Arg Asp Val Ser Leu Thr Ile Glu Asn Thr Ala

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										12/25										
					85						90						95			
Val	Ser	Asp	Ser	Gly	Val	Tyr	Cys	Cys	Arg	Val	Glu	His	Arg	Gly	Trp					
					100						105						110			
Phe	Asn	Asp	Met	Lys	Ile	Thr	Val	Ser	Leu	Glu	Ile	Val	Pro	Pro	Lys					
					115						120						125			
Val	Thr	Thr	Thr	Pro	Ile	Val	Thr	Thr	Val	Pro	Thr	Val	Thr	Thr	Val					
					130						135						140			
Arg	Thr	Ser	Thr	Thr	Val	Pro	Thr	Thr	Thr	Thr	Val	Pro	Thr	Thr	Thr					
					145						150						155			
Val	Pro	Thr	Thr	Met	Ser	Ile	Pro	Thr	Thr	Thr	Thr	Val	Pro	Thr	Thr					
					165						170						175			
Met	Thr	Val	Ser	Thr	Thr	Thr	Ser	Val	Pro	Thr	Thr	Thr	Ser	Ile	Pro					
					180						185						190			
Thr	Thr	Thr	Ser	Val	Pro	Val	Thr	Thr	Thr	Val	Ser	Thr	Phe	Val	Pro					
					195						200						205			
Pro	Met	Pro	Leu	Pro	Arg	Gln	Asn	His	Glu	Pro	Val	Ala	Thr	Ser	Pro					
					210						215						220			
Ser	Ser	Pro	Gln	Pro	Ala	Glu	Thr	His	Pro	Thr	Thr	Leu	Gln	Gly	Ala					
					225						230						235			
Ile	Arg	Arg	Glu	Pro	Thr	Ser	Ser	Pro	Leu	Tyr	Ser	Tyr	Thr	Thr	Asp					
					245						250						255			
Gly	Asn	Asp	Thr	Val	Thr	Glu	Ser	Ser	Asp	Gly	Leu	Trp	Asn	Asn	Asn					
					260						265						270			
Gln	Thr	Gln	Leu	Phe	Leu	Glu	His	Ser	Leu	Leu	Thr	Ala	Asn	Thr	Thr					
					275						280						285			
Lys	Gly	Ile	Tyr	Ala	Gly	Val	Cys	Ile	Ser	Val	Leu	Val	Leu	Leu	Ala					
					290						295						300			
Leu	Leu	Gly	Val	Ile	Ile	Ala	Lys	Lys	Tyr	Phe	Phe	Lys	Lys	Glu	Val					
					305						310						315			
Gln	Gln	Leu	Ser	Val	Ser	Phe	Ser	Ser	Leu	Gln	Ile	Lys	Ala	Leu	Gln					
					325						330						335			
Asn	Ala	Val	Glu	Lys	Glu	Val	Gln	Ala	Glu	Asp	Asn	Ile	Tyr	Ile	Glu					
					340						345						350			
Asn	Ser	Leu	Tyr	Ala	Thr	Asp														
					355															

<210> 18

<211> 1080

<212> DNA

<213> H. sapiens

<400> 18

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gctgtcacat caatgtgctg gaatagaggc tcatgttctc tattcacatg ccaaaatggc 180
attgtctgga ccaatggaac ccacgtcacc tatcggaagg acacacgcta taagctattg 240
ggggaccttt caagaaggga tgtctctttg accatagaaa atacagctgt gtctgacagt 300
ggcgtatatt gttgccgtgt tgagcaccgt gggtggttca atgacatgaa aatcacccgt 360
tcattggaga ttgtgccacc caaggtcacg actactccaa ttgtcacaac tgttccaacc 420
gtcacgactg ttcgaaagag caccactgtt ccaacgacaa cgactgttcc aacgacaact 480
gttccaacaa caatgagcat tccaacgaca acgactgttc cgacgacaat gactgtttca 540
acgacaacga gcgttccaac gacaacgagc attccaacaa caacaagtgt tccagtgaca 600
acaacggtct ctacctttgt tcctccaatg cctttgccca ggcagaacca tgaaccagta 660
gccacttcac catcttcacc tcagccagca gaaaccacc ctacgacact gcagggagca 720
ataaggagag aaccaccag ctcaccattg tactcttaca caacagatgg gaatgacacc 780
gtgacagagt cttcagatgg cttttggaat aacaatcaaa ctcaactgtt cctagaacat 840
agtctactga cggccaatac cactaaagga atctatgctg gagtctgtat ttctgtcttg 900
gtgcttcttg ctcttttggg tgtcatcatt gccaaaagt atttcttcaa aaaggaggtt 960
caacaactaa gtgtttcatt tagcagcctt caaattaaag ctttgcaaaa tgcagttgaa 1020
aaggaagtcc aagcagaaga caatatctac attgagaata gtctttatgc cacggactaa 1080

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<210> 19
 <211> 359
 <212> PRT
 <213> H. sapiens

<220>
 <221> VARIANT
 <222> (1)...(359)
 <223> TIM-1, allele 2

<400> 19
 Met His Pro Gln Val Val Ile Leu Ser Leu Ile Leu His Leu Ala Asp
 1 5 10 15
 Ser Val Ala Gly Ser Val Lys Val Gly Gly Glu Ala Gly Pro Ser Val
 20 25 30
 Thr Leu Pro Cys His Tyr Ser Gly Ala Val Thr Ser Met Cys Trp Asn
 35 40 45
 Arg Gly Ser Cys Ser Leu Phe Thr Cys Gln Asn Gly Ile Val Trp Thr
 50 55 60
 Asn Gly Thr His Val Thr Tyr Arg Lys Asp Thr Arg Tyr Lys Leu Leu
 65 70 75 80
 Gly Asp Leu Ser Arg Arg Asp Val Ser Leu Thr Ile Glu Asn Thr Ala
 85 90 95
 Val Ser Asp Ser Gly Val Tyr Cys Cys Arg Val Glu His Arg Gly Trp
 100 105 110
 Phe Asn Asp Met Lys Ile Thr Val Ser Leu Glu Ile Val Pro Pro Lys
 115 120 125
 Val Thr Thr Thr Pro Ile Val Thr Thr Val Pro Thr Val Thr Thr Val
 130 135 140
 Arg Thr Ser Thr Thr Val Pro Thr Thr Thr Thr Val Pro Thr Thr Thr
 145 150 155 160
 Val Pro Thr Thr Met Ser Ile Pro Thr Thr Thr Thr Val Pro Thr Thr
 165 170 175
 Met Thr Val Ser Thr Thr Thr Ser Val Pro Thr Thr Thr Ser Ile Pro
 180 185 190
 Thr Thr Thr Ser Val Pro Val Thr Thr Ala Val Ser Thr Phe Val Pro
 195 200 205
 Pro Met Pro Leu Pro Arg Gln Asn His Glu Pro Val Ala Thr Ser Pro
 210 215 220
 Ser Ser Pro Gln Pro Ala Glu Thr His Pro Thr Thr Leu Gln Gly Ala
 225 230 235 240
 Ile Arg Arg Glu Pro Thr Ser Ser Pro Leu Tyr Ser Tyr Thr Thr Asp
 245 250 255
 Gly Asn Asp Thr Val Thr Glu Ser Ser Asp Gly Leu Trp Asn Asn Asn
 260 265 270
 Gln Thr Gln Leu Phe Leu Glu His Ser Leu Leu Thr Ala Asn Thr Thr
 275 280 285
 Lys Gly Ile Tyr Ala Gly Val Cys Ile Ser Val Leu Val Leu Leu Ala
 290 295 300
 Leu Leu Gly Val Ile Ile Ala Lys Lys Tyr Phe Phe Lys Lys Glu Val
 305 310 315 320
 Gln Gln Leu Ser Val Ser Phe Ser Ser Leu Gln Ile Lys Ala Leu Gln
 325 330 335
 Asn Ala Val Glu Lys Glu Val Gln Ala Glu Asp Asn Ile Tyr Ile Glu
 340 345 350
 Asn Ser Leu Tyr Ala Thr Asp
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<210> 20
 <211> 1080

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14/25

<212> DNA

<213> H. sapiens

<400> 20

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gctgtcacat caatgtgctg gaatagaggc tcatgtttctc tattcacatg ccaaaatggc 180
attgtctgga ccaatggaac ccacgtcacc tatcggaagg acacacgcta taagctattg 240
ggggaccttt caagaaggga tgtctctttg accatagaaa atacagctgt gtctgacagt 300
ggcgtatatt gttgccgtgt tgagcaccgt ggggtgggttca atgacatgaa aatcaccgta 360
tcattggaga ttgtgccacc caagggtcacg actactccaa ttgtcacaac tgttccaacc 420
gtcacgactg ttcgaacgag caccactgtt ccaacgacaa cgactgttcc aacgacaact 480
gttccaacaa caatgagcat tccaacgaca acgactgttc cgacgacaat gactgtttca 540
acgacaacga gcgttccaac gacaacgagc attccaacaa caacaagtgt tccagtgaca 600
acagcgggtct ctacctttgt tcctccaatg cctttgcccc ggcagaacca tgaaccagta 660
gccacttcac catcttcacc tcagccagca gaaaccacc ctacgacact gcagggagca 720
ataaggagag aaccaccag ctcaccattg tactcttaca caacagatgg gaatgacacc 780
gtgacagagt cttcagatgg cctttggaat aacaatcaaa ctcaactgtt cctagaacat 840
agtctactga cggccaatac cactaaagga atctatgctg gagtctgtat ttctgtcttg 900
gtgcttcttg ctcttttggg tgtcatcatt gccaaaaagt atttcttcaa aaaggagggt 960
caacaactaa gtgttttcatt tagcagcctt caaattaaag ctttgcaaaa tgcagttgaa 1020
aaggaagtcc aagcagaaga caatatctac attgagaata gtctttatgc cacggactaa 1080

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<210> 21

<211> 365

<212> PRT

<213> H. sapiens

<220>

<221> VARIANT

<222> (1)...(365)

<223> TIM-1, allele 3

<400> 21

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 20          25          30
Thr Leu Pro Cys His Tyr Ser Gly Ala Val Thr Ser Met Cys Trp Asn
 35          40          45
Arg Gly Ser Cys Ser Leu Phe Thr Cys Gln Asn Gly Ile Val Trp Thr
 50          55          60
Asn Gly Thr His Val Thr Tyr Arg Lys Asp Thr Arg Tyr Lys Leu Leu
 65          70          75          80
Gly Asp Leu Ser Arg Arg Asp Val Ser Leu Thr Ile Glu Asn Thr Ala
 85          90          95
Val Ser Asp Ser Gly Val Tyr Cys Cys Arg Val Glu His Arg Gly Trp
100          105          110
Phe Asn Asp Met Lys Ile Thr Val Ser Leu Glu Ile Val Pro Pro Lys
115          120          125
Val Thr Thr Thr Pro Ile Val Thr Thr Val Pro Thr Val Thr Thr Val
130          135          140
Arg Thr Ser Thr Thr Val Pro Thr Thr Thr Thr Val Pro Met Thr Thr
145          150          155          160
Thr Val Pro Thr Thr Thr Val Pro Thr Thr Met Ser Ile Pro Thr Thr
165          170          175
Thr Thr Val Pro Thr Thr Met Thr Val Ser Thr Thr Thr Ser Val Pro
180          185          190
Thr Thr Thr Ser Ile Pro Thr Thr Thr Ser Val Pro Val Thr Thr Ala
195          200          205
Val Ser Thr Phe Val Pro Pro Met Pro Leu Pro Arg Gln Asn His Glu

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210	215	220
Pro Val Ala Thr Ser	Pro Ser Ser Pro Gln	Pro Ala Glu Thr His Pro
225	230	235
Thr Thr Leu Gln Gly	Ala Ile Arg Arg Glu	Pro Thr Ser Ser Pro Leu
	245	250
Tyr Ser Tyr Thr Thr	Asp Gly Asn Asp Thr	Val Thr Glu Ser Ser Asp
	260	265
Gly Leu Trp Asn Asn Asn	Gln Thr Gln Leu Phe	Leu Glu His Ser Leu
	275	280
Leu Thr Ala Asn Thr Thr	Lys Gly Ile Tyr Ala	Gly Val Cys Ile Ser
	290	295
Val Leu Val Leu Leu Ala	Leu Leu Gly Val Ile	Ile Ala Lys Lys Tyr
305	310	315
Phe Phe Lys Lys Glu	Val Gln Gln Leu Ser	Val Ser Phe Ser Ser Leu
	325	330
Gln Ile Lys Ala Leu Gln	Asn Ala Val Glu Lys	Glu Val Gln Ala Glu
	340	345
Asp Asn Ile Tyr Ile Glu	Asn Ser Leu Tyr Ala	Thr Asp
	355	360

<210> 22
 <211> 1098
 <212> DNA
 <213> H. sapiens

<400> 22

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gctgtcacat caatgtgctg gaatagaggc tcatgtttctc tattcacatg ccaaaatggc 180
attgtctgga ccaatggaac ccacgtcacc tatcggaagg acacacgcta taagctattg 240
ggggaccttt caagaaggga tgtctctttg accatagaaa atacagctgt gtctgacagt 300
ggcgtatatt gttgccgtgt tgagcaccgt ggggtggttca atgacatgaa aatcacctga 360
tcattggaga ttgtgccacc caaggtcacg actactccaa ttgtcacaac tgttccaacc 420
gtcacgactg ttcgaacgag caccactgtt ccaacgacaa cgactgttcc aatgacaacg 480
actgttccaa cgacaactgt tccaacaaca atgagcattc caacgacaac gactgttccg 540
acgacaatga ctgtttcaac gacaacgagc gttccaacga caacgagcat tccaacaaca 600
acaagtgttc cagtgcacaac arcggtctct acctttgttc ctccaatgcc tttgcccagg 660
cagaaccatg aaccagtagc cacttcacca tcttcacctc agccagcaga aaccaccctt 720
acgacactgc agggagcaat aaggagagaa cccaccagct caccattgta ctcttacaca 780
acagatggga atgacaccgt gacagagtct tcagatggcc tttggaataa caatcaaact 840
caactgttcc tagaacatag tctactgacg gccaatacca ctaaaggaat ctatgctgga 900
gtctgtatct ctgtcttggg gcttcttggc cttttgggtg tcatcattgc caaaaagtat 960
ttcttcaaaa aggaggttca acaactaagt gtttcattta gcagccttca aattaaagct 1020
ttgcaaaatg cagttgaaaa ggaagtccaa gcagaagaca atatctacat tgagaatagt 1080
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<210> 23
 <211> 359
 <212> PRT
 <213> H. sapiens

<220>
 <221> VARIANT
 <222> (1)...(359)
 <223> TIM-1, allele 4

<400> 23

Met His Pro Gln Val Val Ile Leu Ser Leu Ile Leu His Leu Ala Asp
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Ser Val Ala Gly Ser Val Lys Val Gly Gly Glu Ala Gly Pro Ser Val
20 25 30

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Thr	Leu	Pro	Cys	His	Tyr	Ser	Gly	Ala	Val	Thr	Ser	Met	Cys	Trp	Asn
		35					40					45			
Arg	Gly	Ser	Cys	Ser	Leu	Phe	Thr	Cys	Gln	Asn	Gly	Ile	Val	Trp	Thr
	50					55					60				
Asn	Gly	Thr	His	Val	Thr	Tyr	Arg	Lys	Asp	Thr	Arg	Tyr	Lys	Leu	Leu
65					70					75					80
Gly	Asp	Leu	Ser	Arg	Arg	Asp	Val	Ser	Leu	Thr	Ile	Glu	Asn	Thr	Ala
				85					90					95	
Val	Ser	Asp	Ser	Gly	Val	Tyr	Cys	Cys	Arg	Val	Glu	His	Arg	Gly	Trp
			100					105					110		
Phe	Asn	Asp	Met	Lys	Ile	Thr	Val	Ser	Leu	Glu	Ile	Val	Pro	Pro	Lys
		115					120					125			
Val	Thr	Thr	Thr	Pro	Ile	Val	Thr	Thr	Val	Pro	Thr	Val	Thr	Thr	Val
	130					135					140				
Arg	Thr	Ser	Thr	Thr	Val	Pro	Thr	Thr	Thr	Thr	Val	Pro	Thr	Thr	Thr
145					150					155					160
Val	Pro	Thr	Thr	Met	Ser	Ile	Pro	Thr	Thr	Thr	Thr	Val	Pro	Thr	Thr
				165					170					175	
Met	Thr	Val	Ser	Thr	Thr	Thr	Ser	Val	Pro	Thr	Thr	Thr	Ser	Ile	Pro
			180					185					190		
Thr	Thr	Thr	Ser	Val	Pro	Val	Thr	Thr	Ser	Val	Ser	Thr	Phe	Val	Pro
		195					200					205			
Pro	Met	Pro	Leu	Pro	Arg	Gln	Asn	His	Glu	Pro	Val	Ala	Thr	Ser	Pro
	210					215					220				
Ser	Ser	Pro	Gln	Pro	Ala	Glu	Thr	His	Pro	Thr	Thr	Leu	Gln	Gly	Thr
225					230					235					240
Ile	Arg	Arg	Glu	Pro	Thr	Ser	Ser	Pro	Leu	Tyr	Ser	Tyr	Thr	Thr	Asp
				245					250					255	
Gly	Asn	Asp	Thr	Val	Thr	Glu	Ser	Ser	Asp	Gly	Leu	Trp	Ser	Asn	Asn
			260					265					270		
Gln	Thr	Gln	Leu	Phe	Leu	Glu	His	Ser	Leu	Leu	Thr	Ala	Asn	Thr	Thr
		275					280					285			
Lys	Gly	Ile	Tyr	Ala	Gly	Val	Cys	Ile	Ser	Val	Leu	Val	Leu	Leu	Ala
	290					295					300				
Leu	Leu	Gly	Val	Ile	Ile	Ala	Lys	Lys	Tyr	Phe	Phe	Lys	Lys	Glu	Val
305					310					315					320
Gln	Gln	Leu	Ser	Val	Ser	Phe	Ser	Ser	Leu	Gln	Ile	Lys	Ala	Leu	Gln
				325					330					335	
Asn	Ala	Val	Glu	Lys	Glu	Val	Gln	Ala	Glu	Asp	Asn	Ile	Tyr	Ile	Glu
			340					345					350		
Asn	Ser	Leu	Tyr	Ala	Thr	Asp									
		355													

<210> 24

<211> 1079

<212> DNA

<213> H. sapiens

<400> 24

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aacgacaacg agcgttccaa cgacaacgag cattccaaca acaacaagtg ttccagtgc 600
aacatgtctc tacctttgtt cctccaatgc ctttgcccag gcagaaccat gaaccagtag 660
ccacttcacc atcttcacct cagccagcag aaaccacccc tacgacactg cagggagcaa 720

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17/25

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 gtctactgac ggccaatacc actaaaggaa tctatgctgg agtctgtatt tctgtcttgg 900
 tgcttcttgc tcttttgggt gtcattcattg ccaaaaagta tttcttcaaa aaggagggtc 960
 aacaactaag tgtttcattt agcagccttc aaattaaagc tttgcaaaat gcagttgaaa 1020
 aggaagtcca agcagaagac aatatctaca ttgagaatag tctttatgcc acggactaa 1079

<210> 25

<211> 364

<212> PRT

<213> H. sapiens

<220>

<221> VARIANT

<222> (1)...(364)

<223> TIM-1 allele 5

<400> 25

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Ser	Val	Ala	Gly	Ser	Val	Lys	Val	Gly	Gly	Glu	Ala	Gly	Pro	Ser	Val
			20					25					30		
Thr	Leu	Pro	Cys	His	Tyr	Ser	Gly	Ala	Val	Thr	Ser	Met	Cys	Trp	Asn
		35					40					45			
Arg	Gly	Ser	Cys	Ser	Leu	Phe	Thr	Cys	Gln	Asn	Gly	Ile	Val	Trp	Thr
	50					55					60				
Asn	Gly	Thr	His	Val	Thr	Tyr	Arg	Lys	Asp	Thr	Arg	Tyr	Lys	Leu	Leu
65					70					75				80	
Gly	Asp	Leu	Ser	Arg	Arg	Asp	Val	Ser	Leu	Thr	Ile	Glu	Asn	Thr	Ala
				85					90					95	
Val	Ser	Asp	Ser	Gly	Val	Tyr	Cys	Cys	Arg	Val	Glu	His	Arg	Gly	Trp
			100				105						110		
Phe	Asn	Asp	Met	Lys	Ile	Thr	Val	Ser	Leu	Glu	Ile	Val	Pro	Pro	Lys
		115					120					125			
Val	Thr	Thr	Thr	Pro	Ile	Val	Thr	Thr	Val	Pro	Thr	Val	Thr	Thr	Val
	130					135					140				
Arg	Thr	Ser	Thr	Thr	Val	Pro	Thr	Thr	Thr	Thr	Val	Pro	Met	Thr	Thr
145					150					155				160	
Thr	Val	Pro	Thr	Thr	Thr	Val	Pro	Thr	Thr	Met	Ser	Ile	Pro	Thr	Thr
				165					170					175	
Thr	Thr	Val	Pro	Thr	Thr	Met	Thr	Val	Ser	Thr	Thr	Thr	Ser	Val	Pro
		180					185						190		
Thr	Thr	Thr	Ser	Ile	Pro	Thr	Thr	Ser	Val	Pro	Val	Thr	Thr	Thr	Val
	195					200						205			
Ser	Thr	Phe	Val	Pro	Pro	Met	Pro	Leu	Pro	Arg	Gln	Asn	His	Glu	Pro
	210					215					220				
Val	Ala	Thr	Ser	Pro	Ser	Ser	Pro	Gln	Pro	Ala	Glu	Thr	His	Pro	Thr
225					230					235				240	
Thr	Leu	Gln	Gly	Ala	Ile	Arg	Arg	Glu	Pro	Thr	Ser	Ser	Pro	Leu	Tyr
				245					250					255	
Ser	Tyr	Thr	Thr	Asp	Gly	Asn	Asp	Thr	Val	Thr	Glu	Ser	Ser	Asp	Gly
		260					265						270		
Leu	Trp	Asn	Asn	Asn	Gln	Thr	Gln	Leu	Phe	Leu	Glu	His	Ser	Leu	Leu
	275					280						285			
Thr	Ala	Asn	Thr	Thr	Lys	Gly	Ile	Tyr	Ala	Gly	Val	Cys	Ile	Ser	Val
	290					295					300				
Leu	Val	Leu	Leu	Ala	Leu	Leu	Gly	Val	Ile	Ile	Ala	Lys	Lys	Tyr	Phe
305					310					315				320	
Phe	Lys	Lys	Glu	Val	Gln	Gln	Leu	Ser	Val	Ser	Phe	Ser	Ser	Leu	Gln
			325						330					335	
Ile	Lys	Ala	Leu	Gln	Asn	Ala	Val	Glu	Lys	Glu	Val	Gln	Ala	Glu	Asp
		340						345					350		

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Asn Ile Tyr Ile Glu Asn Ser Leu Tyr Ala Thr Asp
 355 360

<210> 26
 <211> 1095
 <212> DNA
 <213> H. sapiens

<400> 26
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 gctgtcacat caatgtgctg gaatagaggc tcatgttctc tattcacatg ccaaaatggc 180
 attgtctgga ccaatggaac ccacgtcacc tatcggaagg acacacgcta taagctattg 240
 ggggaccttt caagaaggga tgtctctttg accatagaaa atacagctgt gtctgacagt 300
 ggcgtatatt gttgccgtgt tgagcaccgt ggggtggttca atgacatgaa aatcaccgta 360
 tcattggaga ttgtgccacc caaggtcacg actactccaa ttgtcacaac tgttccaacc 420
 gtcacgactg ttcgaacgag caccactgtt ccaacgacaa cgactgttcc aatgacaacg 480
 actgttccaa cgacaactgt tccaacaaca atgagcattc caacgacaac gactgttccg 540
 acgacaatga ctgtttcaac gacaacgagc gttccaacga caacgagcat tccaacaaca 600
 agtgttccag tgacaacaac ggtctctacc tttgttcctc caatgccttt gcccaggcag 660
 aacctgaac cagtagccac ttcaccatct tcacctcagc cagcagaaac ccaccctacg 720
 aactgcagg gagcaataag gagagaaccc accagctcac cattgtactc ttacacaaca 780
 gatgggaatg acaccgtgac agagtcttca gatggccttt ggaataacaa tcaaactcaa 840
 ctgttcctag aacatagtct actgacggcc aataccacta aaggaatcta tgctggagtc 900
 tgtattttctg tcttggtgct tcttgctctt ttgggtgtca tcattgcaa aaagtatttc 960
 ttcaaaaagg aggttcaaca actaagtgtt tcatttagca gccttcaa at taaagctttg 1020
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 tatgccacgg actaa 1095

<210> 27
 <211> 364
 <212> PRT
 <213> H. sapiens

<220>
 <221> VARIANT
 <222> (1)...(364)
 <223> TIM-1, allele 6

<400> 27
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 1 5 10 15
 Ser Val Ala Gly Ser Val Lys Val Gly Gly Glu Ala Gly Pro Ser Val
 20 25 30
 Thr Leu Pro Cys His Tyr Ser Gly Ala Val Thr Ser Met Cys Trp Asn
 35 40 45
 Arg Gly Ser Cys Ser Leu Phe Thr Cys Gln Asn Gly Ile Val Trp Thr
 50 55 60
 Asn Gly Thr His Val Thr Tyr Arg Lys Asp Thr Arg Tyr Lys Leu Leu
 65 70 75 80
 Gly Asp Leu Ser Arg Arg Asp Val Ser Leu Thr Ile Glu Asn Thr Ala
 85 90 95
 Val Ser Asp Ser Gly Val Tyr Cys Cys Arg Val Glu His Arg Gly Trp
 100 105 110
 Phe Asn Asp Met Lys Ile Thr Val Ser Leu Gly Ile Val Pro Pro Lys
 115 120 125
 Val Thr Thr Thr Pro Ile Val Thr Thr Val Pro Thr Val Thr Thr Val
 130 135 140
 Arg Thr Ser Thr Thr Val Pro Thr Thr Thr Thr Val Pro Met Thr Thr
 145 150 155 160
 Thr Val Pro Thr Thr Thr Val Pro Thr Thr Met Ser Ile Pro Thr Thr

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

<210> 28

<211> 1099

<212> DNA

<213> H. sapiens

<400> 28

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gctgtcacat caatgtgctg gaatagaggc tcatgtttctc tattcacatg ccaaaatggc 180
attgtctgga ccaatggaac ccacgtcacc tatcggaagg acacacgcta taagctattg 240
ggggaccttt caagaaggga tgtctctttg accatagaaa atacagctgt gtctgacagt 300
ggcgtatatt gttgccgtgt tgagcaccgt ggggtggttca atgacatgaa aatcaccgta 360
tcattggaga ttgtgccacc caagggtcacg actactccaa ttgtcacaac tgttccaacc 420
gtcacgactg ttcgaacgag caccactgtt ccaacgacaa cgactgttcc aatgacaacc 480
gactgttcca acgacaactg ttccaacaac aatgagcatt ccaacgacaa cgactgttcc 540
gacgacaatg actgtttcaa cgacaacgag cgttccaacg acaacgagca ttccaacaac 600
aacaagtgtt ccagtgcaca caacgggtctc tacctttgtt cctccaatgc ctttgcccag 660
gcagaacat gaaccagtag ccacttcacc atcttcacct cagccagcag aaaccacccc 720
tacgacactg cagggagcaa taaggagaga acccaccagc tcaccattgt actcttacac 780
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tcaactgttc ctagaacata gtctactgac ggccaatacc actaaaggaa tctatgctgg 900
agtctgtatt tctgtcttgg tgcttcttgc tcttttgggt gtcattcattg ccaaaaagta 960
tttcttcaaa aaggagggtc aacaactaag tgtttcattt agcagccttc aaattaaagc 1020
tttgcaaaat gcagttgaaa aggaagtcca agcagaagac aatatctaca ttgagaatag 1080
tctttatgcc acggactaa                                     1099

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<210> 29

<211> 301

<212> PRT

<213> H. sapiens

<220>

<221> VARIANT

<222> (1)...(301)

<223> TIM-3, allele 1

<400> 29

Met Phe Ser His Leu Pro Phe Asp Cys Val Leu Leu Leu Leu Leu Leu
 1 5 10 15
 Leu Leu Thr Arg Ser Ser Glu Val Glu Tyr Arg Ala Glu Val Gly Gln
 20 25 30
 Asn Ala Tyr Leu Pro Cys Phe Tyr Thr Pro Ala Ala Pro Gly Asn Leu
 35 40 45
 Val Pro Val Cys Trp Gly Lys Gly Ala Cys Pro Val Phe Glu Cys Gly
 50 55 60
 Asn Val Val Leu Arg Thr Asp Glu Arg Asp Val Asn Tyr Trp Thr Ser
 65 70 75 80
 Arg Tyr Trp Leu Asn Gly Asp Phe Arg Lys Gly Asp Val Ser Leu Thr
 85 90 95
 Ile Glu Asn Val Thr Leu Ala Asp Ser Gly Ile Tyr Cys Cys Arg Ile
 100 105 110
 Gln Ile Pro Gly Ile Met Asn Asp Glu Lys Phe Asn Leu Lys Leu Val
 115 120 125
 Ile Lys Pro Ala Lys Val Thr Pro Ala Pro Thr Arg Gln Arg Asp Phe
 130 135 140
 Thr Ala Ala Phe Pro Arg Met Leu Thr Thr Arg Gly His Gly Pro Ala
 145 150 155 160
 Glu Thr Gln Thr Leu Gly Ser Leu Pro Asp Ile Asn Leu Thr Gln Ile
 165 170 175
 Ser Thr Leu Ala Asn Glu Leu Arg Asp Ser Arg Leu Ala Asn Asp Leu
 180 185 190
 Arg Asp Ser Gly Ala Thr Ile Arg Ile Gly Ile Tyr Ile Gly Ala Gly
 195 200 205
 Ile Cys Ala Gly Leu Ala Leu Ala Leu Ile Phe Gly Ala Leu Ile Phe
 210 215 220
 Lys Trp Tyr Ser His Ser Lys Glu Lys Ile Gln Asn Leu Ser Leu Ile
 225 230 235 240
 Ser Leu Ala Asn Leu Pro Pro Ser Gly Leu Ala Asn Ala Val Ala Glu
 245 250 255
 Gly Ile Arg Ser Glu Glu Asn Ile Tyr Thr Ile Glu Glu Asn Val Tyr
 260 265 270
 Glu Val Glu Glu Pro Asn Glu Tyr Tyr Cys Tyr Val Ser Ser Arg Gln
 275 280 285
 Gln Pro Ser Gln Pro Leu Gly Cys Arg Phe Ala Met Pro
 290 295 300

<210> 30

<211> 1116

<212> DNA

<213> H. sapiens

<400> 30

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 tcagaagtgg aatacagagc ggaggtcggt cagaatgcct atctgccctg cttctacacc 180
 ccagccgccc cagggaaacct cgtgcccgtc tgctggggca aaggagcctg tcctgtgttt 240
 gaatgtggca acgtggtgct caggactgat gaaagggatg tgaattattg gacatccaga 300
 tactggctaa atggggattt ccgcaaagga gatgtgtccc tgaccataga gaatgtgact 360
 ctagcagaca gtgggatcta ctgctgccgg atccaaatcc caggcataat gaatgatgaa 420
 aaatttaacc tgaagttggt catcaaacca gccaaagtca cccctgcacc gactctgcag 480
 agagacttca ctgcagcctt tccaaggatg cttaccacca ggggacatgg cccagcagag 540
 acacagacac tggggagcct ccctgatata aatctaacac aaatatccac attggccaat 600
 gagttacggg actctagatt ggccaatgac ttacgggact ctggagcaac catcagaata 660
 ggcattctaca tcggagcagg gatctgtgct gggctggctc tggctcttat cttcggcgct 720
 ttaattttca aatggtattc tcatagcaaa gagaagatac agaatttaag cctcatctct 780
 ttggccaacc tccctccctc aggattggca aatgcagtag cagaggggaat tcgctcagaa 840

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gaaaacatct ataccattga agagaacgta tatgaagtgg aggagcccaa tgagtattat 900
 tgctatgtca gcagcaggca gcaaccctca caacctttgg gttgtcgctt tgcaatgcca 960
 tagatccaac caccttattt ttgagcttgg tgttttgtct ttttcagaaa ctatgagctg 1020
 tgtcacctga ctggttttgg aggttctgtc cactgctatg gagcagagtt ttcccatatt 1080
 cagaagataa tgactcacat gggaattgaa ctggga 1116

<210> 31
 <211> 301
 <212> PRT
 <213> H. sapiens

<220>
 <221> VARIANT
 <222> (1)...(301)
 <223> TIM-3, allele 2

<400> 31
 Met Phe Ser His Leu Pro Phe Asp Cys Val Leu Leu Leu Leu Leu Leu
 1 5 10 15
 Leu Leu Thr Arg Ser Ser Glu Val Glu Tyr Arg Ala Glu Val Gly Gln
 20 25 30
 Asn Ala Tyr Leu Pro Cys Phe Tyr Thr Pro Ala Ala Pro Gly Asn Leu
 35 40 45
 Val Pro Val Cys Trp Gly Lys Gly Ala Cys Pro Val Phe Glu Cys Gly
 50 55 60
 Asn Val Val Leu Arg Thr Asp Glu Arg Asp Val Asn Tyr Trp Thr Ser
 65 70 75 80
 Arg Tyr Trp Leu Asn Gly Asp Phe Arg Lys Gly Asp Val Ser Leu Thr
 85 90 95
 Ile Glu Asn Val Thr Leu Ala Asp Ser Gly Ile Tyr Cys Cys Arg Ile
 100 105 110
 Gln Ile Pro Gly Ile Met Asn Asp Glu Lys Phe Asn Leu Lys Leu Val
 115 120 125
 Ile Lys Pro Ala Lys Val Thr Pro Ala Pro Thr Leu Gln Arg Asp Phe
 130 135 140
 Thr Ala Ala Phe Pro Arg Met Leu Thr Thr Arg Gly His Gly Pro Ala
 145 150 155 160
 Glu Thr Gln Thr Leu Gly Ser Leu Pro Asp Ile Asn Leu Thr Gln Ile
 165 170 175
 Ser Thr Leu Ala Asn Glu Leu Arg Asp Ser Arg Leu Ala Asn Asp Leu
 180 185 190
 Arg Asp Ser Gly Ala Thr Ile Arg Ile Gly Ile Tyr Ile Gly Ala Gly
 195 200 205
 Ile Cys Ala Gly Leu Ala Leu Ala Leu Ile Phe Gly Ala Leu Ile Phe
 210 215 220
 Lys Trp Tyr Ser His Ser Lys Glu Lys Ile Gln Asn Leu Ser Leu Ile
 225 230 235 240
 Ser Leu Ala Asn Leu Pro Pro Ser Gly Leu Ala Asn Ala Val Ala Glu
 245 250 255
 Gly Ile Arg Ser Glu Glu Asn Ile Tyr Thr Ile Glu Glu Asn Val Tyr
 260 265 270
 Glu Val Glu Glu Pro Asn Glu Tyr Tyr Cys Tyr Val Ser Ser Arg Gln
 275 280 285
 Gln Pro Ser Gln Pro Leu Gly Cys Arg Phe Ala Met Pro
 290 295 300

<210> 32
 <211> 1116
 <212> DNA
 <213> H. sapiens

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<400> 32

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tcagaagtgg aatacagagc ggaggtcggc cagaatgcct atctgccctg cttctacacc 180
ccagccgccc cagggaacct cgtgcccgct tgctggggca aaggagcctg tcctgtgttt 240
gaatgtggca acgtggtgct caggactgat gaaagggatg tgaattattg gacatccaga 300
tactggctaa atggggattt ccgcaaagga gatgtgtccc tgaccataga gaatgtgact 360
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aaatttaacc tgaagttggt catcaaacca gccaaaggta cccctgcacc gactcggcag 480
agagacttca ctgcagcctt tccaaggatg cttaccacca ggggacatgg cccagcagag 540
acacagacac tggggagcct ccctgatata aatctaacac aaatatccac attggccaat 600
gagttacggg actctagatt ggccaatgac ttacgggact ctggagcaac catcagaata 660
ggcatctaca tcggagcagg gatctgtgct gggctggctc tggctcttat cttcggcgct 720
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ttggccaacc tccctccctc aggattggca aatgcagtag cagaggggat tcgctcagaa 840
gaaaacatct ataccattga agagaacgta tatgaagtgg aggagcccaa tgagtattat 900
tgctatgtca gcagcaggca gcaaccctca caacctttgg gttgtcgctt tgcaatgcca 960
tagatccaac caccttattt ttgagcttgg tgttttgtct ttttcagaaa ctatgagctg 1020
tgtcacctga ctggttttgg aggttctgtc cactgctatg gagcagagtt ttcccatatt 1080
cagaagataa tgactcacat ggggaattgaa ctggga 1116

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<210> 33

<211> 378

<212> PRT

<213> H. sapiens

<220>

<221> VARIANT

<222> (1)...(378)

<223> TIM-4, allele 1

<400> 33

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Leu Tyr Leu Thr Pro Val Thr Ser Glu Thr Val Val Thr Glu Val Leu
          20          25          30
Gly His Arg Val Thr Leu Pro Cys Leu Tyr Ser Ser Trp Ser His Asn
          35          40          45
Ser Asn Ser Met Cys Trp Gly Lys Asp Gln Cys Pro Tyr Ser Gly Cys
          50          55          60
Lys Glu Ala Leu Ile Arg Thr Asp Gly Met Arg Val Thr Ser Arg Lys
          65          70          75          80
Ser Ala Lys Tyr Arg Leu Gln Gly Thr Ile Pro Arg Gly Asp Val Ser
          85          90          95
Leu Thr Ile Leu Asn Pro Ser Glu Ser Asp Ser Gly Val Tyr Cys Cys
          100          105          110
Arg Ile Glu Val Pro Gly Trp Phe Asn Asp Val Lys Ile Asn Val Arg
          115          120          125
Leu Asn Leu Gln Arg Ala Ser Thr Thr Thr His Arg Thr Ala Thr Thr
          130          135          140
Thr Thr Arg Arg Thr Thr Thr Thr Ser Pro Thr Thr Thr Arg Gln Met
          145          150          155          160
Thr Thr Thr Pro Ala Leu Pro Thr Thr Val Val Thr Thr Pro Asp
          165          170          175
Leu Thr Thr Gly Thr Pro Leu Gln Met Thr Thr Ile Ala Val Phe Thr
          180          185          190
Thr Ala Asn Thr Cys Leu Ser Leu Thr Pro Ser Thr Leu Pro Glu Glu
          195          200          205
Ala Thr Gly Leu Leu Thr Pro Glu Pro Ser Lys Glu Gly Pro Ile Leu
          210          215          220
Thr Ala Glu Ser Glu Thr Val Leu Pro Ser Asp Ser Trp Ser Ser Ala
          225          230          235          240

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Glu	Ser	Thr	Ser	Ala	Asp	Thr	Val	Leu	Leu	Thr	Ser	Lys	Glu	Ser	Lys
				245					250					255	
Val	Trp	Asp	Leu	Pro	Ser	Thr	Ser	His	Val	Ser	Met	Trp	Lys	Thr	Ser
			260					265					270		
Asp	Ser	Val	Ser	Ser	Pro	Gln	Pro	Gly	Ala	Ser	Asp	Thr	Ala	Val	Pro
		275					280					285			
Glu	Gln	Asn	Lys	Thr	Thr	Lys	Thr	Gly	Gln	Met	Asp	Gly	Ile	Pro	Met
	290					295					300				
Ser	Met	Lys	Asn	Glu	Met	Pro	Ile	Ser	Gln	Leu	Leu	Met	Ile	Ile	Ala
305					310					315					320
Pro	Ser	Leu	Gly	Phe	Val	Leu	Phe	Ala	Leu	Phe	Val	Ala	Phe	Leu	Leu
			325					330					335		
Arg	Gly	Lys	Leu	Met	Glu	Thr	Tyr	Cys	Ser	Gln	Lys	His	Thr	Arg	Leu
			340					345					350		
Asp	Tyr	Ile	Gly	Asp	Ser	Lys	Asn	Val	Leu	Asn	Asp	Val	Gln	His	Gly
	355					360					365				
Arg	Glu	Asp	Glu	Asp	Gly	Leu	Phe	Thr	Leu						
	370					375									

<210> 34
 <211> 1156
 <212> DNA
 <213> H. sapiens

<400> 34
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 ctgtactcat cctggtctca caacagcaac agcatgtgct gggggaaaga ccagtgcacc 180
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 aaccccagtg aaagtgacag cgggtgtgtac tgctgcccga tagaagtgcc tggctgggtc 360
 aacgatgtaa agataaacgt gcgcctgaat ctacagagag cctcaacaac cacgcacaga 420
 acagcaacca ccaccacacg cagaacaaca acaacaagcc ccaccaccac ccgacaaatg 480
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 acaccactcc agatgacaac cattgccgtc ttcacaacag caaacacgtg cctttcacta 600
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 gagtctactt ctgctgacac tgtcctgctg acatccaaag agtccaaagt ttgggatctc 780
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 ggaataccca tgtcaatgaa gaatgaaatg cccatctccc aactactgat gatcatcgcc 960
 ccctccttgg gatttgtgct cttcgcattg tttgtggcgt ttctcctgag agggaaactc 1020
 atggaaacct attgttcgca gaaacacaca aggctagact acattggaga tagtaaaaaat 1080
 gtcctcaatg acgtgcagca tggaagggaa gacgaagacg gcctttttac cctctaacaa 1140
 cgcagtagca tgtag 1156

<210> 35
 <211> 378
 <212> PRT
 <213> H. sapiens

<220>
 <221> VARIANT
 <222> (1)...(378)
 <223> TIM-4, allele 2

<400> 35
 Met Ser Lys Glu Pro Leu Ile Leu Trp Leu Met Ile Glu Phe Trp Trp
 1 5 10 15
 Leu Tyr Leu Thr Pro Val Thr Ser Glu Thr Val Val Thr Glu Val Leu
 20 25 30

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Gly	His	Arg	Val	Thr	Leu	Pro	Cys	Leu	Tyr	Ser	Ser	Trp	Ser	His	Asn
	35						40					45			
Ser	Asn	Ser	Met	Cys	Trp	Gly	Lys	Asp	Gln	Cys	Pro	Tyr	Ser	Gly	Cys
	50					55					60				
Lys	Glu	Ala	Leu	Ile	Arg	Thr	Asp	Gly	Met	Arg	Val	Thr	Ser	Arg	Lys
65					70					75					80
Ser	Ala	Lys	Tyr	Arg	Leu	Gln	Gly	Thr	Ile	Pro	Arg	Gly	Asp	Val	Ser
				85					90					95	
Leu	Thr	Ile	Leu	Asn	Pro	Ser	Glu	Ser	Asp	Ser	Gly	Val	Tyr	Cys	Cys
			100					105					110		
Arg	Ile	Glu	Val	Pro	Gly	Trp	Phe	Asn	Asp	Val	Lys	Ile	Asn	Val	Arg
	115						120					125			
Leu	Asn	Leu	Gln	Arg	Ala	Ser	Thr	Thr	Thr	His	Arg	Thr	Ala	Thr	Thr
	130					135					140				
Thr	Thr	Arg	Arg	Thr	Thr	Thr	Thr	Ser	Pro	Thr	Thr	Thr	Arg	Gln	Met
145					150					155					160
Thr	Thr	Thr	Pro	Ala	Ala	Leu	Pro	Thr	Thr	Val	Val	Thr	Thr	Pro	Asp
				165					170					175	
Leu	Thr	Thr	Gly	Thr	Pro	Leu	Gln	Met	Thr	Thr	Ile	Ala	Val	Phe	Thr
			180					185					190		
Thr	Ala	Asn	Thr	Cys	Leu	Ser	Leu	Thr	Pro	Ser	Thr	Leu	Pro	Glu	Glu
	195						200				205				
Ala	Thr	Gly	Leu	Leu	Thr	Pro	Glu	Pro	Ser	Lys	Glu	Gly	Pro	Ile	Leu
	210					215					220				
Thr	Ala	Glu	Ser	Glu	Thr	Val	Leu	Pro	Ser	Asp	Ser	Trp	Ser	Ser	Val
225					230					235					240
Glu	Ser	Thr	Ser	Ala	Asp	Thr	Val	Leu	Leu	Thr	Ser	Lys	Glu	Ser	Lys
				245					250					255	
Val	Trp	Asp	Leu	Pro	Ser	Thr	Ser	His	Val	Ser	Met	Trp	Lys	Thr	Ser
			260					265					270		
Asp	Ser	Val	Ser	Ser	Pro	Gln	Pro	Gly	Ala	Ser	Asp	Thr	Ala	Val	Pro
	275						280					285			
Glu	Gln	Asn	Lys	Thr	Thr	Lys	Thr	Gly	Gln	Met	Asp	Gly	Ile	Pro	Met
	290					295					300				
Ser	Met	Lys	Asn	Glu	Met	Pro	Ile	Ser	Gln	Leu	Leu	Met	Ile	Ile	Ala
305					310					315					320
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				325					330					335	
Arg	Gly	Lys	Leu	Met	Glu	Thr	Tyr	Cys	Ser	Gln	Lys	His	Thr	Arg	Leu
			340					345					350		
Asp	Tyr	Ile	Gly	Asp	Ser	Lys	Asn	Val	Leu	Asn	Asp	Val	Gln	His	Gly
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Arg	Glu	Asp	Glu	Asp	Gly	Leu	Phe	Thr	Leu						
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WHAT IS CLAIMED IS:

1. An isolated nucleic acid molecule comprising a mammalian TIM gene sequence.
- 5 2. An isolated nucleic acid molecule according to Claim 1, wherein said mammalian TIM gene sequence is a human sequence selected from the group consisting of alleles 2, 3, 4, 5, and 6 of TIM-1, TIM-3, and TIM-4.
- 10 3. An isolated nucleic acid according to Claim 1, wherein said mammalian TIM gene sequence is a mouse sequence selected from the group consisting of TIM-1, TIM-2, TIM-3 and TIM-4.
- 15 4. An isolated nucleic acid comprising at least 20 nucleotides of contiguous sequence as set forth in any one of SEQ ID NO:2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34 or 36.
5. An isolated nucleic acid comprising a sequence as set forth in any one of SEQ ID NO:2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34 or 36.
- 20 6. An isolated nucleic acid molecule according to Claim 1, comprising a probe for detection of a TIM gene polymorphism.
7. An array of oligonucleotides comprising:
two or more probes according to Claim 6.
- 25 8. A cell comprising a nucleic acid composition according to claim 1.
9. A purified polypeptide composition comprising at least 50 weight % of the protein present as the product of the nucleic acid of Claim 1 or a fragment thereof.
- 30 10. The purified polypeptide according to Claim 9, wherein said polypeptide comprises a sequence as set forth in SEQ ID NO:1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23, 25, 27, 29, 31, 33 and 35.
- 35 11. An antibody specific for a mammalian TIM polypeptide.
12. A method for detecting a predisposition to asthma in an individual,

the method comprising:

analyzing said individual for the presence of at least one predisposing TIM polymorphism; wherein the presence of said predisposing polymorphism is indicative of an increased susceptibility to asthma.

5

13. The method according to Claim 12, wherein said analyzing step comprises detection of specific binding between genomic DNA or mRNA of said individual with a probe or probes according to Claim 6.

10

14. The method according to Claim 12, wherein said analyzing step comprises detection of specific binding between cells or protein from said individual and the antibody according to Claim 11.

15

15. A non-human transgenic animal model for TIM gene function comprising a knockout of a TIM gene.

20

16. A method of screening for biologically active agents that modulate TIM function, the method comprising:

combining a candidate biologically active agent with any one of:

(a) a mammalian TIM polypeptide;

(b) a cell comprising a nucleic acid encoding a mammalian TIM polypeptide;

or

(c) a non-human transgenic animal model for TIM gene function; and

determining the effect of said agent on TIM function.

25

17. The method according to Claim 16, wherein said biologically active agent downregulates or upregulates TIM expression.

30

18. The method according to Claim 16, wherein said biologically active agent inhibits or increases activity of said TIM polypeptide.

19. A method for the diagnosis or staging of immune dysfunction in an individual, the method comprising:

analyzing said individual for the presence of at least one predisposing TIM polymorphism; wherein the presence of said predisposing polymorphism is indicative of an increased susceptibility to said immune dysfunction.

35

20. A method for the diagnosis or staging of cancer in an individual, the method comprising:

analyzing said individual for the presence of at least one predisposing TIM polymorphism; wherein the presence of said predisposing polymorphism is indicative of an
5 increased resistance to cancer therapy.

21. A method for the diagnosis or staging of cancer in an individual, the method comprising:

analyzing said individual for the presence of at least one predisposing TIM-1
10 expression profile; wherein the expression profile of TIM-1 indicative of an increased resistance to cancer therapy.

22. A method for the diagnosis or staging of cancer in an individual, the method comprising:

15 analyzing said individual for the presence of at least one predisposing TIM-4 expression profile; wherein the expression profile of TIM-4 indicative of an increased resistance to cancer therapy.

23. A method for the treatment of an immunological disorder in an
20 individual, the method comprising:

administering to said individual an agent that modulates function of a TIM polypeptide.

24. The method according to Claim 23, wherein said TIM polypeptide is
25 TIM-1 or TIM-4.

25. The method according to Claim 24, wherein said agent is an antibody or antibody fragment specific for TIM-1.

30 26. The method according to Claim 24, wherein said agent is a compound that inhibits TIM-1 function.

27. The method according to Claim 24, wherein said immunological disorder is asthma.

35

28. The method according to Claim 24, wherein said immunological disorder is an allergy.

29. The method according to Claim 24, wherein said immunological disorder is eczema.

5 30. The method according to Claim 24, wherein said immunological disorder is an autoimmune disease.

 31. The method according to Claim 23, wherein said agent is an antibody or antibody fragment specific for TIM-4.
10

 32. The method according to Claim 30, wherein said agent is a compound that inhibits the function of TIM-4.

 33. A method for the treatment of malignancy in an individual, the method comprising: administering to said individual an agent that modulates function of a TIM polypeptide.
15

 34. The method according to Claim 33, wherein said TIM polypeptide is TIM-1.
20

 35. The method according to Claim 34, wherein said agent is an antibody or antibody fragment specific for TIM-1.

 36. The method according to Claim 35, wherein said agent is a compound that inhibits the function of TIM-1 and potentiates the effect of chemotherapeutic agents or radiation therapy.
25

 37. The method according to Claim 33, wherein said TIM polypeptide is TIM-4.
30

 38. The method according to Claim 37, wherein said agent is an antibody or antibody fragment specific for TIM-4.

 39. The method according to Claim 38, wherein said agent is a compound that inhibits the function of TIM-4 and potentiates the effect of chemotherapeutic agents or radiation therapy.
35

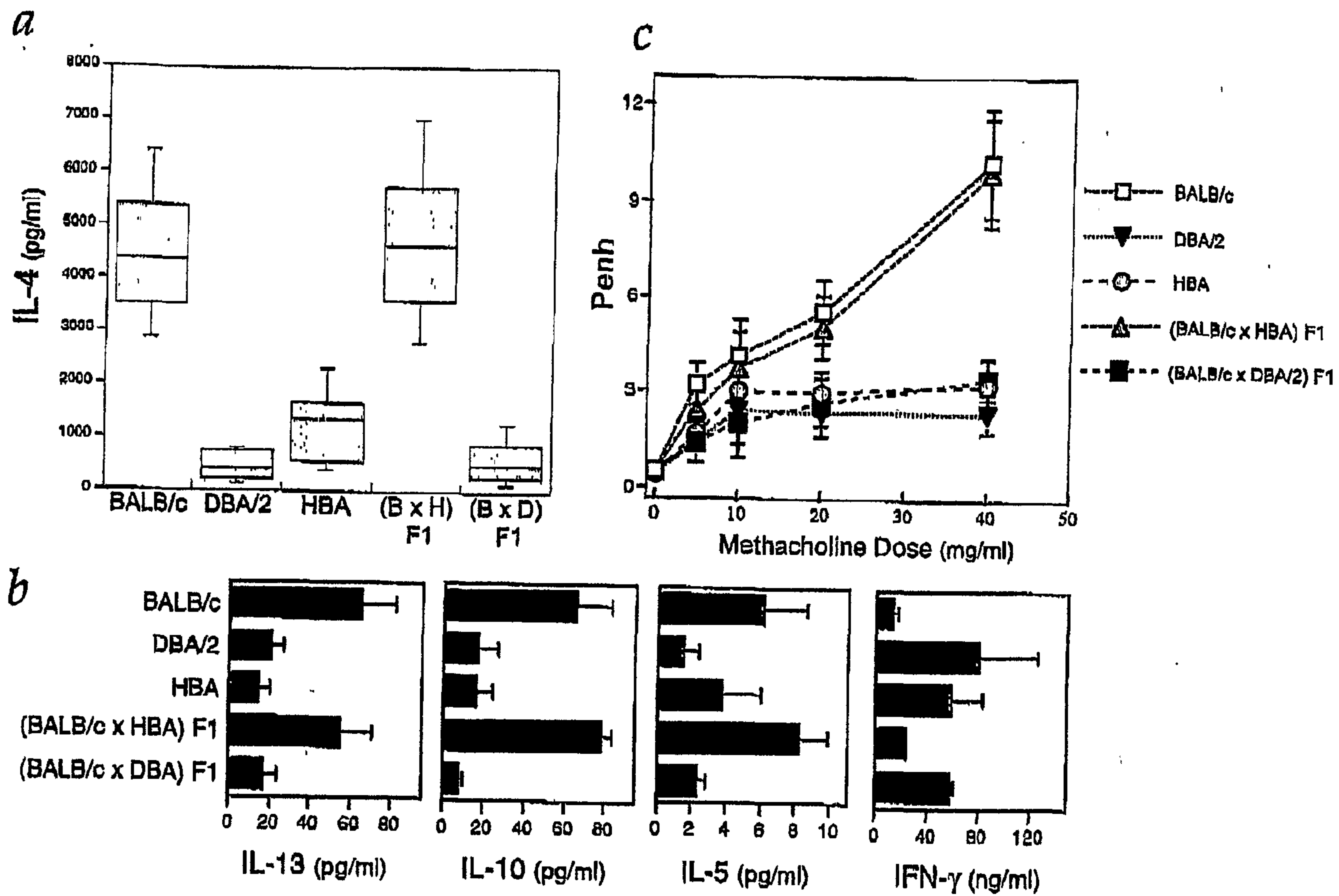


Figure 1

Figure 2

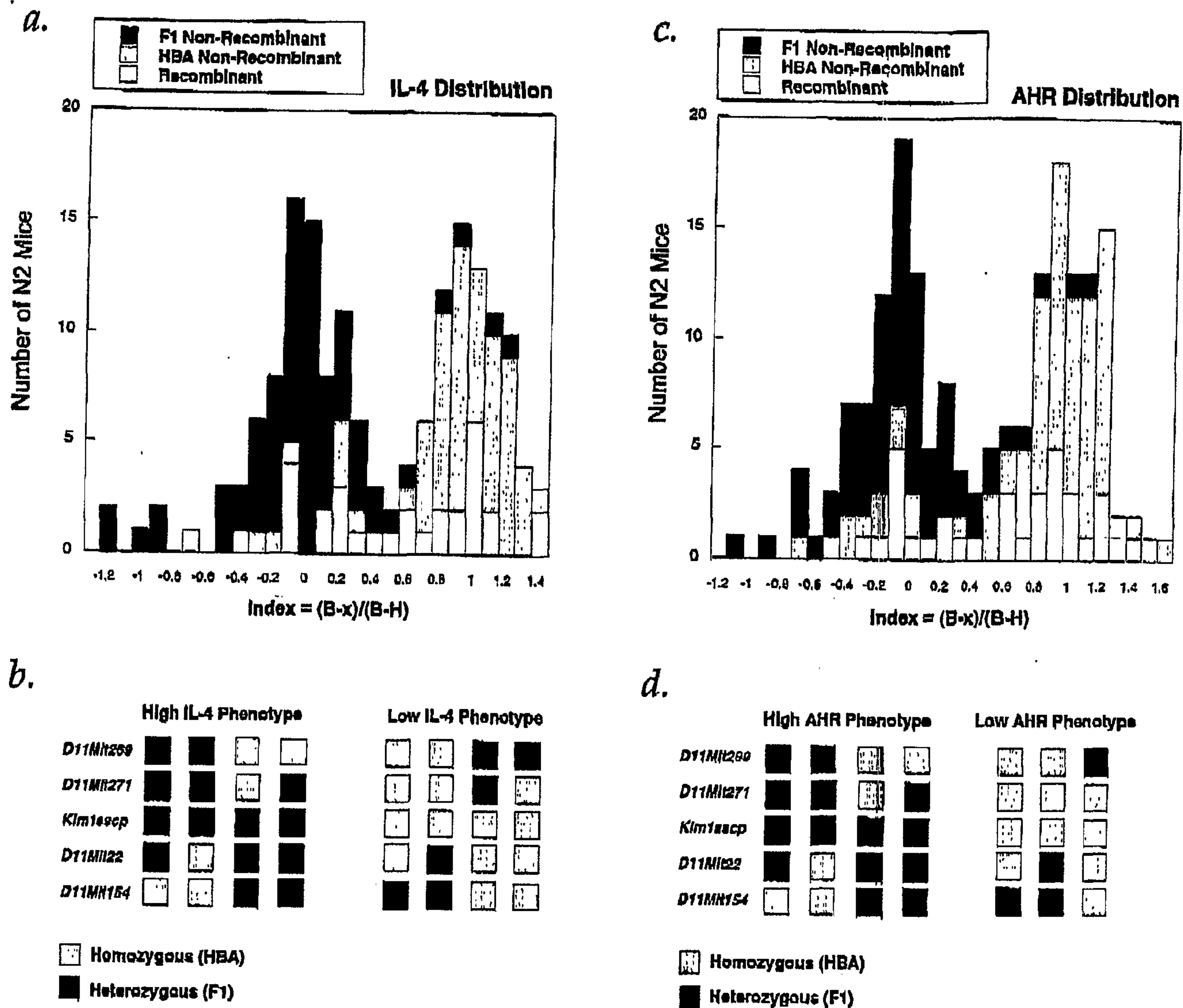


Figure 3

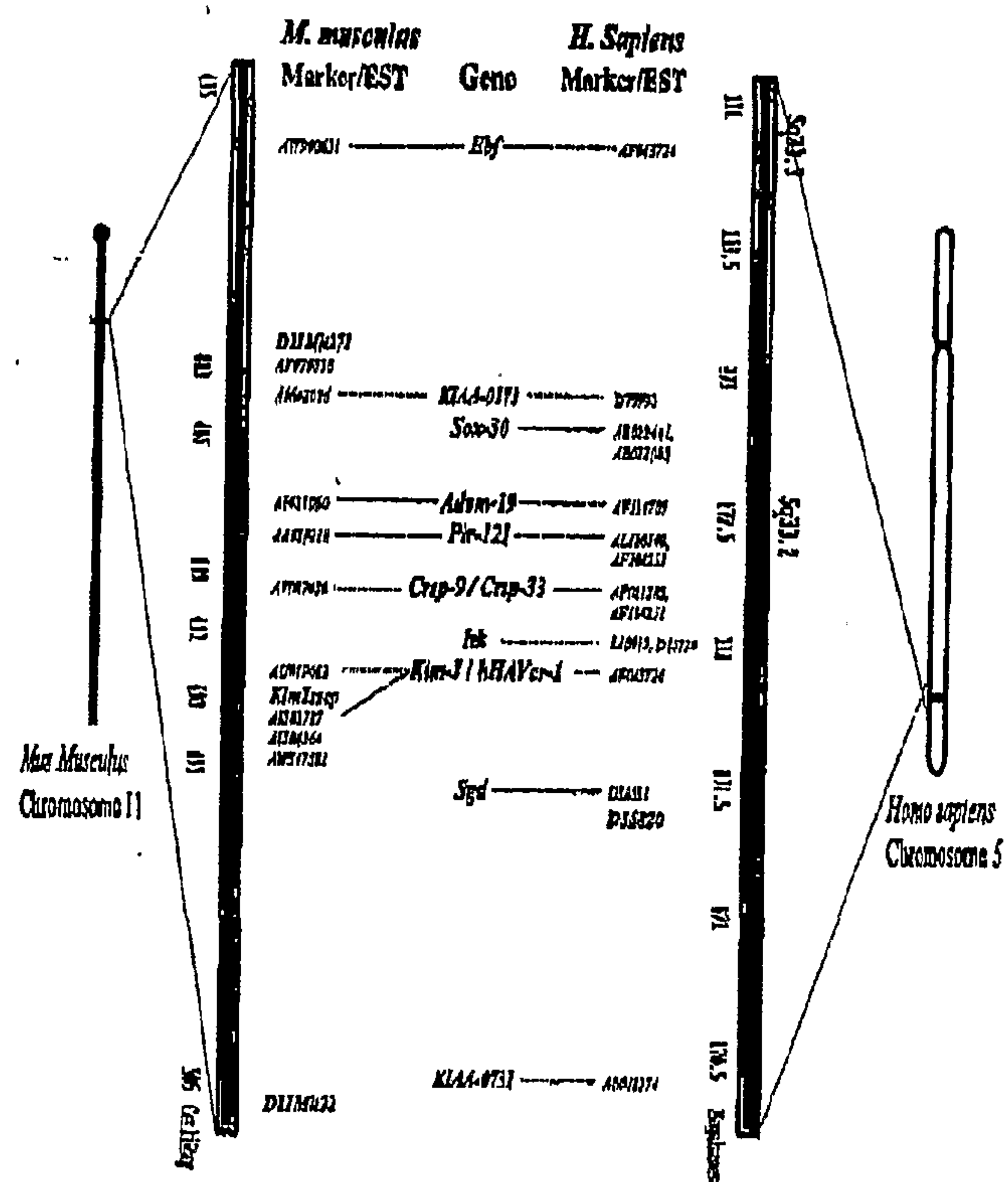


Figure 4

Figure 5 b

Mouse	TIM-1	M-NQIQVFISGLILLPGTVDSYVEVKGVVGHVPILPCTYSTYR-G-ITTTQWGRGOCPSAONTLIWNGHRVTVOKSSRYNLKGHISEGDSVSLTIEN
Mouse	TIM-2	M-NQIQVFISGLILLPGAVESHTAVQGLAGHPVILPCTYSTHL-GGIVPMCMWGLGECRHSYGIRSLIKWNGYVTVHQRNSRYOLKGNISEGNVSLTIEN
Mouse	a2-11	MFSGLTLNCVLLLOLLARSLEDGYKVEVGKNAYIPGSXYLTPTSGLVPMCMWKGFCPWSQCTNELLRTDERNNTYOKSSRYOLKGDNLKNGDVSLLIKN
Mouse	TIM-1	SVESDSGLYCCRVEIPGWFNQDKVTFSLQVKPEIPTRPPTTTTRPTATNGRPTTISTRSTHPTSTRVSTSTPPTSTHTWTHKPEPTTECPHETTAEV
Mouse	TIM-2	TWVGDGOPYCCVVEIPGAHF--VDYMIIEVKPEISTSPRPT-----ATCRPTTISTRSTHPTSTRVSTSTPPTPAHTETYPKEATTFYPDQTTAEVT
Mouse	a2-11	VTLDHGYCCRIQFPGLMNDKKLELKDIK-----AAKVTPAQTAHG-----AAKVTPAQTAHG-----DSTTASPRTLTTTERN
Mouse	TIM-1	GIPSHPTDNGVTSSGDTWSNHTEAIPGKPKQKNPTKGFVVGICIAA-LLILLLVSTVAITRYILMKRKSASLSVVAERVSKEALQNAAVVHSRAED
Mouse	TIM-2	ETLPSTPADWHTWISSDDPDNDNTEVIPPQKPKQKNLNGFYVGISIAA-LLIIMLLSTNVITRYVVMKRKSESLSFVAFPIISKIGASPKKVVERTCED
Mouse	a2-11	GSETQTLVTLHNNNGTKISTWADEIK----DSGETIRTAHIGVGVSAGITLADIIIGVLILKWYSCKKKKLSSLSLITLANLPFGGLANAGAVRIRSEE
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Mouse	a2-11	NIYTIENVYEVENSENEYCYVNSQQPS

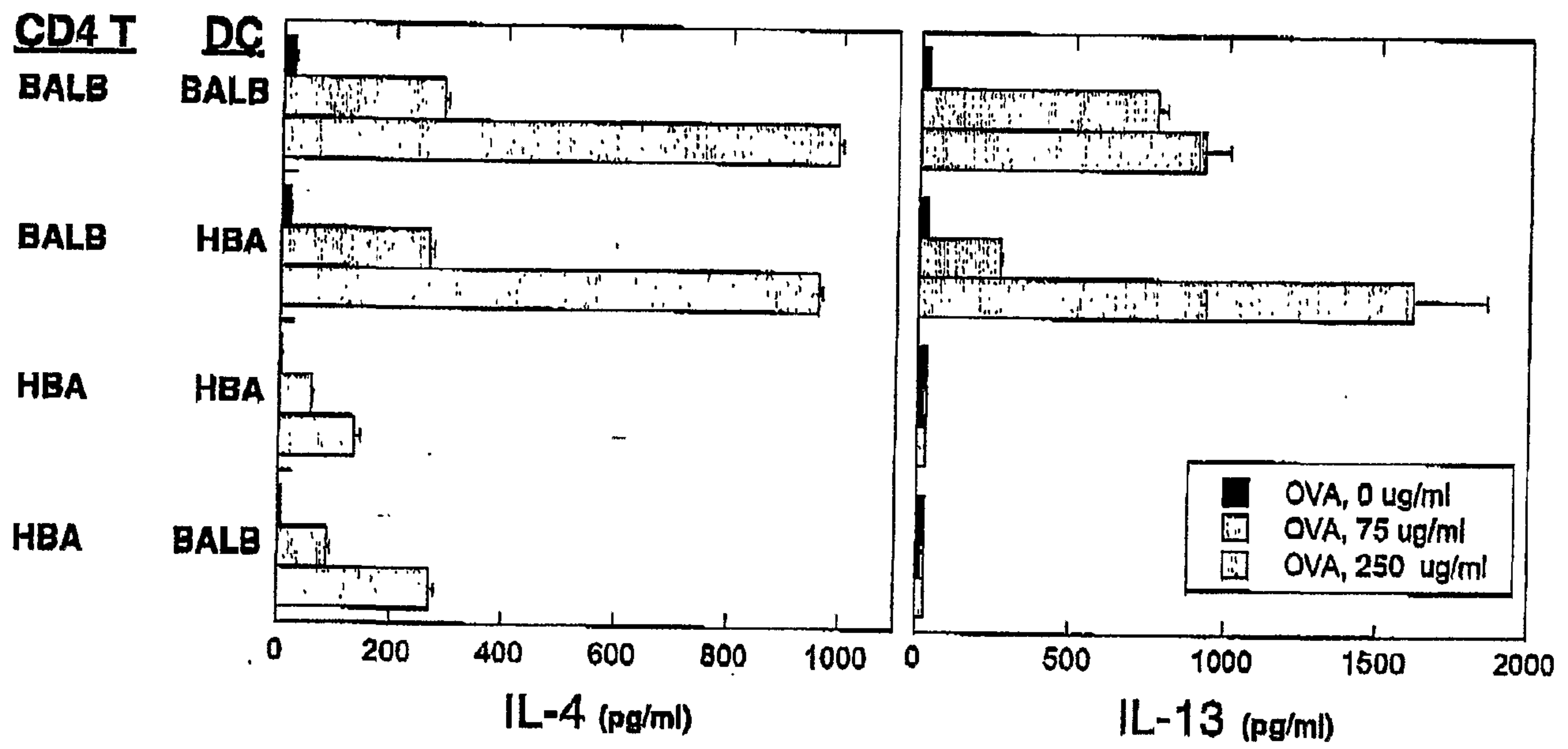


Figure 6

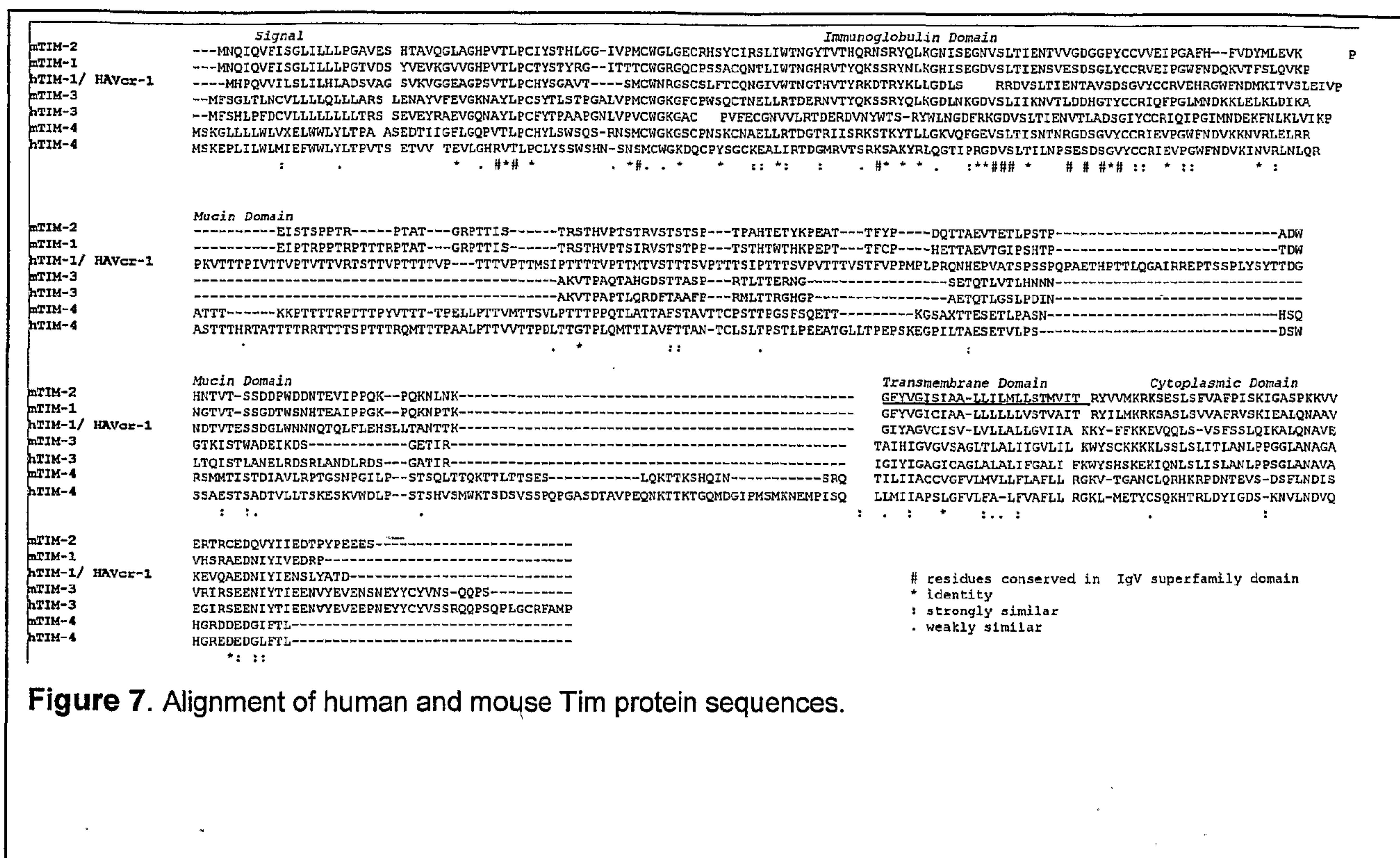
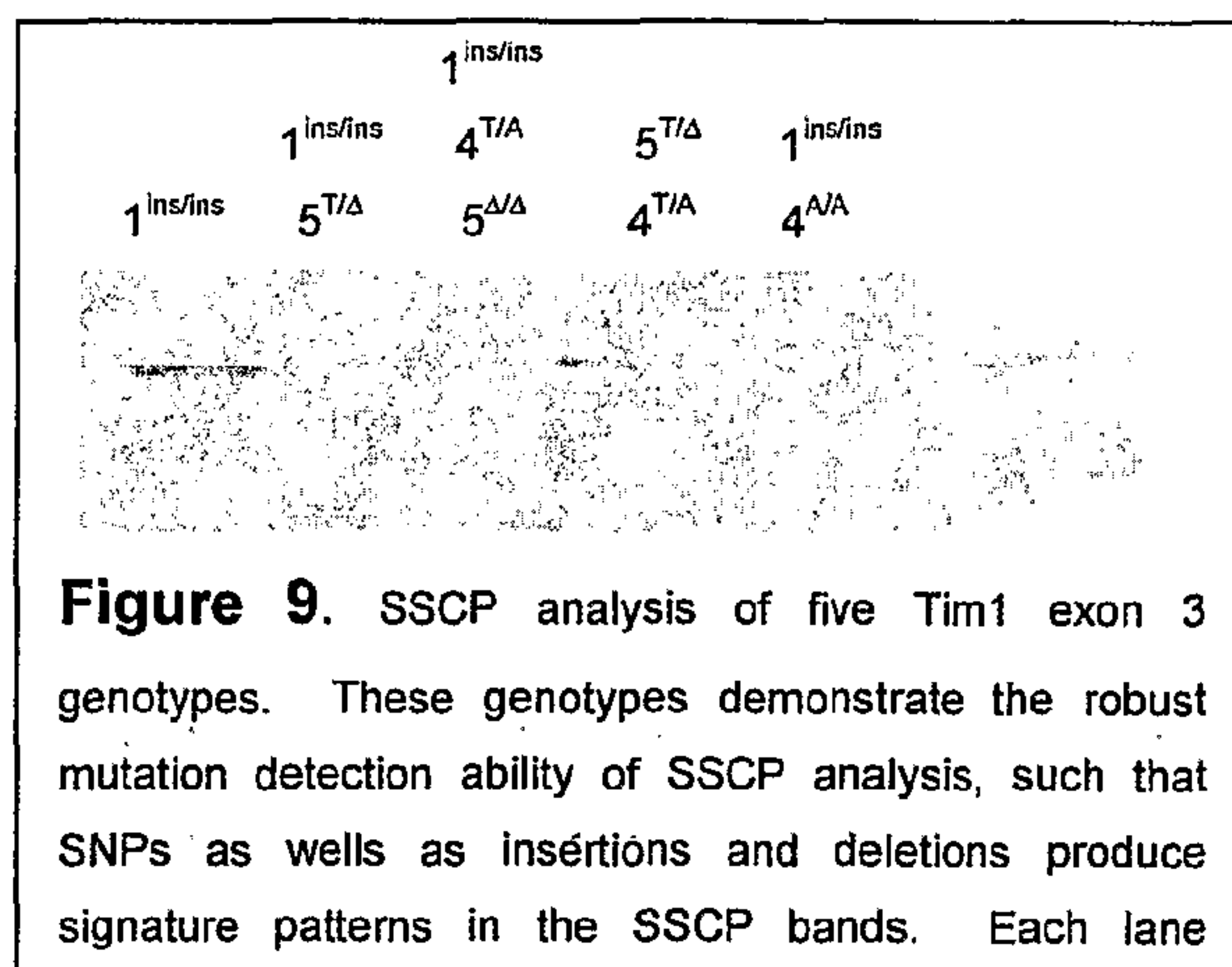


FIGURE 8

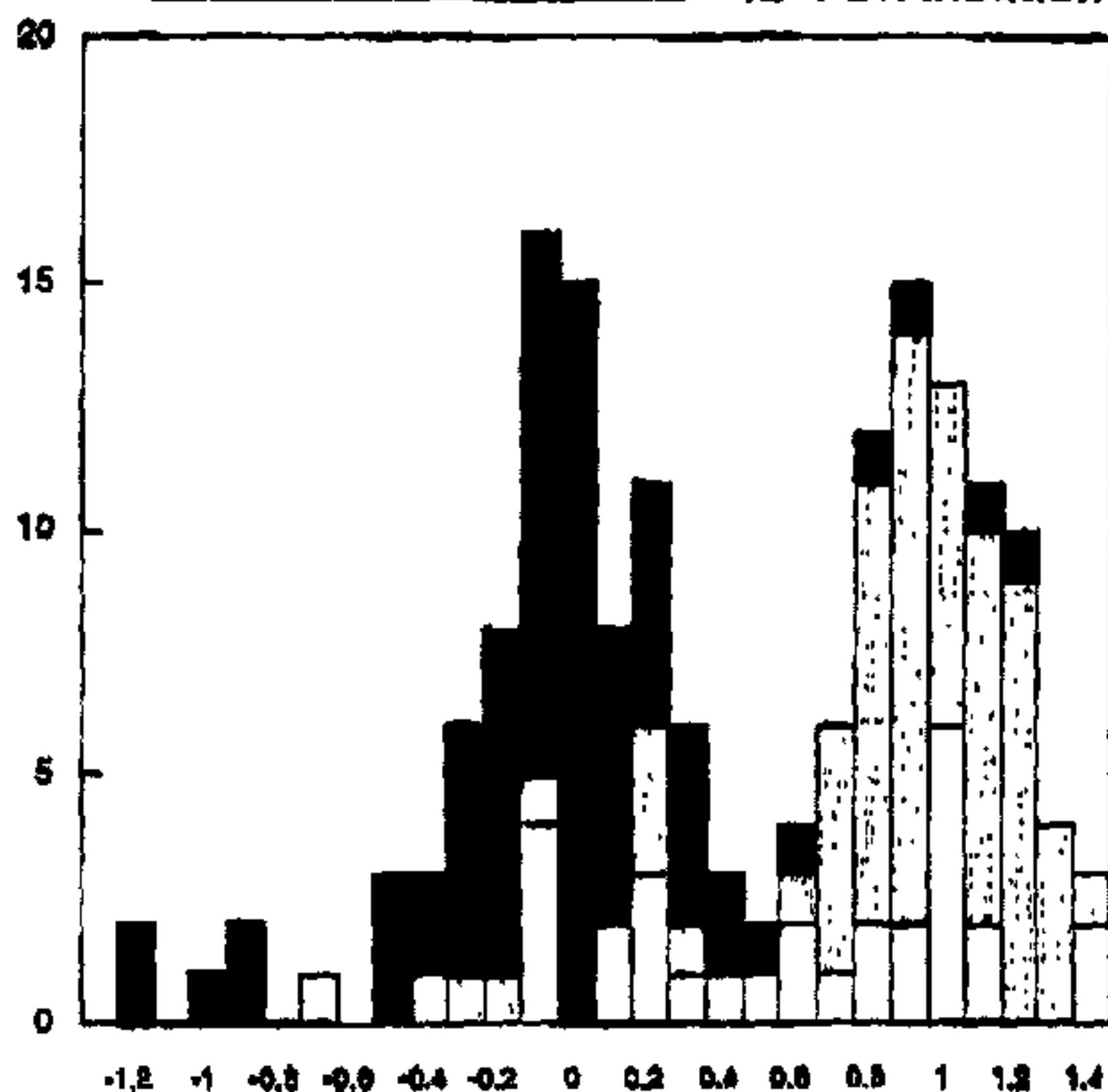
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2		A	.05
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6		D	.02



a.



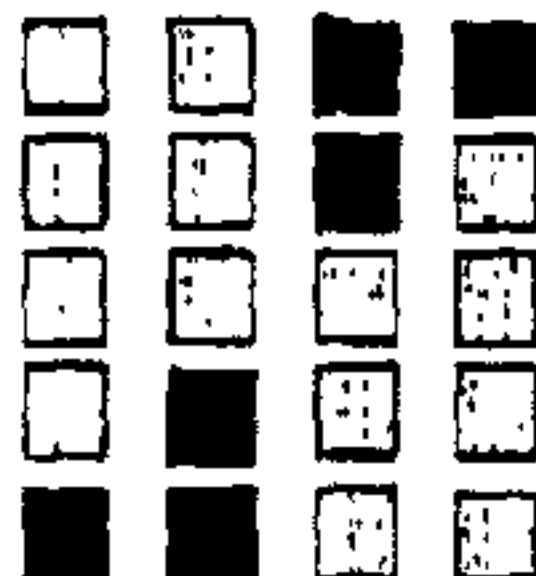
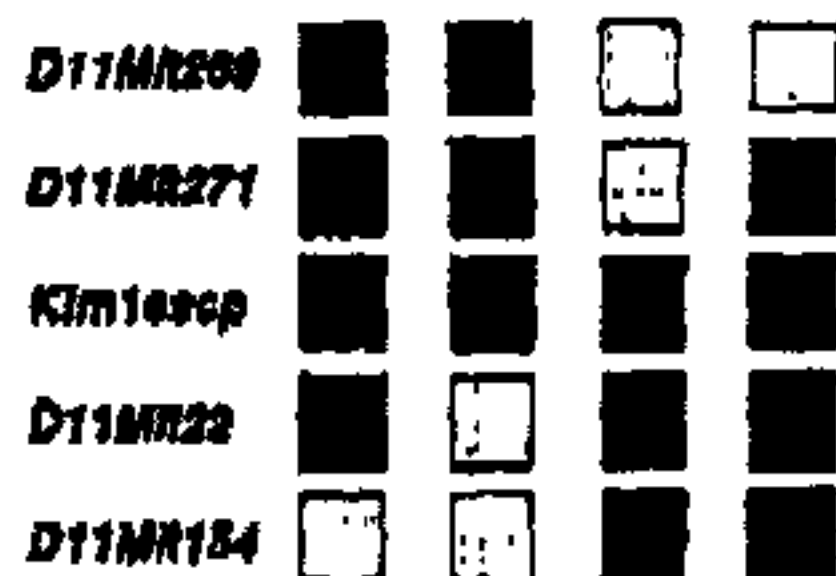
IL-4 Distribution

Index = $(B-x)/(B-H)$

b.

High IL-4 Phenotype

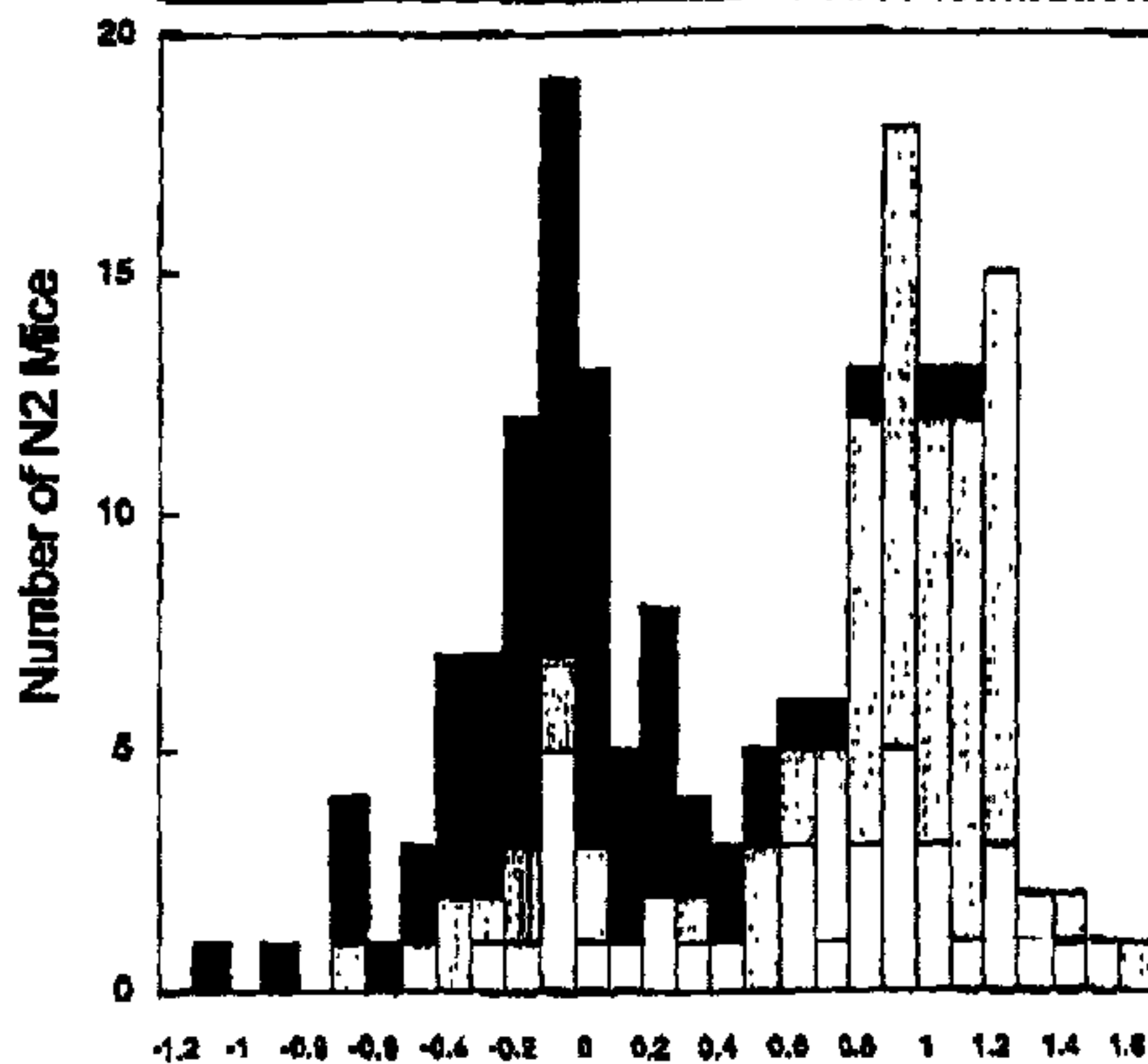
Low IL-4 Phenotype



c.



AHR Distribution

Index = $(B-x)/(B-H)$

d.

High AHR Phenotype

Low AHR Phenotype

