

HUMANIZED SIRPA-IL15 KNOCKIN MICE AND METHODS OF USE THEREOF

CROSS-REFERENCE

[0001] This application claims the benefit of U.S. Provisional Application Nos. 62/146,938, filed April 13, 2015; 62/148,667, filed 04/16/2015; and 62/287,842, filed January 27, 2016, the disclosure of each of which is incorporated herein by reference in its entirety.

FIELD OF INVENTION

[0002] The invention relates to the field of genetically modified non-human animals.

INTRODUCTION

[0003] Genetically modified non-human animals, such as humanized mice, hold great promise for translational research, as they allow modeling and studying of human diseases *in vivo*. Within the last decade, considerable progress has been made in developing humanized mice by genetically inserting human genes that are essential for the proper development and function of human immune cells in the mouse.

However, some limitations still restrict the utility of humanized mice in translational research. In particular, the development and survival of human T cells is suboptimal.

[0004] Although the bone marrow-liver-thymus (BLT) model has been shown to improve intestinal T cell reconstitution in NS/NSG-BLT mice (Denton PW, Nochi T, Lim A *et al. Mucosal Immunol* 2012; 5:555-566, Nochi T, Denton PW, Wahl A *et al. Cell Rep* 2013; 3:1874-1884), those mice have been shown to develop graft-versus-host disease, resulting in massive immune cell infiltration in multiple tissues (Greenblatt MB, Vrbanc V, Tivey T *et al. PLoS One* 2012; 7:e44664). Therefore, current humanized mouse models still lack proper development and function of human T cells. In particular, the absence of human tissue-resident memory T cells prevents the use of humanized mice as a preclinical tool to develop and test more efficient immunization strategies that aim to induce long-lasting mucosal immunity against pathogens such as HIV.

[0005] In order to better understand the development and survival of human tissue-resident T cells and provide a model to test novel immunization strategies to induce long-lasting T cell-dependent mucosal immunity, it would be useful to have a genetically modified non-human animal which develops human tissue-resident T cells. Such a mouse model could also be used to study the interaction of human tissue-resident immune cells with the gut microbiota, for example, how the microbiota may shape the development and survival of human immune cells in the small intestine and colon.

[0006] In addition, there is a need in the art for non-human animal models of human Natural Killer (NK) cell development and function.

SUMMARY

[0007] Genetically modified non-human animals expressing human SIRP α and human IL-15 from the non-human animal genome are provided. Also provided are methods for making non-human animals expressing human SIRP α and human IL-15 from the non-human animal genome, and methods for using non-human animals expressing human SIRP α and human IL-15 from the non-human animal genome. These animals and methods find many uses in the art, including, for example, in modeling human T cell and/or natural killer (NK) cell development and function; in modeling human pathogen infection of human T cells and/or NK cells; in *in vivo* screens for agents that inhibit infection by a pathogen that activates, induces and/or targets T cells and/or NK cells; in *in vivo* screens for agents that modulate the development and/or function of human T cells and/or NK cells, e.g. in a healthy or a diseased state; in *in vivo* screens for agents that are toxic to human T cells and/or NK cells; in *in vivo* screens for agents that prevent against, mitigate, or reverse the toxic effects of toxic agents on human T cells and/or NK cells; in *in vivo* screens of candidate T cell-inducing vaccines; and in *in vivo* and *in vitro* screens for agents that inhibit tumor growth and/or infection by activating NK cell-mediated antibody dependent cellular cytotoxicity (ADCC) processes.

[0008] In a first aspect, the present disclosure provides a genetically modified non-human animal, including: a nucleic acid sequence incorporated into the genome of the genetically modified non-human animal, which sequence encodes a human SIRP α protein and is operably linked to a SIRP α gene promoter; and a nucleic acid sequence

incorporated into the genome of the genetically modified non-human animal, which sequence encodes a human IL-15 protein and is operably linked to an IL-15 gene promoter, wherein the genetically modified non-human animal expresses the human SIRP α protein and the human IL-15 protein.

[0009] The SIRP α gene promoter can be an endogenous non-human SIRP α gene promoter. For example, the SIRP α gene promoter can be the endogenous non-human SIRP α gene promoter at the non-human animal SIRP α gene locus. Where the SIRP α gene promoter is the endogenous non-human SIRP α gene promoter at the non-human animal SIRP α gene locus, the genetically modified non-human animal can include a null mutation in the non-human SIRP α gene at the non-human animal SIRP α gene locus. In one such embodiment, the genetically modified non-human animal is a mouse and the null mutation is a deletion of at least mouse SIRP α exons 2-4. In another such embodiment, the genetically modified non-human animal is heterozygous for the allele including the nucleic acid sequence that encodes the human SIRP α protein. In another such embodiment, the genetically modified non-human animal is homozygous for the allele including the nucleic acid sequence that encodes the human SIRP α protein.

[0010] In another embodiment of the first aspect, or in a further embodiment of any of the above embodiments thereof, the nucleic acid sequence that encodes the human SIRP α protein includes human SIRP α genomic coding and non-coding sequence.

[0011] In another embodiment of the first aspect, or in a further embodiment of any of the above embodiments thereof, the human SIRP α protein is a functional fragment of a full length human SIRP α protein. In one such embodiment, the functional fragment includes an extracellular domain of human SIRP α , e.g., an extracellular domain that includes at least amino acids 28-362 of SEQ ID NO:12.

[0012] In another embodiment of the first aspect, or in a further embodiment of any of the above embodiments thereof, the IL-15 gene promoter is an endogenous non-human IL-15 gene promoter. In one such embodiment, the IL-15 gene promoter is the endogenous non-human IL-15 gene promoter at the non-human animal IL-15 gene locus. In one embodiment, where the IL-15 gene promoter is the endogenous non-human IL-15 gene promoter at the non-human animal IL-15 gene locus, the genetically modified non-human animal includes a null mutation in the non-human IL-

IL-15 gene at the non-human animal IL-15 gene locus. In one such embodiment, the genetically modified non-human animal is a mouse and the null mutation is a deletion of at least mouse IL-15 exons 5-8. In another such embodiment, the genetically modified non-human animal is heterozygous for the allele including the nucleic acid sequence that encodes the human IL-15 protein. In another such embodiment, the genetically modified non-human animal is homozygous for the allele including the nucleic acid sequence that encodes the human IL-15 protein.

[00013] In another embodiment of the first aspect, or in a further embodiment of any of the above embodiments thereof, the nucleic acid sequence that encodes the human IL-15 protein includes human IL-15 genomic coding and non-coding sequence.

[00014] In another embodiment of the first aspect, or in a further embodiment of any of the above embodiments thereof, the human IL-15 protein is a functional fragment of a full length human IL-15 protein.

[00015] In another embodiment of the first aspect, or in a further embodiment of any of the above embodiments thereof, the genetically modified non-human animal is immunodeficient. For example, in one embodiment the genetically modified non-human animal includes a Rag2 gene knock-out. In another embodiment, the genetically modified non-human animal includes an IL2rg gene knock-out or both a Rag2 gene knock-out and an IL2rg gene knock-out.

[00016] In another embodiment of the first aspect, or in a further embodiment of any of the above embodiments thereof, the non-human animal is a mammal. In one such embodiment, the mammal is a rodent, e.g., a mouse.

[00017] In another embodiment of the first aspect, or in a further embodiment of any of the above embodiments thereof, the genetically modified non-human animal includes an engraftment of human hematopoietic cells. In one such embodiment, the genetically modified non-human animal includes an infection with a human pathogen. In one embodiment, where the the genetically modified non-human animal includes an infection with a human pathogen, the human pathogen activates, induces and/or targets T cells and/or natural killer (NK) cells. In another embodiment, where the the genetically modified non-human animal includes an infection with a human pathogen, the human pathogen is a pathogen that affects (e.g., by infecting) human intestine. In one such embodiment, the human pathogen is a human rotavirus. In another embodiment, where the the genetically modified non-human animal includes an infection with a human pathogen, the pathogen affects (e.g., by infecting) human lung.

In one such embodiment, the human pathogen is an influenza virus. In another embodiment, where the the genetically modified non-human animal includes an infection with a human pathogen, the pathogen affects (e.g., by infecting) human liver. In yet another embodiment, a genetically modified non-human animal includes an engraftment of human hematopoietic cells and a tumor, e.g., a human tumor, e.g., transplanted human tumor.

[00018] In a second aspect, the present disclosure provides an *in vivo* model, including a genetically modified non-human animal including: a nucleic acid sequence incorporated into the genome of the genetically modified non-human animal, which sequence encodes a human SIRP α protein and is operably linked to a SIRP α gene promoter; a nucleic acid sequence incorporated into the genome of the genetically modified non-human animal, which sequence encodes a human IL-15 protein and is operably linked to an IL-15 gene promoter; and an engraftment of human hematopoietic cells, wherein the genetically modified non-human animal (i) expresses the human SIRP α protein and the human IL-15 protein, and (ii) includes human intraepithelial lymphocytes (IELs) in the small intestine and Peyer's patches of the genetically modified non-human animal.

[00019] In one embodiment of the second aspect, the genetically modified non-human animal includes an infection with a human pathogen, e.g., an intestinal pathogen. In one such embodiment, the intestinal pathogen is selected from: *Campylobacter jejuni*, *Clostridium difficile*, *Enterococcus faecalis*, *Enterococcus faecium*, *Escherichia coli*, Human Rotavirus, *Listeria monocytogenes*, Norwalk Virus, *Salmonella enterica*, *Shigella flexneri*, *Shigella sonnei*, *Shigella dysenteriae*, *Yersinia pestis*, *Yersinia enterocolitica*, and *Helicobacter pylori*.

[00020] In another embodiment of the second aspect, or in a further embodiment of any of the above embodiments thereof, the SIRP α gene promoter is an endogenous non-human SIRP α gene promoter. In one such embodiment, the SIRP α gene promoter is the endogenous non-human SIRP α gene promoter at the non-human animal SIRP α gene locus. In one embodiment, where the SIRP α gene promoter is the endogenous non-human SIRP α gene promoter at the non-human animal SIRP α gene locus, the genetically modified non-human animal includes a null mutation in the non-human SIRP α gene at the non-human animal SIRP α gene locus. In one such embodiment, the genetically modified non-human animal is a mouse and the null

mutation is a deletion of at least mouse SIRP α exons 2-4. In another such embodiment, the genetically modified non-human animal is heterozygous for the allele including the nucleic acid sequence that encodes the human SIRP α protein. In another such embodiment, the genetically modified non-human animal is homozygous for the allele including the nucleic acid sequence that encodes the human SIRP α protein.

[00021] In another embodiment of the second aspect, or in a further embodiment of any of the above embodiments thereof, the nucleic acid sequence that encodes the human SIRP α protein includes human SIRP α genomic coding and non-coding sequence.

[00022] In another embodiment of the second aspect, or in a further embodiment of any of the above embodiments thereof, the human SIRP α protein is a functional fragment of a full length human SIRP α protein. In one such embodiment, the functional fragment includes an extracellular domain of human SIRP α , e.g., an extracellular domain that includes amino acids 28-362 of SEQ ID NO:12.

[00023] In another embodiment of the second aspect, or in a further embodiment of any of the above embodiments thereof, the IL-15 gene promoter is an endogenous non-human IL-15 gene promoter. In one such embodiment, the IL-15 gene promoter is the endogenous non-human IL-15 gene promoter at the non-human animal IL-15 gene locus. In one embodiment, where the IL-15 gene promoter is the endogenous non-human IL-15 gene promoter at the non-human animal IL-15 gene locus, the genetically modified non-human animal includes a null mutation in the non-human IL-15 gene at the non-human animal IL-15 gene locus. In one such embodiment, the genetically modified non-human animal is a mouse and the null mutation is a deletion of at least mouse IL-15 exons 5-8. In one such embodiment, the genetically modified non-human animal is heterozygous for the allele including the nucleic acid sequence that encodes the human IL-15 protein. In another such embodiment, the genetically modified non-human animal is homozygous for the allele including the nucleic acid sequence that encodes the human IL-15 protein.

[00024] In another embodiment of the second aspect, or in a further embodiment of any of the above embodiments thereof, the nucleic acid sequence that encodes the human IL-15 protein includes human IL-15 genomic coding and non-coding sequence.

[00025] In another embodiment of the second aspect, or in a further

embodiment of any of the above embodiments thereof, the human IL-15 protein is a functional fragment of a full length human IL-15 protein.

[00026] In another embodiment of the second aspect, or in a further embodiment of any of the above embodiments thereof, the genetically modified non-human animal is immunodeficient. For example, in one embodiment the genetically modified non-human animal includes a Rag2 gene knock-out. In another embodiment, the genetically modified non-human animal includes an an IL2rg gene knock-out or both a Rag2 gene knock-out and an an IL2rg gene knock-out.

[00027] In another embodiment of the second aspect, or in a further embodiment of any of the above embodiments thereof, the non-human animal is a mammal. In one such embodiment, the mammal is a rodent, e.g., a mouse.

[00028] In a third aspect, the present disclosure provides an *in vivo* model, including a genetically modified non-human animal including: a nucleic acid sequence incorporated into the genome of the genetically modified non-human animal, which sequence encodes a human SIRP α protein and is operably linked to a SIRP α gene promoter; a nucleic acid sequence incorporated into the genome of the genetically modified non-human animal, which sequence encodes a human IL-15 protein and is operably linked to an IL-15 gene promoter; and an engraftment of human hematopoietic cells, wherein the genetically modified non-human animal (i) expresses the human SIRP α protein and the human IL-15 protein, and (ii) includes human intraepithelial lymphocytes (IELs) in the lung of the genetically modified non-human animal.

[00029] In one embodiment of the third aspect, the genetically modified non-human animal includes an infection with a human pathogen, e.g., a lung pathogen. In one such embodiment, the lung pathogen is selected from: *Streptococcus pyogenes*, *Haemophilus influenza*, *Corynebacterium diphtheria*, *SARS coronavirus*, *Bordetella pertussis*, *Moraxella catarrhalis*, Influenza virus (A, B, C), Coronavirus, Adenovirus, Respiratory Syncytial Virus, Parainfluenza virus, Mumps virus, *Streptococcus pneumoniae*, *Staphylococcus aureus*, *Legionella pneumophila*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, *Mycoplasma pneumonia*, *Mycobacterium tuberculosis*, *Chlamydia Pneumoniae*, *Blastomyces dermatitidis*, *Cryptococcus neoformans*, and *Aspergillus fumigatus*.

[00030] In another embodiment of the third aspect, or in a further embodiment of any of the above embodiments thereof, the SIRP α gene promoter is an endogenous non-human SIRP α gene promoter. In one such embodiment, the SIRP α gene promoter is the endogenous non-human SIRP α gene promoter at the non-human animal SIRP α gene locus. In one embodiment, where the SIRP α gene promoter is the endogenous non-human SIRP α gene promoter at the non-human animal SIRP α gene locus, the genetically modified non-human animal includes a null mutation in the non-human SIRP α gene at the non-human animal SIRP α gene locus. In one such embodiment, the genetically modified non-human animal is a mouse and the null mutation is a deletion of at least mouse SIRP α exons 2-4. In another such embodiment, the genetically modified non-human animal is heterozygous for the allele including the nucleic acid sequence that encodes the human SIRP α protein. In another such embodiment, the genetically modified non-human animal is homozygous for the allele including the nucleic acid sequence that encodes the human SIRP α protein.

[00031] In another embodiment of the third aspect, or in a further embodiment of any of the above embodiments thereof, the nucleic acid sequence that encodes the human SIRP α protein includes human SIRP α genomic coding and non-coding sequence.

[00032] In another embodiment of the third aspect, or in a further embodiment of any of the above embodiments thereof, the human SIRP α protein is a functional fragment of a full length human SIRP α protein. In one such embodiment, the functional fragment includes an extracellular domain of human SIRP α , e.g., an extracellular domain including at least amino acids 28-362 of SEQ ID NO:12.

[00033] In another embodiment of the third aspect, or in a further embodiment of any of the above embodiments thereof, the IL-15 gene promoter is an endogenous non-human IL-15 gene promoter. In one such embodiment, the IL-15 gene promoter is the endogenous non-human IL-15 gene promoter at the non-human animal IL-15 gene locus.

[00034] In one embodiment, where the IL-15 gene promoter is the endogenous non-human IL-15 gene promoter at the non-human animal IL-15 gene locus, the genetically modified non-human animal includes a null mutation in the non-human IL-15 gene at the non-human animal IL-15 gene locus. In one such embodiment, the genetically modified non-human animal is a mouse and the null mutation is a deletion

of at least mouse IL-15 exons 5-8. In another such embodiment, the genetically modified non-human animal is heterozygous for the allele including the nucleic acid sequence that encodes the human IL-15 protein. In another such embodiment, the genetically modified non-human animal is homozygous for the allele including the nucleic acid sequence that encodes the human IL-15 protein.

[00035] In another embodiment of the third aspect, or in a further embodiment of any of the above embodiments thereof, the nucleic acid sequence that encodes the human IL-15 protein includes human IL-15 genomic coding and non-coding sequence.

[00036] In another embodiment of the third aspect, or in a further embodiment of any of the above embodiments thereof, the human IL-15 protein is a functional fragment of a full length human IL-15 protein.

[00037] In another embodiment of the third aspect, or in a further embodiment of any of the above embodiments thereof, the genetically modified non-human animal is immunodeficient. For example, in one embodiment the genetically modified non-human animal includes a Rag2 gene knock-out. In another embodiment, the genetically modified non-human animal includes an IL2rg gene knock-out or both a Rag2 gene knock-out and an IL2rg gene knock-out.

[00038] In another embodiment of the third aspect, or in a further embodiment of any of the above embodiments thereof, the non-human animal is a mammal. In one such embodiment, the mammal is a rodent, e.g., a mouse.

[00039] In a fourth aspect, the present disclosure provides a method of determining the efficacy of a candidate T-cell inducing vaccine, the method including: administering a candidate T-cell inducing vaccine to a genetically modified non-human animal, wherein the genetically modified non-human animal is deficient for an endogenous immune system and includes: (i) a nucleic acid sequence incorporated into the genome of the genetically modified non-human animal, which sequence encodes a human SIRP α protein and is operably linked to a SIRP α gene promoter, (ii) a nucleic acid sequence incorporated into the genome of the genetically modified non-human animal, which sequence encodes a human IL-15 protein and is operably linked to an IL-15 gene promoter, and (iii) an engraftment of human hematopoietic cells, wherein the genetically modified non-human animal expresses the human SIRP α protein and the human IL-15 protein; challenging the genetically modified non-human animal with a human pathogen; and determining whether the candidate T-cell inducing vaccine

induces a T cell mediated immune response in the genetically modified non-human animal.

[00040] In one embodiment of the fourth aspect, the SIRP α gene promoter is an endogenous non-human SIRP α gene promoter. In one such embodiment, the SIRP α gene promoter is the endogenous non-human SIRP α gene promoter at the non-human animal SIRP α gene locus. In one embodiment, where the SIRP α gene promoter is the endogenous non-human SIRP α gene promoter at the non-human animal SIRP α gene locus, the genetically modified non-human animal includes a null mutation in the non-human SIRP α gene at the non-human animal SIRP α gene locus. In one such embodiment, the genetically modified non-human animal is a mouse and the null mutation is a deletion of at least mouse SIRP α exons 2-4. In another such embodiment, the genetically modified non-human animal is heterozygous for the allele including the nucleic acid sequence that encodes the human SIRP α protein. In another such embodiment, the genetically modified non-human animal is homozygous for the allele including the nucleic acid sequence that encodes the human SIRP α protein.

[00041] In another embodiment of the fourth aspect, or in a further embodiment of any of the above embodiments thereof, the nucleic acid sequence that encodes the human SIRP α protein includes human SIRP α genomic coding and non-coding sequence.

[00042] In another embodiment of the fourth aspect, or in a further embodiment of any of the above embodiments thereof, the human SIRP α protein is a functional fragment of a full length human SIRP α protein. In one such embodiment, the functional fragment includes an extracellular domain of human SIRP α , e.g., an extracellular domain including at least amino acids 28-362 of SEQ ID NO:12.

[00043] In another embodiment of the fourth aspect, or in a further embodiment of any of the above embodiments thereof, the IL-15 gene promoter is an endogenous non-human IL-15 gene promoter. In one such embodiment, the IL-15 gene promoter is the endogenous non-human IL-15 gene promoter at the non-human animal IL-15 gene locus. In one embodiment, where the IL-15 gene promoter is the endogenous non-human IL-15 gene promoter at the non-human animal IL-15 gene locus, the genetically modified non-human animal includes a null mutation in the non-human IL-15 gene at the non-human animal IL-15 gene locus. In one such embodiment, the genetically modified non-human animal is a mouse and the null mutation is a deletion

of at least mouse IL-15 exons 5-8. In another such embodiment, the genetically modified non-human animal is heterozygous for the allele including the nucleic acid sequence that encodes the human IL-15 protein. In another such embodiment, the genetically modified non-human animal is homozygous for the allele including the nucleic acid sequence that encodes the human IL-15 protein.

[00044] In another embodiment of the fourth aspect, or in a further embodiment of any of the above embodiments thereof, the nucleic acid sequence that encodes the human IL-15 protein includes human IL-15 genomic coding and non-coding sequence.

[00045] In another embodiment of the fourth aspect, or in a further embodiment of any of the above embodiments thereof, the human IL-15 protein is a functional fragment of a full length human IL-15 protein.

[00046] In another embodiment of the fourth aspect, or in a further embodiment of any of the above embodiments thereof, the genetically modified non-human animal includes a Rag2 gene knock-out.

[00047] In another embodiment of the fourth aspect, or in a further embodiment of any of the above embodiments thereof, the genetically modified non-human animal includes an IL2rg gene knock-out.

[00048] In another embodiment of the fourth aspect, or in a further embodiment of any of the above embodiments thereof, the genetically modified non-human animal is a mammal, such as a rodent, e.g., a mouse.

[00049] In a fifth aspect, the present disclosure provides a method of identifying an agent that inhibits an infection by a pathogen that activates, induces and/or targets human T cells and/or natural killer (NK) cells, the method including: administering an agent to a genetically modified non-human animal, wherein the genetically modified non-human animal is deficient for an endogenous immune system and includes: (i) a nucleic acid sequence incorporated into the genome of the genetically modified non-human animal, which sequence encodes a human SIRP α protein and is operably linked to a SIRP α gene promoter, (ii) a nucleic acid sequence incorporated into the genome of the genetically modified non-human animal, which sequence encodes a human IL-15 protein and is operably linked to an IL-15 gene promoter, (iii) an engraftment of human hematopoietic cells, and (iv) an infection by a pathogen that activates, induces and/or targets human T cells and/or natural killer cells, wherein the genetically modified non-human animal expresses the human SIRP α protein and the human IL-15

protein; and determining whether the agent reduces the amount of the pathogen in the pathogen-infected non-human animal.

[00050] In one embodiment of the fifth aspect, the SIRP α gene promoter is an endogenous non-human SIRP α gene promoter. In one such embodiment, the SIRP α gene promoter is the endogenous non-human SIRP α gene promoter at the non-human animal SIRP α gene locus. In one embodiment, where the SIRP α gene promoter is the endogenous non-human SIRP α gene promoter at the non-human animal SIRP α gene locus, the genetically modified non-human animal includes a null mutation in the non-human SIRP α gene at the non-human animal SIRP α gene locus. In one such embodiment, the genetically modified non-human animal is a mouse and the null mutation is a deletion of at least mouse SIRP α exons 2-4. In another such embodiment, the genetically modified non-human animal is heterozygous for the allele including the nucleic acid sequence that encodes the human SIRP α protein. In another such embodiment, the genetically modified non-human animal is homozygous for the allele including the nucleic acid sequence that encodes the human SIRP α protein.

[00051] In another embodiment of the fifth aspect, or in a further embodiment of any of the above embodiments thereof, the nucleic acid sequence that encodes the human SIRP α protein includes human SIRP α genomic coding and non-coding sequence.

[00052] In another embodiment of the fifth aspect, or in a further embodiment of any of the above embodiments thereof, the human SIRP α protein is a functional fragment of a full length human SIRP α protein. In one such embodiment, the functional fragment includes an extracellular domain of human SIRP α , e.g., an extracellular domain which includes amino acids 28-362 of SEQ ID NO:12.

[00053] In another embodiment of the fifth aspect, or in a further embodiment of any of the above embodiments thereof, the IL-15 gene promoter is an endogenous non-human IL-15 gene promoter. In one such embodiment, the IL-15 gene promoter is the endogenous non-human IL-15 gene promoter at the non-human animal IL-15 gene locus. In one embodiment, where the IL-15 gene promoter is the endogenous non-human IL-15 gene promoter at the non-human animal IL-15 gene locus, the genetically modified non-human animal includes a null mutation in the non-human IL-15 gene at the non-human animal IL-15 gene locus. In one such embodiment, the genetically modified non-human animal is a mouse and the null mutation is a deletion

of at least mouse IL-15 exons 5-8. In another such embodiment, the genetically modified non-human animal is heterozygous for the allele including the nucleic acid sequence that encodes the human IL-15 protein. In another such embodiment, the genetically modified non-human animal is homozygous for the allele including the nucleic acid sequence that encodes the human IL-15 protein.

[00054] In another embodiment of the fifth aspect, or in a further embodiment of any of the above embodiments thereof, the nucleic acid sequence that encodes the human IL-15 protein includes human IL-15 genomic coding and non-coding sequence.

[00055] In another embodiment of the fifth aspect, or in a further embodiment of any of the above embodiments thereof, the human IL-15 protein is a functional fragment of a full length human IL-15 protein.

[00056] In another embodiment of the fifth aspect, or in a further embodiment of any of the above embodiments thereof, the genetically modified non-human animal includes a Rag2 gene knock-out.

[00057] In another embodiment of the fifth aspect, or in a further embodiment of any of the above embodiments thereof, the genetically modified non-human animal includes an IL2rg gene knock-out.

[00058] In another embodiment of the fifth aspect, or in a further embodiment of any of the above embodiments thereof, the genetically modified non-human animal is a mammal, such as a rodent, e.g., a mouse.

[00059] In a sixth aspect, the present disclosure provides a method of making a non-human animal expressing a human IL-15 protein and a human SIRP α protein, including: introducing into a genome of a first non-human animal a nucleic acid sequence encoding a human IL-15 protein, wherein the sequence encoding the human IL-15 protein is operably linked to an IL-15 gene promoter sequence; introducing into a genome of a second non-human animal a nucleic acid sequence encoding a human SIRP α protein, wherein the sequence encoding the human SIRP α protein is operably linked to a SIRP α promoter sequence; and making a third non-human animal that includes the nucleic acid sequence encoding the human IL-15 protein and the nucleic acid sequence encoding the human SIRP α protein, wherein the third non-human animal expresses the human IL-15 protein and the human SIRP α protein.

[00060] In one embodiment of the sixth aspect, the steps of introducing include generating a non-human animal from a pluripotent stem cell including the nucleic acid

encoding human IL-15 or human SIRP α .

[00061] In another embodiment of the sixth aspect, or in a further embodiment of any of the above embodiments thereof, the first animal is a different animal than the second animal, and the step of making the third animal includes breeding the first and the second animal.

[00062] In another embodiment of the sixth aspect, the first animal and the second animal are the same, the step of introducing into the genome of the first animal includes contacting a first pluripotent stem cell with the nucleic acid sequence encoding the human IL-15 protein to obtain a second pluripotent stem cell, the step of introducing into the genome of the second animal includes contacting the second pluripotent stem cell with the nucleic acid sequence encoding the human SIRP α protein to obtain a third pluripotent stem cell, and the third non-human animal is made from the third pluripotent stem cell.

[00063] In an alternative version of the sixth aspect, the present disclosure provides a method of making a non-human animal expressing a human IL-15 protein and a human SIRP α protein, including: introducing into a genome of a first non-human animal a nucleic acid sequence encoding a human SIRP α protein, wherein the sequence encoding the human SIRP α protein is operably linked to an SIRP α gene promoter sequence; introducing into a genome of a second non-human animal a nucleic acid sequence encoding a human IL-15 protein, wherein the sequence encoding the human IL-15 protein is operably linked to a IL-15 promoter sequence; and making a third non-human animal that includes the nucleic acid sequence encoding the human IL-15 protein and the nucleic acid sequence encoding the human SIRP α protein, wherein the third non-human animal expresses the human IL-15 protein and the human SIRP α protein.

[00064] In yet another embodiment of the sixth aspect, the first animal and the second animal are the same, the step of introducing into the genome of the first animal includes contacting a first pluripotent stem cell with the nucleic acid sequence encoding the human SIRP α protein to obtain a second pluripotent stem cell, the step of introducing into the genome of the second animal includes contacting the second pluripotent stem cell with the nucleic acid sequence encoding the human IL-15 protein to obtain a third pluripotent stem cell, and the third non-human animal is made from the third pluripotent stem cell.

[00065] In another embodiment of the sixth aspect, or in a further embodiment of any of the above embodiments thereof, the pluripotent stem cell is an ES cell or an iPS cell.

[00066] In another embodiment of the sixth aspect, or in a further embodiment of any of the above embodiments thereof, the pluripotent stem cell is deficient for Rag2.

[00067] In another embodiment of the sixth aspect, or in a further embodiment of any of the above embodiments thereof, the pluripotent stem cell is deficient for IL2rg.

[00068] In another embodiment of the sixth aspect, or in a further embodiment of any of the above embodiments thereof, the third non-human animal is deficient in one or both of Rag2 and IL2rg.

[00069] In another embodiment of the sixth aspect, or in a further embodiment of any of the above embodiments thereof, the IL-15 promoter sequence is a sequence for the human IL-15 promoter.

[00070] In another embodiment of the sixth aspect, or in a further embodiment of any of the above embodiments thereof, the IL-15 promoter sequence is a sequence for the endogenous non-human animal IL-15 promoter.

[00071] In another embodiment of the sixth aspect, or in a further embodiment of any of the above embodiments thereof, the integration results in a replacement of the non-human IL-15 gene at the non-human IL-15 gene locus.

[00072] In another embodiment of the sixth aspect, or in a further embodiment of any of the above embodiments thereof, the nucleic acid sequence that encodes the human IL-15 protein includes human IL-15 genomic coding and non-coding sequence.

[00073] In a seventh aspect, the present disclosure provides a method of engrafting a genetically modified non-human animal expressing a human IL-15 protein, including: transplanting a population of cells including human hematopoietic cells into the genetically modified non-human animal made by a method according to the sixth aspect or any embodiment thereof. In one such embodiment, the transplanting includes tail-vein injection, fetal liver injection, or retro-orbital injection.

[00074] In another embodiment of the seventh aspect, or in a further embodiment of any of the above embodiments thereof, the genetically modified non-human animal is sublethally irradiated prior to transplantation.

[00075] In another embodiment of the seventh aspect, or in a further

embodiment of any of the above embodiments thereof, the human hematopoietic cells are CD34+ cells.

[00076] In another embodiment of the seventh aspect, or in a further embodiment of any of the above embodiments thereof, the human hematopoietic cells are from fetal liver, adult bone marrow, or umbilical cord blood.

[00077] In an eighth aspect, the present disclosure provides a method of determining the efficacy of a candidate therapeutic antibody or antigen-binding protein in killing a target cell, the method including: administering the candidate therapeutic antibody or antigen-binding protein to a genetically modified non-human animal, wherein the genetically modified non-human animal is deficient for an endogenous immune system and includes: (i) a nucleic acid sequence incorporated into the genome of the genetically modified non-human animal, which sequence encodes a human SIRP α protein and is operably linked to a SIRP α gene promoter, (ii) a nucleic acid sequence incorporated into the genome of the genetically modified non-human animal, which sequence encodes a human IL-15 protein and is operably linked to an IL-15 gene promoter, and (iii) an engraftment of human hematopoietic cells, wherein the genetically modified non-human animal expresses the human SIRP α protein and the human IL-15 protein; and determining whether the candidate therapeutic antibody or antigen-binding protein modulates an NK cell mediated antibody-dependent cellular cytotoxicity against the target cell in the genetically modified non-human animal.

[00078] In a ninth aspect, the present disclosure provides a method of determining the efficacy of a candidate therapeutic antibody or antigen-binding protein, in killing a target cell including: isolating an NK cell from a genetically modified non-human animal, wherein the genetically modified non-human animal is deficient for an endogenous immune system and includes: (i) a nucleic acid sequence incorporated into the genome of the genetically modified non-human animal, which sequence encodes a human SIRP α protein and is operably linked to a SIRP α gene promoter, (ii) a nucleic acid sequence incorporated into the genome of the genetically modified non-human animal, which sequence encodes a human IL-15 protein and is operably linked to an IL-15 gene promoter, and (iii) an engraftment of human hematopoietic cells, wherein the genetically modified non-human animal expresses the human SIRP α protein and the human IL-15 protein; contacting the isolated NK cell with the candidate therapeutic antibody or antigen-binding protein and the target cell;

and determining the antibody- or the antigen-binding protein-dependent cytolytic activity of the isolated NK cell against the target cell.

[00079] In a tenth aspect, the present disclosure provides a method of screening a candidate therapeutic antibody or antigen-binding protein for improved efficacy in killing a target cell including: administering the candidate therapeutic antibody or antigen-binding protein to a genetically modified non-human animal, wherein the genetically modified non-human animal is deficient for an endogenous immune system and includes: (i) a nucleic acid sequence incorporated into the genome of the genetically modified non-human animal, which sequence encodes a human SIRP α protein and is operably linked to a SIRP α gene promoter, (ii) a nucleic acid sequence incorporated into the genome of the genetically modified non-human animal, which sequence encodes a human IL-15 protein and is operably linked to an IL-15 gene promoter, and (iii) an engraftment of human hematopoietic cells, wherein the genetically modified non-human animal expresses the human SIRP α protein and the human IL-15 protein; and determining whether the candidate therapeutic antibody or antigen-binding protein displays improved efficacy in killing the target cell in the genetically modified non-human animal.

[00080] In an embodiment of any one of the eighth, ninth and tenth aspects, the target cell is one or more of a tumor cell, a virally-infected cell, a bacterially-infected cell, a bacterial cell, a fungal cell, and a parasitic cell.

BRIEF DESCRIPTION OF THE DRAWINGS

[00081] The patent or application file contains at least one drawing executed in color. Copies of this patent or patent application publication with color drawing(s) will be provided by the Office upon request and payment of the necessary fee.

[00082] **FIG. 1** provides a schematic representation of replacement of the mouse SIRP α gene with human SIRP α sequence. FIG. 1 (top) shows the mouse Sirp α locus indicating the relative location of exons 1-8. FIG. 1 (bottom) provides a schematic representation showing the final targeted allele with human exons 2-4. The encoded chimeric protein possesses an extracellular region corresponding to amino acids 28-362 of the wild-type human SIRP α protein fused to the intracellular portion of the mouse SIRP α protein. Diagonally striped shapes represent inserted human

sequence.

[00083] **FIG. 2** provides a schematic representation illustrating targeted genomic replacement of the mouse IL-15 gene as achieved for mouse 2. Empty shapes represent inserted human sequence.

[00084] **FIG. 3A** provides graphs showing hIL-15 gene expression in various tissues of non-engrafted SRG (human SIRP α , Rag KO, IL-2rg KO) and SRG-15 (human SIRP α , Rag KO, IL-2rg KO, human IL-15 (mouse 1) mice. Y-axis shows level of hIL-15 mRNA relative to the housekeeping gene *Hprt*.

[00085] **FIG. 3B** provides graphs showing human hIL-15 gene expression in various tissues of non-engrafted RG (Rag KO, IL-2rg KO) and non-engrafted SRG-15 (human SIRP α , Rag KO, IL-2rg KO, human IL-15) mice (mouse #1 and mouse #2 as indicated).

[00086] **FIG. 4** provides serum levels of human IL-15 protein in SRG, SRG IL-15^{h/m} (mouse 2) and SRG IL-15^{h/h} (mouse 2) mice after challenge with poly (I:C).

[00087] **FIG. 5A** provides a graph showing efficient engraftment of human hematopoietic cells in the blood of NSG, SRG and SRG-15 (mouse 2) mice 12-14 weeks post engraftment. All data are shown as mean $\pm$ s.e.m. Statistical analyses were performed using unpaired, two-tailed Mann-Whitney U-test (* P < 0.05, ** P < 0.01, **** P < 0.0001).

[00088] **FIG. 5B** provides graphs showing human CD45⁺ cell numbers in the BM, spleen, LN, liver and lung of SRG and SRG-15 (mouse 2) 14 weeks post engraftment.

[00089] **FIG. 6A** provides plots showing human T and NK cell frequencies in SRG and SRG-15 mice (mouse 1) in bone marrow (BM), liver, and lung.

[00090] **FIG. 6B** provides graphs showing human NK cell frequencies in SRG and SRG-15 mice (mouse 1) in various tissues.

[00091] **FIG. 6C** provides plots and graphs illustrating human NK cell maturation in the liver of SRG and SRG-15 mice (mouse 1).

[00092] **FIG. 6D** provides plots showing that human CD56^{dim} CD16⁺ NK cells express high levels of human killer inhibitory receptors in the spleen of SRG-15 mice.

[00093] **FIG. 7A** provides a graph showing the frequency of human NK cells in the blood of NSG, SRG and SRG-15 (mouse 2) mice 10-12 weeks post engraftment. All data are shown as mean $\pm$ s.e.m. Statistical analyses were performed

using unpaired, two-tailed Mann-Whitney U-test (* $P < 0.05$, ** $P < 0.01$, **** $P < 0.0001$).

[00094] **FIG. 7B** provides a graph showing the percentage of human NKp46⁺ cells in the spleen 14 weeks post engraftment for SRG, SRG-15^{h/m}, and SRG-15^{h/h}. All data are shown as mean $\pm$ s.e.m. Statistical analyses were performed using unpaired, two-tailed Mann-Whitney U-test (* $P < 0.05$, ** $P < 0.01$, **** $P < 0.0001$).

[00095] **FIG. 7C** provides plots showing the frequency of human NK cells in the blood, spleen (SP), liver and lung of SRG and SRG-15 (mouse 2) mice 14 weeks post engraftment. All data are shown as mean $\pm$ s.e.m. Statistical analyses were performed using unpaired, two-tailed Mann-Whitney U-test (* $P < 0.05$, ** $P < 0.01$, **** $P < 0.0001$).

[00096] **FIG. 7D** provides graphs showing the frequency of human NK cells in the spleen (SP), liver and lung of SRG and SRG-15 (mouse 2) mice 14 weeks post engraftment. All data are shown as mean $\pm$ s.e.m. Statistical analyses were performed using unpaired, two-tailed Mann-Whitney U-test (* $P < 0.05$, ** $P < 0.01$, **** $P < 0.0001$).

[00097] **FIG. 8** provides plots (left) showing human T and NK cell distribution in SRG and SRG-15 (mouse 2) mice in blood (gated on human CD45⁺ cells (hematopoietic cells) and NKp46⁺ cells (NK cells); and a graph (right) showing the percentage of the hCD45⁺ cells that are NKp46⁺ cells in the blood of engrafted SRG-15 mice.

[00098] **FIG. 9A** provides plots showing the distribution of NK cells and T cells in the spleen and graphs showing the percentage and number of NKp46⁺ cells in the spleen of SRG-15 mice (mouse 2) engrafted with CD34⁺ huHSCs relative to SRG mice engrafted with CD34⁺ huHSCs.

[00099] **FIG. 9B** provides a graph showing human immune cell composition in the blood of NSG (n=5), SRG (n=19) and SRG-15 (mouse 2) mice (n=39) 10-12 weeks post engraftment.

[000100] **FIG. 9C** provides human CD45⁺ cell numbers in the thymus of SRG and SRG-15 (mouse 2) mice 14 weeks post engraftment.

[000101] **FIG. 9D** provides representative flow cytometry plots of hCD45⁺ cells in the thymus of an SRG and SRG-15 (mouse 2) mouse.

[000102] **FIG. 9E** provides a graph showing the composition of hCD45⁺ cells in

the thymus of SRG (n=8) and SRG-15 (mouse 2) mice (n=4) 14 weeks post engraftment.

[000103] **FIG. 10A** provides plots showing the frequency of CD56^{bright} CD16⁻ and CD56^{dim} CD16⁺ NK cell subsets in the blood and spleen of SRG and SRG-15 (mouse 2) mice seven weeks post engraftment.

[000104] **FIG. 10B** provides graphs showing the frequency of CD56^{bright} CD16⁻ and CD56^{dim} CD16⁺ NK cell subsets in the blood and spleen of SRG and SRG-15 (mouse 2) mice seven weeks post engraftment.

[000105] **FIG. 10C** provides plots and graphs showing expression of killer inhibitory receptors (KIRs) on NK cell subsets in humans and SRG-15 mice (mouse 2).

[000106] **FIG. 11** provides two plots (top left and top right) showing the distribution of CD16⁺ vs. CD16⁻ NK cells in the blood of SRG-15 mice (mouse 2) relative to a PBMC sample. FIG. 11 also provides a graph (bottom) showing the percentage of NKp46⁺ cells that are CD16⁺ vs. CD16⁻ in either blood obtained from SRG-15 mice (mouse 2) or PBMC-derived sample.

[000107] **FIG. 12** provides graphs showing human NK cell development in the bone marrow of SRG and SRG-15 (mouse 2) mice seven weeks post engraftment. All data are shown as mean $\pm$ s.e.m. Statistical analyses were performed using unpaired, two-tailed Mann-Whitney *U*-test (* $P < 0.05$, ** $P < 0.01$, **** $P < 0.0001$).

[000108] **FIG. 13A** provides graphs showing human T cell frequencies in SRG and SRG-15 mice (mouse 1) in various tissues. (K/ μ l = thousands of cells per μ l).

[000109] **FIG. 13B** provides plots and graphs showing human CD8⁺ T cell phenotype in blood and liver for SRG and SRG-15 mice (mouse 1).

[000110] **FIG. 14A** provides plots and a graph showing expression of the tissue-resident marker CD69 in lung CD8⁺ T cells of SRG and SRG-15 (mouse 1) mice.

[000111] **FIG. 14B** provides a plot and a graph showing expression of the tissue-resident marker CD69 in liver CD8⁺ T cells of SRG and SRG-15 (mouse 1) mice.

[000112] **FIG. 15A** provides graphs showing the frequency of hCD3⁺ T cells in the spleen, lung and liver of SRG and SRG-15 (mouse 2) mice 16 weeks post engraftment.

[000113] **FIG. 15B** provides graphs showing the CD4/CD8 ratio in the spleen, lung and liver of SRG and SRG-15 (mouse 2) mice 16 weeks post engraftment.

[000114] **FIG. 16A** provides plots illustrating the frequency of human lamina propria lymphocytes (LPLs) in the colon of SRG and SRG-15 (mouse 1) mice.

[000115] **FIG. 16B** provides graphs illustrating the frequency of human lamina propria lymphocytes (LPLs) in the colon of SRG and SRG-15 (mouse 1) mice.

[000116] **FIG. 17A** together with FIGS. 17B-17C, illustrates efficient engraftment of human intraepithelial lymphocytes (IELs) in the small intestine of 16 week old SRG-15 mice (mouse 1). FIG. 17A provides plots and graphs showing human CD45⁺ cells and CD8⁺ T cells within the IEL fraction of SRG and SRG-15 (mouse 1) mice.

[000117] **FIG. 17B** provides images of immunohistochemical staining of hCD45 in the small intestine of 16 week old SRG and SRG-15 (mouse 1) mice.

[000118] **FIG. 17C** provides plots showing phenotypic characteristics of human CD8⁺ T cells in the spleen and small intestine of SRG-15 mice (mouse 1).

[000119] **FIG. 18A** provides representative FACS plots showing mouse and human CD45⁺ cells within the IEL fraction of SRG and SRG-15 (mouse 2) mice 16 weeks post engraftment.

[000120] **FIG. 18B** provides graphs showing the number of human IELs in the small intestine of SRG relative to SRG-15 (mouse 2) mice and the number of human LPLs in the large intestine SRG relative to SRG-15 (mouse 2) mice. All data are shown as mean $\pm$ s.e.m. Statistical analyses were performed using unpaired, two-tailed Mann-Whitney U-test (***) $P < 0.001$.

[000121]

[000122] **FIG. 18C** provides a plot showing composition of hCD3⁺ cells in the small intestine of SRG-15 mice (mouse 2). One representative FACS plot of eight SRG-15 mice (mouse 2).

[000123] **FIG. 18D** provides graphs showing phenotypic characteristics of hCD3⁺ hCD8⁺ T cells in the spleen and small intestine of SRG-15 mice (mouse 2).

[000124] **FIG. 18E** provides images of immunohistochemical staining of hCD8 in the small intestine of SRG and SRG-15 (mouse 2) mice. The arrows indicate hCD8⁺ IELs. The pictures are representative of three mice per group.

[000125] **FIG. 19A** provides plots and graphs showing the distribution and the number of hCD45⁺ cells in the intraepithelial lymphocyte populations of SRG and SRG-15 mice and the relative percentages of NK cells and T cells in the populations of hCD45⁺ cells in the intraepithelial lymphocyte populations of SRG and SRG-15

(mouse 2) mice.

[000126] **FIG. 19B** provides plots and graphs showing the distribution and percentage of CD16⁺ and CD16⁻ NK cells in intraepithelial lymphocytes of SRG-15 mice (mouse 2) as compared with blood and spleen.

[000127] **FIG. 19C** provides plots and graphs showing the distribution and numbers of human IELs and human lamina propria lymphocytes (LPLs) in SRG and SRG-15 (mouse 2) mice.

[000128] **FIGs. 20A and 20B** provides plots and graphs demonstrating the presence of discernible Peyer's Patches containing predominantly hCD45⁺ cells in SRG-15 mice (mouse 2).

[000129] **FIG. 21A** provides a timeline for cohousing and feces sample collection for gut microbiota sequencing.

[000130] **FIG. 21B** provides a diagram showing the relative abundance of mouse bacteria in the gut of non-engrafted and engrafted SRG and SRG-15 (mouse 1) mice.

[000131] **FIG. 22** illustrates the functional relevance of human tissue-resident T cells in SRG-15 mice. More specifically, FIG. 22 provides a graph demonstrating the functional relevance of human IELs in clearing acute rotavirus infection.

[000132] **FIG. 23A** provides ViSNE plots showing CyTOF-based analysis of 42 parameters of CD56^{bright} CD16⁻ and CD56^{dim} CD16⁺ NK cell subsets in humans (n=20) and SRG-15 mice (mouse 2) (n=9). Each dot represents a single cell.

[000133] **FIG. 23B** provides ViSNE plots showing the expression intensity of eight selected markers on CD56^{bright} CD16⁻ NK cells in humans (n=20) and SRG-15 mice (mouse 2) (n=9).

[000134] **FIG. 23C** ViSNE plots showing the expression intensity of eight selected markers on CD56^{dim} CD16⁺ NK cells in humans (n=20) and SRG-15 mice (n=9).

[000135] **FIG. 24A** provides a graph showing the percentage of blood NK cells in SRG vs SRG-15 (mouse 2) mice that are CD69⁺ before and after poly-IC injection.

[000136] **FIG. 24B** provides graphs showing IFN γ production from SRG and SRG-15 (mouse 2) derived NK cells after *in vitro* stimulation with poly I:C or human IL-12p70. NK cells from mice are compared against NK cells derived from healthy human PBMCs. All samples are normalized for NK number.

[000137] **FIG. 24C** provides graphs showing the cytolytic capacity of splenic

NK cells from SRG and SRG-15 (mouse 2) mice either against HLA class I deficient K562 cells (left) or against Raji cells in the absence (top right) or the presence (bottom right) of anti-CD20 antibody. SRG-15 #1 and SRG-15 #2 represent two different NK cell preparations from SRG-15 (mouse 2) littermates.

[000138] FIG. 25A provides a graph showing that Human NK cells in SRG-15 mice (mouse 2) inhibit tumor growth following treatment with rituximab (RTX). All data are shown as mean $\pm$ s.e.m. Statistical analyses were performed using unpaired, two-tailed Mann-Whitney *U*-test (***P* < 0.001).

[000139] FIG. 25B provides plots and a graph showing the frequency of human NK cells and T cells in human tumor xenografts of untreated (n=5) and RTX-treated SRG-15 mice (n=1). All data are shown as mean $\pm$ s.e.m. Statistical analyses were performed using unpaired, two-tailed Mann-Whitney *U*-test (***P* < 0.001).

[000140] FIG. 25C provides plots and graphs showing human NK cell subsets in the blood and tumor of untreated (n=2) and RTX-treated SRG-15 mice (n=1). All data are shown as mean $\pm$ s.e.m. Statistical analyses were performed using unpaired, two-tailed Mann-Whitney *U*-test (***P* < 0.001).

DETAILED DESCRIPTION

[000141] Before the present methods and compositions are described, it is to be understood that this invention is not limited to particular method or composition 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 be limiting, since the scope of the present invention will be limited only by the appended claims.

[000142] Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. Although any methods and materials similar or equivalent to those described herein can be used in the practice or testing of the present invention, particular methods and materials are now described. All publications mentioned herein are incorporated herein by reference to disclose and describe the methods and/or materials in connection with which the publications are cited. It is understood that the present disclosure supersedes any disclosure of an incorporated publication to the extent there is a contradiction.

[000143] As will be apparent to those of skill in the art upon reading this disclosure, each of the individual embodiments described and illustrated herein has discrete components and features which may be readily separated from or combined with the features of any of the other several embodiments without departing from the scope or spirit of the present invention. Any recited method can be carried out in the order of events recited or in any other order which is logically possible.

[000144] It must be noted that as used herein and in the appended claims, the singular forms "a", "an", 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 protein" includes reference to one or more proteins and equivalents thereof known to those skilled in the art, and so forth.

[000145] The publications discussed herein 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 present invention is not entitled to antedate such publication.

[000146] Genetically modified non-human animals expressing human SIRP α and human IL-15 from the non-human animal genome are provided. Also provided are methods for making non-human animals expressing human SIRP α and human IL-15 from the non-human animal genome, and methods for using non-human animals expressing human SIRP α and human IL-15 from the non-human animal genome. These animals and methods find many uses in the art, including, for example, in modeling human T cell and/or natural killer (NK) cell development and function; in modeling human pathogen infection, e.g., human pathogen infection of specific tissues, e.g., human gut, lung or liver pathogen infection; in modeling human pathogen infection of human T cells and/or NK cells; in *in vivo* screens for agents that inhibit infection by a pathogen that activates, induces and/or targets T cells and/or NK cells; in *in vivo* screens for agents that modulate the development and/or function of human T cells and/or NK cells, e.g. in a healthy or a diseased state; in *in vivo* screens for agents that are toxic to human T cells and/or NK cells; in *in vivo* screens for agents that prevent against, mitigate, or reverse the toxic effects of toxic agents on human T cells and/or NK cells; in *in vivo* screens of candidate T cell-inducing vaccines; and in *in vivo* and *in vitro* screens for agents that inhibit tumor growth and/or infection by activating NK cell-mediated antibody dependent cellular cytotoxicity (ADCC) processes.

HUMANIZED SIRP α NON-HUMAN ANIMALS

[000147] In some aspects of the present disclosure, a humanized SIRP α non-human animal is provided. By a humanized SIRP α non-human animal, or “SIRP α non-human animal”, is meant a non-human animal including a nucleic acid sequence that encodes a human SIRP α protein. As used herein, “human SIRP α protein” means a protein that is a wild-type (or native) human SIRP α protein or a variant of a wild-type (or native) human SIRP α protein, which retains one or more signaling and/or receptor functions of a wild-type human SIRP α protein. As used herein, the term “variant” defines either an isolated naturally occurring genetic mutant of a human polypeptide or nucleic acid sequence or a recombinantly prepared variation of a human polypeptide or nucleic acid sequence, each of which contains one or more mutations compared with the corresponding wild-type human nucleic acid or polypeptide sequence. For example, such mutations can be one or more amino acid substitutions, additions, and/or deletions. The term “variant” also includes human homologs and orthologues. In some embodiments, a variant polypeptide of the present invention has 70% or more identity, e.g. 75%, 80%, or 85% or more identity to a wild-type human polypeptide, e.g. 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98% or 99% identity to a wild-type human polypeptide.

[000148] The percent identity between two sequences may be determined using any convenient technique in the art, for example, aligning the sequences using, e.g., publicly available software. Mutations can be introduced using standard molecular biology techniques, such as site-directed mutagenesis, PCR-mediated mutagenesis, directed evolution, and the like. One of skill in the art will recognize that one or more nucleic acid substitutions can be introduced without altering the amino acid sequence, and that one or more amino acid mutations can be introduced without altering the functional properties of the human protein.

[000149] Conservative amino acid substitutions can be made in human proteins to produce human protein variants. By conservative amino acid substitutions it is meant art-recognized substitutions of one amino acid for another amino acid having similar characteristics. For example, each amino acid may be described as having one or more of the following characteristics: electropositive, electronegative, aliphatic, aromatic, polar, hydrophobic and hydrophilic. A conservative substitution is a substitution of one amino acid having a specified structural or functional characteristic

for another amino acid having the same characteristic. Acidic amino acids include aspartate, glutamate; basic amino acids include histidine, lysine, arginine; aliphatic amino acids include isoleucine, leucine and valine; aromatic amino acids include phenylalanine, glycine, tyrosine and tryptophan; polar amino acids include aspartate, glutamate, histidine, lysine, asparagine, glutamine, arginine, serine, threonine and tyrosine; and hydrophobic amino acids include alanine, cysteine, phenylalanine, glycine, isoleucine, leucine, methionine, proline, valine and tryptophan; and conservative substitutions include substitution among amino acids within each group. Amino acids may also be described in terms of relative size, alanine, cysteine, aspartate, glycine, asparagine, proline, threonine, serine, valine, all typically considered to be small.

[000150] Human variants can include synthetic amino acid analogs, amino acid derivatives and/or non-standard amino acids, illustratively including, without limitation, alpha-aminobutyric acid, citrulline, canavanine, cyanoalanine, diaminobutyric acid, diaminopimelic acid, dihydroxy-phenylalanine, djenkolic acid, homoarginine, hydroxyproline, norleucine, norvaline, 3-phosphoserine, homoserine, 5-hydroxytryptophan, 1-methylhistidine, methylhistidine, and ornithine.

[000151] Human variants will typically be encoded by nucleic acids having a high degree of identity with a nucleic acid encoding the wild-type human protein. The complement of a nucleic acid encoding a human variant specifically hybridizes with a nucleic acid encoding a wild-type human under high stringency conditions. Nucleic acids encoding a human variant can be isolated or generated recombinantly or synthetically using well-known methodology. Also encompassed by the term “human SIRP α protein” are fragments of a wild-type human SIRP α protein (or a variant thereof), which retain one or more signaling and/or receptor functions of a wild-type human SIRP α protein, e.g., an extracellular domain of a human SIRP α protein.

[000152] The term “human SIRP α protein” also encompasses fusion proteins, i.e., chimeric proteins, which include one or more fragments of a wild-type human SIRP α protein (or a variant thereof) and which retain one or more signaling and/or receptor functions of a wild-type human SIRP α protein. A fusion protein which includes one or more fragments of a wild-type human SIRP α protein (or a variant thereof), e.g., in combination with one or more non-human peptides or polypeptides, may also be referred to herein as a humanized SIRP α protein. Thus, for example, a protein which includes an amino acid sequence of an extracellular domain of a wild-

type human SIRP α protein fused with a signaling domain of a wild-type mouse SIRP α protein is encompassed by the term “human SIRP α protein”.

[000153] In some instances, a human SIRP α protein accordingly to the present disclosure includes an amino acid sequence having at least about 70%, at least about 75%, at least about 80%, at least about 85%, at least about 90%, at least about 95%, at least about 98%, at least about 99%, or 100%, amino acid sequence identity to amino acids 28-362 of SEQ ID NO:12.

[000154] A nucleic acid sequence that encodes a human SIRP α protein is, therefore, a polynucleotide that includes a coding sequence for a human SIRP α protein, e.g., a wild-type human SIRP α protein, a variant of a wild-type human SIRP α protein, a fragment of a wild-type human SIRP α protein (or a variant thereof) which retains one or more signaling and/or receptor functions of a wild-type human SIRP α protein, or fusion proteins, i.e., chimeric proteins, which include one or more fragments of a wild-type human SIRP α protein (or a variant thereof) and which retain one or more signaling and/or receptor functions of a wild-type human SIRP α protein.

[000155] SIRP α (also known as “signal regulatory protein α ” and “CD172A” in humans) is a member of the signal-regulatory-protein (SIRP) family, and also belongs to the immunoglobulin superfamily. SIRP α has been shown to improve cell engraftment in immunodeficient mice (Strowig et al. *Proc Natl Acad Sci USA* 2011; 108:13218-13223). Polypeptide sequence for wild-type human SIRP α and the nucleic acid sequence that encodes wild-type human SIRP α may be found at Genbank Accession Nos. NM_001040022.1 (variant 1), NM_001040023.1 (variant 2), and NM_080792.2 (variant 3). The SIRP α gene is conserved in at least chimpanzee, Rhesus monkey, dog, cow, mouse, rat, and chicken. The genomic locus encoding the wild-type human SIRP α protein may be found in the human genome at Chromosome 20; NC_000020.11 (1894117-1939896). Protein sequence is encoded by exons 1 through 8 at this locus. As such, in some embodiments, a nucleic acid sequence including coding sequence for human SIRP α includes one or more of exons 1-8 of the human SIRP α gene. In some instances, the nucleic acid sequence also includes aspects of the genomic locus of the human SIRP α , e.g., introns, 3' and/or 5' untranslated sequence (UTRs). In some instances, the nucleic acid sequence includes whole regions of the human SIRP α genomic locus. In some instances, the nucleic acid sequence includes exons 2-4 of the human SIRP α genomic locus.

[000156] In the humanized SIRP α non-human animals of the subject application,

the nucleic acid sequence that encodes a human SIRP α protein is operably linked to one or more regulatory sequences of a SIRP α gene, e.g., a regulatory sequence of a SIRP α gene of the non-human animal. Non-human animal, e.g., mouse, SIRP α regulatory sequences are those sequences of the non-human animal SIRP α genomic locus that regulate the non-human animal SIRP α expression, for example, 5' regulatory sequences, e.g., the SIRP α promoter, SIRP α 5' untranslated region (UTR), etc.; 3' regulatory sequences, e.g., the 3'UTR; and enhancers, etc.

[000157] A "promoter" or "promoter sequence" refers to a DNA regulatory region capable of binding RNA polymerase in a cell and initiating transcription of a downstream (3' direction) coding sequence. The promoter sequence is bounded at its 3' terminus by the transcription initiation site and extends upstream (5' direction) to include the minimum number of bases or elements necessary to initiate transcription at levels detectable above background. Within the promoter sequence will be found a transcription initiation site, as well as protein binding domains responsible for the binding of RNA polymerase. Eukaryotic promoters will often, but not always, contain "TATA" boxes and "CAT" boxes. Of particular interest to the present disclosure are DNA regulatory elements, e.g. promoters, which promote the transcription of the human protein in the same spatial and temporal expression pattern, i.e., in the same cells and tissues and at the same times, as would be observed for the corresponding endogenous protein.

[000158] Mouse SIRP α is located on chromosome 2; NC_000068.7 (129592606-129632228), and the mouse SIRP α coding sequence may be found at Genbank Accession Nos. NM_007547.4 (isoform 1), NM_001177647.2 (isoform 2), NM_001291019.1 (isoform 3), NM_001291020.1 (isoform 3), NM_001291021.1 (isoform 4), NM_001291022.1 (isoform 5). The regulatory sequences of mouse SIRP α are well defined in the art, and may be readily identified using *in silico* methods, e.g., by referring to the above Genbank Accession Nos. on the UCSC Genome Browser on the world wide web, or by experimental methods as described in the art. In some instances, e.g., when the nucleic acid sequence that encodes a human SIRP α protein is located at the mouse SIRP α genomic locus, the regulatory sequences operably linked to the human SIRP α coding sequence are endogenous, or native, to the mouse genome, i.e., they were present in the mouse genome prior to integration of human nucleic acid sequences.

[000159] In some instances, the humanized SIRP α non-human animal, e.g., mouse, is generated by the random integration, or insertion, of a human nucleic acid sequence encoding a human SIRP α protein (including fragments as described above), i.e., a “human SIRP α nucleic acid sequence”, or “human SIRP α sequence”, into the genome. Typically, in such embodiments, the location of the nucleic acid sequence encoding a human SIRP α protein in the genome is unknown. In other instances, the humanized SIRP α non-human animal is generated by the targeted integration, or insertion, of human SIRP α nucleic acid sequence into the genome, by, for example, homologous recombination. In homologous recombination, a polynucleotide is inserted into the host genome at a target locus while simultaneously removing host genomic material, e.g., 50 base pairs (bp) or more, 100 bp or more, 200 bp or more, 500 bp or more, 1 kb or more, 2 kb or more, 5 kb or more, 10 kb or more, 15 kb or more, 20 kb or more, or 50 kb or more of genomic material, from the target locus. So, for example, in a humanized SIRP α mouse including a nucleic acid sequence that encodes a human SIRP α protein created by targeting human SIRP α nucleic acid sequence to the mouse SIRP α locus, human SIRP α nucleic acid sequence may replace some or all of the mouse sequence, e.g. exons and/or introns, at the SIRP α locus. In some such instances, a human SIRP α nucleic acid sequence is integrated into the mouse SIRP α locus such that expression of the human SIRP α sequence is regulated by the native, or endogenous, regulatory sequences at the mouse SIRP α locus. In other words, the regulatory sequence(s) to which the nucleic acid sequence encoding a human SIRP α protein is operably linked are the native SIRP α regulatory sequences at the mouse SIRP α locus.

[000160] In some instances, the integration of a human SIRP α sequence does not affect the transcription of the gene into which the human SIRP α sequence has integrated. For example, if the human SIRP α sequence integrates into a coding sequence as an intein, or the human SIRP α sequence includes a 2A peptide, the human SIRP α sequence will be transcribed and translated simultaneously with the gene into which the human SIRP α sequence has integrated. In other instances, the integration of the human SIRP α sequence interrupts the transcription of the gene into which the human SIRP α sequence has integrated. For example, upon integration of the human SIRP α sequence by homologous recombination, some or all of the coding sequence at the integration locus may be removed, such that the human SIRP α sequence is transcribed instead. In some such instances, the integration of a human

SIRP α sequence creates a null mutation, and hence, a null allele. A null allele is a mutant copy of a gene that completely lacks that gene's normal function. This can be the result of the complete absence of the gene product (protein, RNA) at the molecular level, or the expression of a non-functional gene product. At the phenotypic level, a null allele is indistinguishable from a deletion of the entire locus.

[000161] In some instances, the humanized SIRP α non-human animal, e.g., mouse, includes one copy of the nucleic acid sequence encoding a human SIRP α protein. For example, the non-human animal may be heterozygous for the nucleic acid sequence. In other words, one allele at a locus will include the nucleic acid sequence, while the other will be the endogenous allele. For example, as discussed above, in some instances, a human SIRP α nucleic acid sequence is integrated into the non-human animal, e.g., mouse, SIRP α locus such that it creates a null allele for the non-human animal SIRP α . In some such embodiments, the humanized SIRP α non-human animal may be heterozygous for the nucleic acid sequence encoding human SIRP α , i.e., the humanized SIRP α non-human animal includes one null allele for the non-human animal SIRP α (the allele including the nucleic acid sequence) and one endogenous SIRP α allele (wild-type or otherwise). In other words, the non-human animal is a SIRP $\alpha^{h/m}$ non-human animal, where “h” represents the allele including the human sequence and “m” represents the endogenous allele. In other instances, the humanized SIRP α includes two copies of the nucleic acid sequence encoding a human SIRP α protein. For example, the non-human animal, e.g., mouse, may be homozygous for the nucleic acid sequence, i.e., both alleles for a locus in the diploid genome will include the nucleic acid sequence, i.e., the humanized SIRP α non-human animal includes two null alleles for the non-human animal SIRP α (the allele including the nucleic acid sequence). In other words, the non-human animal is a SIRP $\alpha^{h/h}$ non-human animal.

[000162] In some embodiments, the humanized SIRP α non-human animal, e.g., mouse, includes other genetic modifications. In some embodiments, the humanized SIRP α non-human animal is an immunocompromised animal. For example, the humanized SIRP α non-human animal may include at least one null allele for the Rag2 gene (“recombination activating gene 2”, wherein the coding sequence for the mouse gene may be found at Genbank Accession No. NM_009020.3). In some embodiments, the humanized SIRP α non-human animal includes two null alleles for Rag2. In other words, the humanized SIRP α non-human animal is homozygous null for Rag2. As

another example, the humanized SIRP α non-human animal includes at least one null allele for the IL2rg gene (“interleukin 2 receptor, gamma”, also known as the common gamma chain, or γ C, wherein the coding sequence for the mouse gene may be found at Genbank Accession No. NM_013563.3). In some embodiments, the humanized SIRP α non-human animal includes two null alleles for IL2rg. In other words, the humanized SIRP α non-human animal is homozygous null for IL2rg, i.e., it is IL2rg^{-/-} (or IL2rg^{Y/-} where the IL2rg gene is located on the X chromosome as in mouse). In some embodiments, the SIRP α non-human animal includes a null allele for both Rag2 and IL2rg, i.e., it is Rag2^{-/-} IL2rg^{-/-} (or Rag2^{-/-} IL2rg^{Y/-} where the IL2rg gene is located on the X chromosome as in mouse). Other genetic modifications are also contemplated. For example, the humanized SIRP α non-human animal may include modifications in other genes associated with the development and/or function of hematopoietic cells and the immune system, e.g. the replacement of one or more other non-human animal genes with nucleic acid sequence encoding the human ortholog. Additionally or alternatively, the humanized SIRP α non-human animal may include modifications in genes associated with the development and/or function of other cells and tissues, e.g., genes associated with human disorders or disease, or genes that, when modified in a non-human animal, e.g., mice, provide for models of human disorders and disease.

HUMANIZED IL-15 NON-HUMAN ANIMALS

[000163] In some aspects of the present disclosure, a humanized IL-15 non-human animal is provided. By a humanized IL-15 non-human animal, or “IL-15 non-human animal”, is meant a non-human animal including a nucleic acid sequence that encodes a human IL-15 protein. As used herein, “human IL-15 protein”, means a protein that is a wild-type (or native) human IL-15 protein or a variant of a wild-type (or native) human IL-15 protein, which retains one or more signaling functions of a wild-type (or native) human IL-15 protein, e.g., which allows for stimulation of (or signaling via) the human IL-15 receptor, and/or which is capable of binding to the human IL-15 receptor alpha subunit of the human IL-15 receptor, and/or which is capable of binding to IL-2R beta/IL-15R beta and the common γ -chain (γ C). Also encompassed by the term “human IL-15 protein” are fragments of a wild-type human IL-15 protein (or variants thereof), which retain one or more signaling functions of a

wild-type human IL-15 protein, e.g., a fragment of a human IL-15 protein, which allows for stimulation of (or signaling via) the human IL-15 receptor, and/or which is capable of binding to the human IL-15 receptor alpha subunit of the human IL-15 receptor, and/or which is capable of binding to IL-2R beta/IL-15R beta and the common γ -chain (γ_c).

[000164] The term “human IL-15 protein” also encompasses fusion proteins, i.e., chimeric proteins, which include one or more fragments of a wild-type human IL-15 protein (or a variant thereof) and which retain one or more signaling functions of a wild-type human IL-15 protein, e.g., as described above. A fusion protein which includes one or more fragments of a wild-type human IL-15 protein (or a variant thereof) may also be referred to herein as a humanized IL-15 protein.

[000165] A nucleic acid sequence that encodes a human IL-15 protein is, therefore, a polynucleotide that includes a coding sequence for a human IL-15 protein, i.e., a wild-type human IL-15 protein, a variant of a wild-type human IL-15 protein, a fragment of a wild-type human IL-15 protein (or a variant thereof) which retains one or more signaling functions of a wild-type human IL-15 protein, or fusion proteins, i.e., chimeric proteins, which include one or more fragments of a wild-type human IL-15 protein (or a variant thereof) and which retain one or more signaling functions of a wild-type human IL-15 protein, e.g., as described above.

[000166] IL-15 (also known as “Interleukin 15”) is a cytokine that stimulates the proliferation of T lymphocytes. Polypeptide sequence for wild-type human IL-15 and the nucleic acid sequence that encodes wild-type human IL-15 may be found at Genbank Accession Nos. NM_000585.4; NP_000576.1 (isoform 1), NM_172175.2; NP_751915.1 (isoform 2). The genomic locus encoding the wild-type human IL-15 protein may be found in the human genome at Chromosome 4; NC_000004.12 (141636596-141733987). The human IL-15 locus includes 8 exons, with exons 3-8 being coding exons. As such, in some embodiments, a nucleic acid sequence including coding sequence for human IL-15 includes one or more of exons 3-8 of the human IL-15 gene (i.e., coding exons 1-6, see FIG. 2). For example, various IL-15 mRNA isoforms have been identified which are produced through the following exon usage combinations Exons 1-2-3-4-5-6-7-8; Exons 1-3-4-5-6-7-8 or Exons 1-3-4-(alternative exon 5)-5-6-7-8). In some instances, the nucleic acid sequence also includes aspects of the genomic locus of the human IL-15, e.g., introns, 3' and/or 5' untranslated sequence (UTRs). In some instances, the nucleic acid sequence includes

whole regions of the human IL-15 genomic locus. In some instances, the nucleic acid sequence includes exons 5-8 of the human IL-15 genomic locus (i.e., coding exons 3-6).

[000167] In some instances, a human IL-15 protein accordingly to the present disclosure includes an amino acid sequence having at least about 70%, at least about 75%, at least about 80%, at least about 85%, at least about 90%, at least about 95%, at least about 98%, at least about 99%, or 100%, amino acid sequence identity to SEQ ID NO:31.

[000168] In the humanized IL-15 non-human animals of the subject application, the nucleic acid sequence that encodes a human IL-15 protein is operably linked to one or more regulatory sequences of an IL-15 gene, e.g., a regulatory sequence of an IL-15 gene of the non-human animal. Non-human animal, e.g., mouse, IL-15 regulatory sequences are those sequences of the non-human animal IL-15 genomic locus that regulate the non-human animal IL-15 expression, for example, 5' regulatory sequences, e.g., the IL-15 promoter, IL-15 5' untranslated region (UTR), etc.; 3' regulatory sequences, e.g., the 3'UTR; and enhancers, etc. Mouse IL-15 is located on Chromosome 8, NC_000074.6 (82331624-82403227, complement), and the mouse IL-15 coding sequence may be found at Genbank Accession Nos. NM_008357.2 (variant 1); NM_001254747.1 (variant 2). The regulatory sequences of mouse IL-15 are well defined in the art, and may be readily identified using *in silico* methods, e.g., by referring to the above Genbank Accession Nos. on the UCSC Genome Browser, on the world wide web at genome.ucsc.edu, or by experimental methods as described in the art. In some instances, e.g., when the nucleic acid sequence that encodes a human IL-15 protein is located at the mouse IL-15 genomic locus, the regulatory sequences operably linked to the human IL-15 coding sequence are endogenous, or native, to the mouse genome, i.e., they were present in the mouse genome prior to integration of human nucleic acid sequences.

[000169] In some instances, the humanized IL-15 non-human animal, e.g., mouse, is generated by the random integration, or insertion, of a human nucleic acid sequence encoding a human IL-15 protein (including fragments as described above), i.e., a "human IL-15 nucleic acid sequence", or "human IL-15 sequence", into the genome. Typically, in such embodiments, the location of the nucleic acid sequence encoding a human IL-15 protein in the genome is unknown. In other instances, the humanized IL-15 non-human animal is generated by the targeted integration, or

insertion, of human IL-15 nucleic acid sequence into the genome, by, for example, homologous recombination. In homologous recombination, a polynucleotide is inserted into the host genome at a target locus while simultaneously removing host genomic material, e.g., 50 base pairs (bp) or more, 100 bp or more, 200 bp or more, 500 bp or more, 1 kB or more, 2 kB or more, 5 kB or more, 10 kB or more, 15 kB or more, 20 kB or more, or 50 kB or more of genomic material, from the target locus. So, for example, in a humanized IL-15 mouse including a nucleic acid sequence that encodes a human IL-15 protein created by targeting human IL-15 nucleic acid sequence to the mouse IL-15 locus, human IL-15 nucleic acid sequence may replace some or all of the mouse sequence, e.g. exons and/or introns, at the IL-15 locus. In some such instances, a human IL-15 nucleic acid sequence is integrated into the mouse IL-15 locus such that expression of the human IL-15 sequence is regulated by the native, or endogenous, regulatory sequences at the mouse IL-15 locus. In other words, the regulatory sequence(s) to which the nucleic acid sequence encoding a human IL-15 protein is operably linked are the native IL-15 regulatory sequences at the mouse IL-15 locus.

[000170] In some instances, the integration of a human IL-15 sequence does not affect the transcription of the gene into which the human IL-15 sequence has integrated. For example, if the human IL-15 sequence integrates into a coding sequence as an intein, or the human IL-15 sequence includes a 2A peptide, the human IL-15 sequence will be transcribed and translated simultaneously with the gene into which the human IL-15 sequence has integrated. In other instances, the integration of the human IL-15 sequence interrupts the transcription of the gene into which the human IL-15 sequence has integrated. For example, upon integration of the human IL-15 sequence by homologous recombination, some or all of the coding sequence at the integration locus may be removed, such that the human IL-15 sequence is transcribed instead. In some such instances, the integration of a human IL-15 sequence creates a null mutation, and hence, a null allele. A null allele is a mutant copy of a gene that completely lacks that gene's normal function. This can be the result of the complete absence of the gene product (protein, RNA) at the molecular level, or the expression of a non-functional gene product. At the phenotypic level, a null allele is indistinguishable from a deletion of the entire locus.

[000171] In some instances, the humanized IL-15 non-human animal, e.g., mouse, includes one copy of the nucleic acid sequence encoding a human IL-15

protein. For example, the non-human animal may be heterozygous for the nucleic acid sequence. In other words, one allele at a locus will include the nucleic acid sequence, while the other will be the endogenous allele. For example, as discussed above, in some instances, a human IL-15 nucleic acid sequence is integrated into the non-human animal, e.g., mouse, IL-15 locus such that it creates a null allele for the non-human animal IL-15. In some such embodiments, the humanized IL-15 non-human animal may be heterozygous for the nucleic acid sequence encoding human IL-15, i.e., the humanized IL-15 non-human animal includes one null allele for the non-human animal IL-15 (the allele including the nucleic acid sequence) and one endogenous IL-15 allele (wild-type or otherwise). In other words, the non-human animal is an IL-15^{h/m} non-human animal, where “h” represents the allele including the human sequence and “m” represents the endogenous allele. In other instances, the humanized IL-15 includes two copies of the nucleic acid sequence encoding a human IL-15 protein. For example, the non-human animal, e.g., mouse, may be homozygous for the nucleic acid sequence, i.e., both alleles for a locus in the diploid genome will include the nucleic acid sequence, i.e., the humanized IL-15 non-human animal includes two null alleles for the non-human animal IL-15 (the allele including the nucleic acid sequence). In other words, the non-human animal is an IL-15^{h/h} non-human animal.

HUMANIZED SIRP α -IL-15 NON-HUMAN ANIMALS

[000172] By crossing humanized IL-15 non-human animals as described above with humanized SIRP α non-human animals of the same species as described above, genetically modified non-human animals expressing both human SIRP α and human IL-15 can be produced. In some embodiments, such genetically modified non-human animals are deficient for an endogenous immune system e.g., immunocompromised animals, e.g., as a result of a null allele for one or both of Rag2 and IL2rg. For example, in some embodiments a non-human animal according to the present disclosure is Rag2^{-/-} and/or IL2rg^{-/-} (or Rag2^{-/-} and/or IL2rg^{Y/-} where the IL2rg gene is located on the X chromosome as in mouse). In some embodiments, a genetically modified non-human animal, e.g., mouse, is provided wherein the genetically modified non-human animal, e.g., mouse is SIRP α ^{h/m} IL-15^{h/m} Rag2^{-/-} IL2rg^{Y/-}, SIRP α ^{h/h} IL-15^{h/m} Rag2^{-/-} IL2rg^{Y/-}, or SIRP α ^{h/m} IL-15^{h/h} Rag2^{-/-} IL2rg^{Y/-}.

[000173] In some embodiments, a genetically modified non-human animal, e.g.,

mouse, is provided which includes a nucleic acid sequence incorporated into the genome of the genetically modified non-human animal, which sequence encodes a human SIRP α protein and is operably linked to a SIRP α gene promoter; and a nucleic acid sequence incorporated into the genome of the genetically modified non-human animal, which sequence encodes a human IL-15 protein and is operably linked to an IL-15 gene promoter, wherein the genetically modified non-human animal expresses the human SIRP α protein and the human IL-15 protein.

[000174] In some embodiments, the SIRP α gene promoter is an endogenous non-human SIRP α gene promoter. In some such embodiments, the SIRP α gene promoter is the endogenous non-human SIRP α gene promoter at the non-human animal SIRP α gene locus. In another embodiment, the SIRP α gene promoter is a human SIRP α promoter.

[000175] In some embodiments, the IL-15 gene promoter is an endogenous non-human IL-15 gene promoter. In some such embodiments, the IL-15 gene promoter is the endogenous non-human IL-15 gene promoter at the non-human animal IL-15 gene locus. In another embodiment, the IL-15 promoter is a human IL-15 promoter.

[000176] In some embodiments, a genetically modified non-human animal as described herein expresses human IL-15 mRNA in the liver, lung, bone marrow (BM), small intestine (SI) and colon.

[000177] In some embodiments, a genetically modified non-human animal, e.g., mouse, expressing both human SIRP α and human IL-15 as described herein exhibits a higher percentage and number of human T cells and NK cells than a genetically modified non-human animal, e.g., mouse, expressing only human SIRP α , following engraftment with human hematopoietic cells, e.g., CD45⁺ cells. In some embodiments, a genetically modified non-human animal, e.g., mouse, expressing both human SIRP α and human IL-15 as described herein exhibits a higher percentage and number of NK cells in blood and spleen. In some embodiments a genetically modified non-human animal, e.g., mouse, expressing both human SIRP α and human IL-15 as described herein includes both human NK cell subsets, CD56^{bright}CD16⁻ and CD56^{dim}CD16⁺, in the blood, spleen and liver, following engraftment with human hematopoietic cells, e.g., CD45⁺ cells. In some embodiments, a genetically modified non-human animal, e.g., mouse, expressing both human SIRP α and human IL-15 as described herein exhibits similar distribution of CD16⁺ versus CD16⁻ NK cells in

blood as the distribution of CD16⁺ versus CD16⁻ NK cells in PBMCs obtained from human subjects.

[000178] In some embodiments a genetically modified non-human animal, e.g., mouse, expressing both human SIRP α and human IL-15 as described herein includes NK cells in the liver of the genetically modified non-human animal which exhibit a higher expression level of CD16 and CD56, indicating increased NK cell maturation, relative to a genetically modified non-human animal, e.g., mouse, expressing only human SIRP α , following engraftment with human hematopoietic cells, e.g., CD45⁺ cells.

[000179] In some embodiments a genetically modified non-human animal, e.g., mouse, expressing both human SIRP α and human IL-15 as described herein, and engrafted with human hematopoietic cells, e.g., CD45⁺ cells, includes NK cells in the spleen which exhibit a distinct expression level of killer inhibitory receptors, with the CD56^{dim}CD16⁺ NK cell population including the higher percentage of CD158-expressing cells, similar to what is found for NK cell subsets in the blood of humans.

[000180] In some embodiments a genetically modified non-human animal, e.g., mouse, expressing both human SIRP α and human IL-15 as described herein, and engrafted with human hematopoietic cells, e.g., CD45⁺ cells, exhibits a higher frequency of human CD45⁺ and CD8⁺ T cells in the intraepithelial lymphocyte population relative to a genetically modified non-human animal, e.g., mouse, expressing only human SIRP α . In some embodiments, a genetically modified non-human animal, e.g., mouse, expressing both human SIRP α and human IL-15 as described herein, and engrafted with human hematopoietic cells, exhibits comparable CD16⁺ versus CD16⁻ NK cell distribution in IELs, and more CD16⁺ than CD16⁻ NK cells in blood and spleen, which is reflective of normal human physiology.

[000181] In some embodiments a genetically modified non-human animal, e.g., mouse, expressing both human SIRP α and human IL-15 as described herein, and engrafted with human hematopoietic cells, e.g., CD45⁺ cells, exhibits an increased number of human T cells in the lung relative to a genetically modified non-human animal, e.g., mouse, expressing only human SIRP α . In some such embodiments, such a genetically modified non-human animal, e.g., mouse, exhibits a higher level of expression of CD69 on human CD8⁺ T cells in the lung relative to a genetically modified non-human animal, e.g., mouse, expressing only human SIRP α .

[000182] In some embodiments a genetically modified non-human animal, e.g.,

mouse, expressing both human SIRP α and human IL-15 as described herein, and engrafted with human hematopoietic cells, e.g., CD45⁺ cells, exhibits an increased level of CD69 expression on human CD8⁺ T cells in the liver relative to a genetically modified non-human animal, e.g., mouse, expressing only human SIRP α .

[000183] In some embodiments, a genetically modified non-human animal, e.g., mouse, expressing both human SIRP α and human IL-15 as described herein, and engrafted with human hematopoietic cells, exhibits discernable Peyer's Patches which are predominantly human CD45⁺.

[000184] Any non-human mammal animal may be genetically modified according to the subject disclosure. Nonlimiting examples include laboratory animals, domestic animals, livestock, etc., e.g., species such as murine, rodent, canine, feline, porcine, equine, bovine, ovine, non-human primates, etc.; for example, mice, rats, rabbits, hamsters, guinea pigs, cattle, pigs, sheep, goats and other transgenic animal species, particularly-mammalian species, as known in the art. In other embodiments, the non-human animal may be a bird, e.g., of Galliformes order, such as a chicken, a turkey, a quail, a pheasant, or a partridge; e.g., of Anseriformes order, such as a duck, a goose, or a swan, e.g., of Columbiformes order, such as a pigeon or a dove. In various embodiments, the subject genetically modified animal is a mouse, a rat or a rabbit.

[000185] In some embodiments, the non-human animal is a mammal. In some such embodiments, the non-human animal is a small mammal, e.g., of the superfamily Dipodoidea or Muroidea. In one embodiment, the genetically modified animal is a rodent. In one embodiment, the rodent is selected from a mouse, a rat, and a hamster. In one embodiment, the rodent is selected from the superfamily Muroidea. In one embodiment, the genetically modified animal is from a family selected from Calomyscidae (e.g., mouse-like hamsters), Cricetidae (e.g., hamster, New World rats and mice, voles), Muridae (true mice and rats, gerbils, spiny mice, crested rats), Nesomyidae (climbing mice, rock mice, white-tailed rats, Malagasy rats and mice), Platacanthomyidae (e.g., spiny dormice), and Spalacidae (e.g., mole rates, bamboo rats, and zokors). In a specific embodiment, the genetically modified rodent is selected from a true mouse or rat (family Muridae), a gerbil, a spiny mouse, and a crested rat.

[000186] In one embodiment, the subject genetically modified non-human animal is a rat. In one such embodiment, the rat is selected from a Wistar rat, an LEA

strain, a Sprague Dawley strain, a Fischer strain, F344, F6, and Dark Agouti. In another embodiment, the rat strain is a mix of two or more strains selected from the group consisting of Wistar, LEA, Sprague Dawley, Fischer, F344, F6, and Dark Agouti.

[000187] In another embodiment, the subject genetically modified non-human animal is a mouse, e.g. a mouse of a C57BL strain (e.g. C57BL/A, C57BL/An, C57BL/GrFa, C57BL/KaLwN, C57BL/6, C57BL/6J, C57BL/6ByJ, C57BL/6NJ, C57BL/10, C57BL/10ScSn, C57BL/10Cr, C57BL/Ola, etc.); a mouse of the 129 strain (e.g. 129P1, 129P2, 129P3, 129X1, 129S1 (e.g., 129S1/SV, 129S1/SvIm), 129S2, 129S4, 129S5, 129S9/SvEvH, 129S6 (129/SvEvTac), 129S7, 129S8, 129T1, 129T2); a mouse of the BALB strain; e.g., BALB/c; and the like. See, e.g., Festing et al. (1999) *Mammalian Genome* 10:836, see also, Auerbach et al (2000) *Establishment and Chimera Analysis of 129/SvEv- and C57BL/6-Derived Mouse Embryonic Stem Cell Lines*). In another embodiment, a mouse is a mix of the aforementioned strains.

[000188] In some embodiments, the subject genetically modified non-human animal is also immunodeficient. “Immunodeficient,” includes deficiencies in one or more aspects of an animal’s native, or endogenous, immune system, e.g. the animal is deficient for one or more types of functioning host immune cells, e.g. deficient for non-human B cell number and/or function, non-human T cell number and/or function, non-human NK cell number and/or function, etc.

[000189] One method to achieve immunodeficiency in the subject animals is sublethal irradiation. For example, newborn genetically modified mouse pups can be irradiated sublethally, e.g., 2 x 200 cGy with a four hour interval. Alternatively, immunodeficiency may be achieved by any one of a number of gene mutations known in the art, any of which may be bred either alone or in combination into the subject genetically modified non-human animals of the present disclosure or which may be used as the source of stem cells into which the genetic modifications of the subject disclosure may be introduced. Non-limiting examples include X-linked SCID, associated with IL2rg gene mutations and characterized by the lymphocyte phenotype T(-) B(+) NK(-); autosomal recessive SCID associated with Jak3 gene mutations and characterized by the lymphocyte phenotype T(-) B(+) NK(-); ADA gene mutations characterized by the lymphocyte phenotype T(-) B(-) NK(-); IL-7R alpha-chain mutations characterized by the lymphocyte phenotype T(-) B(+) NK(+); CD3 delta or

epsilon mutations characterized by the lymphocyte phenotype T(-) B(+) NK(+); RAG1 and RAG2 mutations characterized by the lymphocyte phenotype T(-) B(-) NK(+); Artemis gene mutations characterized by the lymphocyte phenotype T(-) B(-) NK(+), CD45 gene mutations characterized by the lymphocyte phenotype T(-) B(+) NK(+); and Prkdcscid mutations characterized by the lymphocyte phenotype T(-), B(-). As such, in some embodiments, the genetically modified immunodeficient non-human animal has one or more deficiencies selected from an IL2 receptor gamma chain (Il2rg^{y/-}) deficiency, a Jak3 deficiency, an ADA deficiency, an IL7R deficiency, a CD3 deficiency, a RAG1 and/or RAG2 deficiency, an Artemis deficiency, a CD45 deficiency, and a Prkdc deficiency. These and other animal models of immunodeficiency will be known to the ordinarily skilled artisan, any of which may be used to generate immunodeficient animals of the present disclosure.

[000190] In some embodiments, genetically modified non-human animals in accordance with the invention find use as recipients of human hematopoietic cells that are capable of developing human immune cells from engrafted human hematopoietic cells. As such, in some aspects of the invention, the subject genetically modified animal is a genetically modified, immunodeficient, non-human animal that is engrafted with human hematopoietic cells.

ENGRAFTMENT OF HUMANIZED SIRP α -IL-15 NON-HUMAN ANIMALS

[000191] As discussed above, in some aspects of the invention, the humanized SIRP α -IL-15 non-human animal, e.g., mouse, e.g., a Rag2^{-/-}IL2rg^{y/-} hSIRP α hIL-15 mouse, or a sublethally irradiated hSIRP α hIL-15 mouse, is engrafted, or transplanted, with cells. Cells may be mitotic cells or post-mitotic cells, and include such cells of interest as pluripotent stem cells, e.g., ES cells, iPS cells, and embryonic germ cells; and somatic cells, e.g., fibroblasts, hematopoietic cells, neurons, muscle cells, bone cells, vascular endothelial cells, gut cells, and the like, and their lineage-restricted progenitors and precursors. Cell populations of particular interest include those that include hematopoietic stem or progenitor cells, which will contribute to or reconstitute the hematopoietic system of the humanized SIRP α -IL-15 non-human animal, for example, peripheral blood leukocytes, fetal liver cells, fetal bone, fetal thymus, fetal lymph nodes, vascularized skin, artery segments, and purified hematopoietic stem cells, e.g., mobilized HSCs or cord blood HSCs.

[000192] Any source of human hematopoietic cells, human hematopoietic stem

cells (HSCs) and/or hematopoietic stem progenitor cells (HSPC) as known in the art or described herein may be transplanted into the genetically modified immunodeficient non-human animals of the present disclosure. One suitable source of human hematopoietic cells known in the art is human umbilical cord blood cells, in particular CD34-positive (CD34⁺) cells. Another source of human hematopoietic cells is human fetal liver. Another source is human bone marrow. Also encompassed are induced pluripotent stem cells (iPSC) and induced hematopoietic stem cells (iHSC) produced by the de-differentiation of somatic cells, e.g., by methods known in the art.

[000193] Cells may be from any mammalian species, e.g., murine, rodent, canine, feline, equine, bovine, ovine, primate, human, etc. Cells may be from established cell lines or they may be primary cells, where “primary cells”, “primary cell lines”, and “primary cultures” are used interchangeably herein to refer to cells and cells cultures that have been derived from a subject and allowed to grow *in vitro* for a limited number of passages, i.e., splittings, of the culture. For example, primary cultures are cultures that may have been passaged 0 times, 1 time, 2 times, 4 times, 5 times, 10 times, or 15 times, but not enough times go through the crisis stage. Typically, the primary cell lines of the present invention are maintained for fewer than 10 passages *in vitro*.

[000194] If the cells are primary cells, they may be harvested from an individual by any convenient method. For example, cells, e.g., blood cells, e.g., leukocytes, may be harvested by apheresis, leukocytapheresis, density gradient separation, etc. As another example, cells, e.g., skin, muscle, bone marrow, spleen, liver, pancreas, lung, intestine, stomach tissue, etc. may be harvested by biopsy. An appropriate solution may be used for dispersion or suspension of the harvested cells. Such solution will generally be a balanced salt solution, e.g., normal saline, PBS, Hank’s balanced salt solution, etc., conveniently supplemented with fetal calf serum or other naturally occurring factors, in conjunction with an acceptable buffer at low concentration, generally from 5-25 mM. Convenient buffers include HEPES, phosphate buffers, lactate buffers, etc.

[000195] In some instances, a heterogeneous population of cells will be transplanted into the humanized non-human animal, e.g., mouse. In other instances, a population of cells that is enriched for a particular type of cell, e.g., a progenitor cell, e.g., a hematopoietic progenitor cell, will be engrafted into the humanized non-human animal, e.g., mouse. Enrichment of a cell population of interest may be by any

convenient separation technique. For example, the cells of interest may be enriched by culturing methods. In such culturing methods, particular growth factors and nutrients are typically added to a culture that promotes the survival and/or proliferation of one cell population over others. Other culture conditions that affect survival and/or proliferation include growth on adherent or non-adherent substrates, culturing for particular lengths of time, etc. Such culture conditions are well known in the art. As another example, cells of interest may be enriched for by separation the cells of interest from the initial population by affinity separation techniques. Techniques for affinity separation may include magnetic separation using magnetic beads coated with an affinity reagent, affinity chromatography, "panning" with an affinity reagent attached to a solid matrix, e.g., plate, cytotoxic agents joined to an affinity reagent or used in conjunction with an affinity reagent, e.g., complement and cytotoxins, or other convenient technique. Techniques providing accurate separation include fluorescence activated cell sorters, which can have varying degrees of sophistication, such as multiple color channels, low angle and obtuse light scattering detecting channels, impedance channels, etc. The cells may be selected against dead cells by employing dyes associated with dead cells (e.g. propidium iodide). Any technique may be employed which is not unduly detrimental to the viability of the cells of interest.

[000196] For example, using affinity separation techniques, cells that are not the cells of interest for transplantation may be depleted from the population by contacting the population with affinity reagents that specifically recognize and selectively bind markers that are not expressed on the cells of interest. For example, to enrich for a population of hematopoietic progenitor cells, one might deplete cells expressing mature hematopoietic cell markers. Additionally or alternatively, positive selection and separation may be performed using by contacting the population with affinity reagents that specifically recognize and selectively bind markers associated with hematopoietic progenitor cells, e.g. CD34, CD133, etc. By "selectively bind" is meant that the molecule binds preferentially to the target of interest or binds with greater affinity to the target than to other molecules. For example, an antibody will bind to a molecule including an epitope for which it is specific and not to unrelated epitopes. In some embodiments, the affinity reagent may be an antibody, i.e. an antibody that is specific for CD34, CD133, etc. In some embodiments, the affinity reagent may be a specific receptor or ligand for CD34, CD133, etc., e.g., a peptide ligand and receptor; effector and receptor molecules, a T-cell receptor specific for CD34, CD133, etc., and

the like. In some embodiments, multiple affinity reagents specific for the marker of interest may be used.

[000197] Antibodies and T cell receptors that find use as affinity reagents may be monoclonal or polyclonal, and may be produced by transgenic animals, immunized animals, immortalized human or animal B-cells, cells transfected with DNA vectors encoding the antibody or T cell receptor, etc. The details of the preparation of antibodies and their suitability for use as specific binding members are well-known to those skilled in the art. Of particular interest is the use of labeled antibodies as affinity reagents. Conveniently, these antibodies are conjugated with a label for use in separation. Labels include magnetic beads, which allow for direct separation; biotin, which can be removed with avidin or streptavidin bound to a support; fluorochromes, which can be used with a fluorescence activated cell sorter; or the like, to allow for ease of separation of the particular cell type. Fluorochromes that find use include phycobiliproteins, e.g., phycoerythrin and allophycocyanins, fluorescein and Texas red. Frequently each antibody is labeled with a different fluorochrome, to permit independent sorting for each marker.

[000198] The initial population of cells are contacted with the affinity reagent(s) and incubated for a period of time sufficient to bind the available cell surface antigens. The incubation will usually be at least about 5 minutes and usually less than about 60 minutes. It is desirable to have a sufficient concentration of antibodies in the reaction mixture, such that the efficiency of the separation is not limited by lack of antibody. The appropriate concentration is determined by titration, but will typically be a dilution of antibody into the volume of the cell suspension that is about 1:50 (i.e., 1 part antibody to 50 parts reaction volume), about 1:100, about 1:150, about 1:200, about 1:250, about 1:500, about 1:1000, about 1:2000, or about 1:5000. The medium in which the cells are suspended will be any medium that maintains the viability of the cells. A preferred medium is phosphate buffered saline containing from 0.1 to 0.5% BSA or 1-4% goat serum. Various media are commercially available and may be used according to the nature of the cells, including Dulbecco's Modified Eagle Medium (dMEM), Hank's Basic Salt Solution (HBSS), Dulbecco's phosphate buffered saline (dPBS), RPMI, Iscove's medium, PBS with 5 mM EDTA, etc., frequently supplemented with fetal calf serum, BSA, HSA, goat serum etc.

[000199] The cells in the contacted population that become labeled by the affinity reagent are selected for by any convenient affinity separation technique, e.g.,

as described above or as known in the art. Following separation, the separated cells may be collected in any appropriate medium that maintains the viability of the cells, usually having a cushion of serum at the bottom of the collection tube. Various media are commercially available and may be used according to the nature of the cells, including dMEM, HBSS, dPBS, RPMI, Iscove's medium, etc., frequently supplemented with fetal calf serum.

[000200] Compositions highly enriched for a cell type of interest, e.g., hematopoietic cells, are achieved in this manner. The cells will be about 70%, about 75%, about 80%, about 85% about 90% or more of the cell composition, about 95% or more of the enriched cell composition, and will preferably be about 95% or more of the enriched cell composition. In other words, the composition will be a substantially pure composition of cells of interest.

[000201] The cells to be transplanted into the humanized SIRP α -IL-15 non-human animals, e.g., mice, be they a heterogeneous population of cells or an enriched population of cells, may be transplanted immediately. Alternatively, the cells may be frozen at liquid nitrogen temperatures and stored for long periods of time, being thawed and capable of being reused. In such cases, the cells will usually be frozen in 10% DMSO, 50% serum, 40% buffered medium, or some other such solution as is commonly used in the art to preserve cells at such freezing temperatures, and thawed in a manner as commonly known in the art for thawing frozen cultured cells. Additionally or alternatively, the cells may be cultured *in vitro* under various culture conditions. Culture medium may be liquid or semi-solid, e.g. containing agar, methylcellulose, etc. The cell population may be conveniently suspended in an appropriate nutrient medium, such as Iscove's modified DMEM or RPMI-1640, normally supplemented with fetal calf serum (about 5-10%), L-glutamine, a thiol, particularly 2-mercaptoethanol, and antibiotics, e.g. penicillin and streptomycin. The culture may contain growth factors to which the cells are responsive. Growth factors, as defined herein, are molecules capable of promoting survival, growth and/or differentiation of cells, either in culture or in the intact tissue, through specific effects on a transmembrane receptor. Growth factors include polypeptides and non-polypeptide factors.

[000202] The cells may be genetically modified prior to transplanting to the SIRP α -IL-15 non-human animals, e.g., mice, e.g., to provide a selectable or traceable marker, to induce a genetic defect in the cells (e.g., for disease modeling), to repair a

genetic defect or ectopically express a gene in the cells (e.g., to determine if such modifications will impact the course of a disease), etc. Cells may be genetically modified by transfection or transduction with a suitable vector, homologous recombination, or other appropriate technique, so that they express a gene of interest, or with an antisense mRNA, siRNA or ribozymes to block expression of an undesired gene. Various techniques are known in the art for the introduction of nucleic acids into target cells. To prove that one has genetically modified the cells, various techniques may be employed. The genome of the cells may be restricted and used with or without amplification. The polymerase chain reaction; gel electrophoresis; restriction analysis; Southern, Northern, and Western blots; sequencing; or the like, may all be employed. General methods in molecular and cellular biochemistry for these and other purposes disclosed in this application can be found in such standard textbooks as *Molecular Cloning: A Laboratory Manual*, 3rd Ed. (Sambrook *et al.*, Cold Spring Harbor Laboratory Press 2001); *Short Protocols in Molecular Biology*, 4th Ed. (Ausubel *et al.* eds., John Wiley & Sons 1999); *Protein Methods* (Bollag *et al.*, John Wiley & Sons 1996); *Nonviral Vectors for Gene Therapy* (Wagner *et al.* eds., Academic Press 1999); *Viral Vectors* (Kaplift & Loewy eds., Academic Press 1995); *Immunology Methods Manual* (I. Lefkovits ed., Academic Press 1997); and *Cell and Tissue Culture: Laboratory Procedures in Biotechnology* (Doyle & Griffiths, John Wiley & Sons 1998), the disclosures of which are incorporated herein by reference. Reagents, cloning vectors, and kits for genetic manipulation referred to in this disclosure are available from commercial vendors such as BioRad, Stratagene, Invitrogen, Sigma-Aldrich, and ClonTech.

[000203] The cells may be transplanted in the humanized SIRP α -IL-15 non-human animals, e.g., mice, by any convenient method, including, for example, intra-hepatic injection, tail-vein injection, retro-orbital injection, and the like. Typically, about 0.5×10^5 - 2×10^6 pluripotent or progenitor cells are transplanted, e.g. about 1×10^5 – 1×10^6 cells, or about 2×10^5 – 5×10^5 cells. In some instances, the non-human animal, e.g., mouse, is sublethally irradiated prior to transplanting the human cells. In other words, the non-human animal, e.g., mouse, is exposed to a sublethal dose of radiation, e.g., as well-known in the art. The engrafted humanized SIRP α -IL-15 non-human animals, e.g., mice, are then maintained under laboratory animal husbandry conditions for at least 1 week, e.g., 1 week or more, or two weeks or more, sometimes 4 weeks or more, and in some instances 6 weeks or more, such as 10 weeks or more

or 15 weeks or more, to allow sufficient reconstitution of the immune system with the engrafted cells.

[000204] The humanized SIRP α -IL-15 non-human animals, e.g., mice, and humanized SIRP α -IL-15 non-human animals, e.g., mice, engrafted with human hematopoietic cells, e.g., engrafted Rag2^{-/-}IL2rg^{Y/-} hSIRP α hIL-15 mice, and optionally other genetic modifications are useful in many applications. For example, these non-human animals, e.g., mice, provide a useful system for modeling human immune diseases and human pathogens. For example, the subject non-human animals, e.g., mice, are useful for modeling, for example, human T cell and/or natural killer (NK) cell development and function; human pathogen infection of specific tissues and/or cells, e.g., human pathogen infection of the gut or lungs, and/or human pathogen infection of or response to human T cells and/or NK cells. Such non-human animals also find use in *in vivo* screens for agents that inhibit infection by a pathogen, e.g., a pathogen that affects (e.g., by infecting) a specific tissue or cell type, e.g., a human pathogen of the gut or lungs, e.g., a human pathogen that activates, induces and/or targets T cells and/or NK cells; in *in vivo* screens for agents that modulate the development and/or function of human T cells and/or NK cells, e.g. in a healthy or a diseased state; in *in vivo* screens for agents that are toxic to human T cells and/or NK cells; in *in vivo* screens for agents that prevent against, mitigate, or reverse the toxic effects of toxic agents on human T cells and/or NK cells; in *in vivo* screens of candidate T cell-inducing vaccines; and in *in vivo* and *in vitro* screens for agents that inhibit tumor growth and/or infection by activating NK cell-mediated antibody dependent cellular cytotoxicity (ADCC) processes.

[000205] The present disclosure provides unexpected results demonstrating that humanized SIRP α -IL-15 non-human animals, e.g., mice, engrafted with human hematopoietic cells, e.g., engrafted Rag2^{-/-}IL2rg^{Y/-} hSIRP α hIL-15 mice, develop tissue-resident lymphocytes, e.g., intraepithelial lymphocytes, in the gut and lung. Accordingly, the present disclosure provides previously unavailable animal models which enable the monitoring and testing of such tissue-resident lymphocytes. Such animal models are particularly useful in modeling the immune response of tissue-resident lymphocytes, e.g., T cells and NK cells, to human pathogens which affect (e.g., by infecting) the gut and/or lung and for screening therapeutics and vaccines which target such pathogens and/or induce or improve a tissue-resident lymphocyte response. In addition, the presence of these tissue-resident lymphocytes also allows

for modeling of human immune cell driven autoimmune diseases that affect the gastrointestinal tract such as celiac diseases and IBD.

[000206] Accordingly, in some embodiments, the present disclosure provides an *in vivo* model, including a genetically modified non-human animal including a nucleic acid sequence incorporated into the genome of the genetically modified non-human animal, which sequence encodes a human SIRP α protein and is operably linked to a SIRP α gene promoter. The genetically modified non-human animal also includes a nucleic acid sequence incorporated into the genome of the genetically modified non-human animal, which sequence encodes a human IL-15 protein and is operably linked to an IL-15 gene promoter. Finally, the genetically modified non-human animal includes an engraftment of human hematopoietic cells, wherein the genetically modified non-human animal (i) expresses the human SIRP α protein and the human IL-15 protein, and (ii) includes human tissue-resident lymphocytes, e.g., intraepithelial lymphocytes (IELs), in the gut of the genetically modified non-human. In some such embodiments, the genetically modified non-human animal is infected with a human pathogen, e.g., a human pathogen which affects (e.g., by infecting) the gut.

[000207] Human pathogens which can affect (e.g., by infecting) the gut include, but are not limited to, *Campylobacter jejuni*, *Clostridium difficile*, *Enterococcus faecalis*, *Enterococcus faecium*, *Escherichia coli*, Human Rotavirus, *Listeria monocytogenes*, Norwalk Virus, *Salmonella enterica*, *Shigella flexneri*, *Shigella sonnei*, *Shigella dysenteriae*, *Yersinia pestis*, *Yersinia enterocolitica*, and *Helicobacter pylori*.

[000208] In other embodiments, the present disclosure provides an *in vivo* model, including a genetically modified non-human animal including a nucleic acid sequence incorporated into the genome of the genetically modified non-human animal, which sequence encodes a human SIRP α protein and is operably linked to a SIRP α gene promoter. The genetically modified non-human animal also includes a nucleic acid sequence incorporated into the genome of the genetically modified non-human animal, which sequence encodes a human IL-15 protein and is operably linked to an IL-15 gene promoter. Finally, the genetically modified non-human animal includes an engraftment of human hematopoietic cells, wherein the genetically modified non-human animal (i) expresses the human SIRP α protein and the human

IL-15 protein, and (ii) includes human tissue-resident lymphocytes, e.g., intraepithelial lymphocytes (IELs), in the lung of the genetically modified non-human. In some such embodiments, the genetically modified non-human animal is infected with a human pathogen, e.g., a human pathogen which affects (e.g., by infecting) the lung.

[000209] Human pathogens which can affect (e.g., by infecting) the lung include, but are not limited to, *Streptococcus pyogenes*, *Haemophilus influenza*, *Corynebacterium diphtheria*, *SARS coronavirus*, *Bordetella pertussis*, *Moraxella catarrhalis*, Influenza virus (A, B, C), Coronavirus, Adenovirus, Respiratory Syncytial Virus, Parainfluenza virus, Mumps virus, *Streptococcus pneumoniae*, *Staphylococcus aureus*, *Legionella pneumophila*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, *Mycoplasma pneumonia*, *Mycobacterium tuberculosis*, *Chlamydia Pneumoniae*, *Blastomyces dermatitidis*, *Cryptococcus neoformans*, and *Aspergillus fumigatus*.

[000210] New therapeutics, new vaccines, and new ways of testing efficacy of therapeutics and vaccines are needed. A non-human animal, e.g., mouse, which supports efficient human T and NK cell engraftment, for example, would be useful to identify new therapeutics and new vaccines, particularly for a human pathogen which infects human T cells and/or NK cells. New therapeutics and new vaccines could be tested in such a non-human animal, e.g., mouse, by, e.g., determining the amount of a human pathogen, e.g., a virus, in the non-human animal (in blood or a given tissue) in response to treatment with a putative anti-viral agent, or by inoculating the mouse with a putative vaccine followed by exposure to an infective administration of a human pathogen, e.g., HIV, and observing any change in infectivity due to inoculation by the putative vaccine as compared to a control not inoculated with the vaccine but infected with HIV.

[000211] Such non-human animal, e.g., mouse, models of pathogen infection are useful in research, e.g., to better understand the progression of human infection. Such mouse models of infection are also useful in drug discovery, e.g. to identify candidate agents that protect against or treat infection.

[000212] Engrafted genetically modified animals of the present disclosure find use in screening candidate agents to identify those that will treat infections by human pathogens, e.g., human pathogens that target human T and/or NK cells. The terms "treat", "treatment", "treating" and the like are used herein to generally include

obtaining a desired pharmacologic and/or physiologic effect. The effect may be prophylactic in terms of completely or partially preventing a disease or symptom thereof and/or may be therapeutic in terms of a partial or complete cure for a disease and/or adverse effect attributable to the disease. "Treatment" as used herein include any treatment of a disease in a mammal, and includes: (a) preventing the disease from occurring in a subject which may be predisposed to the disease but has not yet been diagnosed as having it; (b) inhibiting the disease, i.e., arresting its development; or (c) relieving the disease, i.e., causing regression of the disease.

[000213] The terms "individual," "subject," "host," and "patient," are used interchangeably herein and include any mammalian subject for whom diagnosis, treatment, or therapy is desired, particularly humans.

[000214] Humanized SIRP α -IL-15 non-human animals, e.g., mice, engrafted with human hematopoietic cells provide a useful system for screening candidate agents for other desired activities *in vivo* as well, for example, for agents that are able to modulate (i.e., promote or suppress) development and/or activity of human T cells and NK cells, e.g., in a healthy or a diseased state, e.g., to identify novel therapeutics and/or develop a better understanding of the molecular basis of the development and function of the immune system; for agents that are toxic to T cells and/or NK cells and progenitors thereof; and for agents that prevent against, mitigate, or reverse the toxic effects of toxic agents on T cells, NK cells, and progenitors thereof; for antibodies or antigen-binding proteins that mediate NK cell dependent ADCC processes, etc. As yet another example, the genetically modified mice described herein provide a useful system for predicting the responsiveness of an individual to a disease therapy, e.g., by providing an *in vivo* platform for screening the responsiveness of an individual's immune system to an agent, e.g., a therapeutic agent, to predict the responsiveness of an individual to that agent.

[000215] In screening assays for biologically active agents, humanized SIRP α -IL-15 non-human animals, e.g., mice, e.g., engrafted Rag2^{-/-}IL2rg^{Y/-} hSIRP α hIL-15 mice, that have been engrafted with human hematopoietic cells and in some instances, infected with human pathogens, or cells to be engrafted into a humanized SIRP α -IL-15 non-human animal, e.g., mouse, are contacted with a candidate agent of interest and the effect of the candidate agent is assessed by monitoring one or more output parameters. These output parameters may be reflective of the viability of the cells, e.g. the total number of hematopoietic cells or the number of cells of a particular

hematopoietic cell type, or of the apoptotic state of the cells, e.g. the amount of DNA fragmentation, the amount of cell blebbing, the amount of phosphatidylserine on the cell surface, and the like by methods that are well known in the art. Alternatively or additionally, the output parameters may be reflective of the differentiation capacity of the cells, e.g. the proportions of differentiated cells and differentiated cell types, e.g., T cells and/or NK cells. Alternatively or additionally, the output parameters may be reflective of the function of the cells, e.g. the cytokines and chemokines produced by the cells, the ability of the cells to home to and extravasate to a site of challenge, the ability of the cells to modulate, i.e. promote or suppress, the activity of other cells *in vitro* or *in vivo*, etc. Other output parameters may be reflective of the extent of pathogen infection in the animal, e.g., the titer of pathogen in the non-human animal, e.g., mouse, etc.

[000216] Parameters are quantifiable components of cells, particularly components that can be accurately measured, desirably in a high throughput system. A parameter can be any cell component or cell product including cell surface determinant, receptor, protein or conformational or posttranslational modification thereof, lipid, carbohydrate, organic or inorganic molecule, nucleic acid, e.g. mRNA, DNA, etc. or a portion derived from such a cell component or combinations thereof. While most parameters will provide a quantitative readout, in some instances a semi-quantitative or qualitative result will be acceptable. Readouts may include a single determined value, or may include mean, median value or the variance, etc. Characteristically a range of parameter readout values will be obtained for each parameter from a multiplicity of the same assays. Variability is expected and a range of values for each of the set of test parameters will be obtained using standard statistical methods with a common statistical method used to provide single values.

[000217] Candidate agents of interest for screening include known and unknown compounds that encompass numerous chemical classes, primarily organic molecules, which may include organometallic molecules, inorganic molecules, genetic sequences, vaccines, antibiotics or other agents suspected of having antibiotic properties, peptides, polypeptides, antibodies, antigen-binding proteins, agents that have been approved pharmaceutical for use in a human, etc. An important aspect of the invention is to evaluate candidate drugs, including toxicity testing; and the like.

[000218] Candidate agents include organic molecules including functional groups necessary for structural interactions, particularly hydrogen bonding, and

typically include at least an amine, carbonyl, hydroxyl or carboxyl group, frequently at least two of the functional chemical groups. The candidate agents often include 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 peptides, polynucleotides, saccharides, fatty acids, steroids, purines, pyrimidines, derivatives, structural analogs or combinations thereof. Included are pharmacologically active drugs, genetically active molecules, etc. Compounds of interest include chemotherapeutic agents, hormones or hormone antagonists, etc. Exemplary of pharmaceutical agents suitable for this invention are those described in, "The Pharmacological Basis of Therapeutics," Goodman and Gilman, McGraw-Hill, New York, N.Y., (1996), Ninth edition. Also included are toxins, and biological and chemical warfare agents, for example see Somani, S. M. (Ed.), "Chemical Warfare Agents," Academic Press, New York, 1992).

[000219] Candidate agents of interest for screening also include nucleic acids, for example, nucleic acids that encode siRNA, shRNA, antisense molecules, or miRNA, or nucleic acids that encode polypeptides. Many vectors useful for transferring nucleic acids into target cells are available. The vectors may be maintained episomally, e.g., as plasmids, minicircle DNAs, virus-derived vectors such as cytomegalovirus, adenovirus, etc., or they may be integrated into the target cell genome, through homologous recombination or random integration, e.g., retrovirus derived vectors such as MMLV, HIV-1, ALV, etc. Vectors may be provided directly to the subject cells. In other words, the pluripotent cells are contacted with vectors including the nucleic acid of interest such that the vectors are taken up by the cells.

[000220] Methods for contacting cells, e.g., cells in culture or cells in a non-human animal, e.g., mouse, with nucleic acid vectors, such as electroporation, calcium chloride transfection, and lipofection, are well known in the art. Alternatively, the nucleic acid of interest may be provided to the cells via a virus. In other words, the cells are contacted with viral particles including the nucleic acid of interest.

Retroviruses, for example, lentiviruses, are particularly suitable to the method of the invention. Commonly used retroviral vectors are "defective", i.e., unable to produce viral proteins required for productive infection. Rather, replication of the vector requires growth in a packaging cell line. To generate viral particles including nucleic acids of interest, the retroviral nucleic acids including the nucleic acid are packaged into viral capsids by a packaging cell line. Different packaging cell lines provide a

different envelope protein to be incorporated into the capsid, this envelope protein determining the specificity of the viral particle for the cells. Envelope proteins are of at least three types, ecotropic, amphotropic and xenotropic. Retroviruses packaged with ecotropic envelope protein, e.g., MMLV, are capable of infecting most murine and rat cell types, and are generated by using ecotropic packaging cell lines such as BOSC23 (Pear *et al.* (1993) P.N.A.S. 90:8392-8396). Retroviruses bearing amphotropic envelope protein, e.g. 4070A (Danos *et al, supra.*), are capable of infecting most mammalian cell types, including human, dog and mouse, and are generated by using amphotropic packaging cell lines such as PA12 (Miller *et al.* (1985) Mol. Cell. Biol. 5:431-437); PA317 (Miller *et al.* (1986) Mol. Cell. Biol. 6:2895-2902); GRIP (Danos *et al.* (1988) PNAS 85:6460-6464). Retroviruses packaged with xenotropic envelope protein, e.g., AKR env, are capable of infecting most mammalian cell types, except murine cells. The appropriate packaging cell line may be used to ensure that the cells of interest—in some instance, the engrafted cells, in some instance, the cells of the host, i.e., the humanized SIRP α -IL-15—are targeted by the packaged viral particles.

[000221] Vectors used for providing nucleic acid of interest to the subject cells will typically include suitable promoters for driving the expression, that is, transcriptional activation, of the nucleic acid of interest. This may include ubiquitously acting promoters, for example, the CMV-b-actin promoter, or inducible promoters, such as promoters that are active in particular cell populations or that respond to the presence of drugs such as tetracycline. By transcriptional activation, it is intended that transcription will be increased above basal levels in the target cell by at least about 10 fold, by at least about 100 fold, more usually by at least about 1000 fold. In addition, vectors used for providing reprogramming factors to the subject cells may include genes that must later be removed, e.g., using a recombinase system such as Cre/Lox, or the cells that express them destroyed, e.g., by including genes that allow selective toxicity such as herpesvirus TK, bcl-xs, etc.

[000222] Candidate agents of interest for screening also include polypeptides. Such polypeptides may optionally be fused to a polypeptide domain that increases solubility of the product. The domain may be linked to the polypeptide through a defined protease cleavage site, e.g., a TEV sequence, which is cleaved by TEV protease. The linker may also include one or more flexible sequences, e.g., from 1 to 10 glycine residues. In some embodiments, the cleavage of the fusion protein is performed in a buffer that maintains solubility of the product, e.g., in the presence of

from 0.5 to 2 M urea, in the presence of polypeptides and/or polynucleotides that increase solubility, and the like. Domains of interest include endosomolytic domains, e.g., influenza HA domain; and other polypeptides that aid in production, e.g., IF2 domain, GST domain, GRPE domain, and the like. Additionally or alternatively, such polypeptides may be formulated for improved stability. For example, the peptides may be PEGylated, where the polyethyleneoxy group provides for enhanced lifetime in the blood stream. The polypeptide may be fused to another polypeptide to provide for added functionality, e.g., to increase the *in vivo* stability. Generally such fusion partners are a stable plasma protein, which may, for example, extend the *in vivo* plasma half-life of the polypeptide when present as a fusion, in particular wherein such a stable plasma protein is an immunoglobulin constant domain. In most cases where the stable plasma protein is normally found in a multimeric form, e.g., immunoglobulins or lipoproteins, in which the same or different polypeptide chains are normally disulfide and/or noncovalently bound to form an assembled multichain polypeptide, the fusions herein containing the polypeptide also will be produced and employed as a multimer having substantially the same structure as the stable plasma protein precursor. These multimers will be homogeneous with respect to the polypeptide agent they include, or they may contain more than one polypeptide agent.

[000223] The candidate polypeptide agent may be produced from eukaryotic cells, or may be produced by prokaryotic cells. It may be further processed by unfolding, e.g., heat denaturation, DTT reduction, etc., and may be further refolded, using methods known in the art. Modifications of interest that do not alter primary sequence include chemical derivatization of polypeptides, e.g., acylation, acetylation, carboxylation, amidation, etc. Also included are modifications of glycosylation, e.g., those made by modifying the glycosylation patterns of a polypeptide during its synthesis and processing or in further processing steps; e.g., by exposing the polypeptide to enzymes which affect glycosylation, such as mammalian glycosylating or deglycosylating enzymes. Also embraced are sequences that have phosphorylated amino acid residues, e.g., phosphotyrosine, phosphoserine, or phosphothreonine. The polypeptides may have been modified using ordinary molecular biological techniques and synthetic chemistry so as to improve their resistance to proteolytic degradation or to optimize solubility properties or to render them more suitable as a therapeutic agent. Analogs of such polypeptides include those containing residues other than naturally occurring L-amino acids, e.g., D-amino acids or non-naturally occurring synthetic

amino acids. D-amino acids may be substituted for some or all of the amino acid residues.

[000224] The candidate polypeptide agent may be prepared by *in vitro* synthesis, using conventional methods as known in the art. Various commercial synthetic apparatuses are available, for example, automated synthesizers by Applied Biosystems, Inc., Beckman, *etc.* By using synthesizers, naturally occurring amino acids may be substituted with unnatural amino acids. The particular sequence and the manner of preparation will be determined by convenience, economics, purity required, and the like. Alternatively, the candidate polypeptide agent may be isolated and purified in accordance with conventional methods of recombinant synthesis. 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. For the most part, the compositions which are used will include at least 20% by weight of the desired product, more usually at least about 75% by weight, preferably at least about 95% by weight, and for therapeutic purposes, usually at least about 99.5% by weight, in relation to contaminants related to the method of preparation of the product and its purification. Usually, the percentages will be based upon total protein.

[000225] In some cases, the candidate polypeptide agents to be screened are antibodies or antigen-binding proteins. The 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. The specific or selective fit of a given structure and its specific epitope is sometimes referred to as a “lock and key” fit. The archetypal antibody molecule is the immunoglobulin, and all 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 either polyclonal antibodies or monoclonal antibodies. Antibodies are typically provided in the media in which the cells are cultured. Besides antibodies, antigen-binding proteins encompass polypeptides that are also designed to bind an antigen of interest and elicit a response, *e.g.*, an immunological reaction. Antigen-binding fragments known in the art (including, *e.g.*, Fab, Fab' F(ab')₂, Fabc, and scFv) are also encompassed by the term “antigen-binding protein”. The terms

“antibody” and “antigen-binding protein” also include one or more immunoglobulin chains or fragments that may be chemically conjugated to, or expressed as, fusion proteins with other proteins, single chain antibodies, and bispecific antibodies.

[000226] Candidate agents may be 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, including 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.

[000227] Candidate agents are screened for biological activity by administering the agent to at least one and usually a plurality of samples, sometimes in conjunction with samples lacking the agent. The change in parameters in response to the agent is measured, and the result evaluated by comparison to reference cultures, e.g. in the presence and absence of the agent, obtained with other agents, etc. In instances in which a screen is being performed to identify candidate agents that will prevent, mitigate or reverse the effects of a toxic agent, the screen is typically performed in the presence of the toxic agent, where the toxic agent is added at the time most appropriate to the results to be determined. For example, in cases in which the protective/preventative ability of the candidate agent is tested, the candidate agent may be added before the toxic agent, simultaneously with the candidate agent, or subsequent to treatment with the candidate agent. As another example, in cases in which the ability of the candidate agent to reverse the effects of a toxic agent is tested, the candidate agent may be added subsequent to treatment with the candidate agent. As mentioned above, in some instances, the sample is the humanized SIRP α -IL-15 non-human animal, e.g., mouse, that has been engrafted with cells, i.e., a candidate agent is provided to the humanized SIRP α -IL-15 non-human animal, e.g., mouse, that has been engrafted with cells. In some instances, the sample is the cells to be engrafted, i.e., the candidate agent is provided to cells prior to transplantation.

[000228] If the candidate agent is to be administered directly to the non-human animal, e.g., mouse, the agent may be administered by any of a number of well-known methods in the art for the administration of peptides, small molecules and nucleic acids. For example, the agent may be administered orally, mucosally, topically, intradermally, or by injection, e.g. intraperitoneal, subcutaneous, intramuscular, intravenous, or intracranial injection, and the like. The agent may be administered in a buffer, or it may be incorporated into any of a variety of formulations, e.g. by combination with appropriate pharmaceutically acceptable vehicle. "Pharmaceutically acceptable vehicles" may be vehicles approved by a regulatory agency of the Federal or a state government or listed in the U.S. Pharmacopeia or other generally recognized pharmacopeia for use in mammals, such as humans. The term "vehicle" refers to a diluent, adjuvant, excipient, or carrier with which a compound of the invention is formulated for administration to a mammal. Such pharmaceutical vehicles can be lipids, e.g. liposomes, e.g. liposome dendrimers; liquids, such as water and oils, including those of petroleum, animal, vegetable or synthetic origin, such as peanut oil, soybean oil, mineral oil, sesame oil and the like, saline; gum acacia, gelatin, starch paste, talc, keratin, colloidal silica, urea, and the like. In addition, auxiliary, stabilizing, thickening, lubricating and coloring agents may be used. Pharmaceutical compositions may be formulated into preparations in solid, semi-solid, liquid or gaseous forms, such as tablets, capsules, powders, granules, ointments, solutions, suppositories, injections, inhalants, gels, microspheres, and aerosols. The agent may be systemic after administration or may be localized by the use of regional administration, intramural administration, or use of an implant that acts to retain the active dose at the site of implantation. The active agent may be formulated for immediate activity or it may be formulated for sustained release. For some conditions, particularly central nervous system conditions, it may be necessary to formulate agents to cross the blood-brain barrier (BBB). One strategy for drug delivery through the blood-brain barrier (BBB) entails disruption of the BBB, either by osmotic means such as mannitol or leukotrienes, or biochemically by the use of vasoactive substances such as bradykinin. A BBB disrupting agent can be co-administered with the agent when the compositions are administered by intravascular injection. Other strategies to go through the BBB may entail the use of endogenous transport systems, including Caveolin-1 mediated transcytosis, carrier-mediated transporters such as glucose and amino acid carriers, receptor-mediated transcytosis for insulin or transferrin, and active efflux transporters

such as p-glycoprotein. Active transport moieties may also be conjugated to the therapeutic compounds for use in the invention to facilitate transport across the endothelial wall of the blood vessel. Alternatively, drug delivery of agents behind the BBB may be by local delivery, for example by intrathecal delivery, e.g. through an Ommaya reservoir (see e.g. US Patent Nos. 5,222,982 and 5,385,582, incorporated herein by reference); by bolus injection, e.g. by a syringe, e.g. intravitreally or intracranially; by continuous infusion, e.g. by cannulation, e.g. with convection (see e.g. US Application No. 20070254842, incorporated here by reference); or by implanting a device upon which the agent has been reversably affixed (see e.g. US Application Nos. 20080081064 and 20090196903, incorporated herein by reference).

[000229] If the agent(s) are provided to cells prior to transplantation, the agents are conveniently added in solution, or readily soluble form, to the medium of cells in culture. The agents may be added in a flow-through system, as a stream, intermittent or continuous, or alternatively, adding a bolus of the compound, singly or incrementally, to an otherwise static solution. In a flow-through system, two fluids are used, where one is a physiologically neutral solution, and the other is the same solution with the test compound added. The first fluid is passed over the cells, followed by the second. In a single solution method, a bolus of the test compound is added to the volume of medium surrounding the cells. The overall concentrations of the components of the culture medium should not change significantly with the addition of the bolus, or between the two solutions in a flow through method.

[000230] A plurality of assays may be run in parallel with different agent concentrations to obtain a differential response to the various concentrations. As known in the art, determining the effective concentration of an agent typically uses a range of concentrations resulting from 1:10, or other log scale, dilutions. The concentrations may be further refined with a second series of dilutions, if necessary. Typically, one of these concentrations serves as a negative control, i.e., at zero concentration or below the level of detection of the agent or at or below the concentration of agent that does not give a detectable change in the phenotype.

[000231] An analysis of the response of cells in a humanized SIRP α -IL-15 non-human animal, e.g., mouse, to the candidate agent may be performed at any time following treatment with the agent. For example, the cells may be analyzed 1, 2, or 3 days, sometimes 4, 5, or 6 days, sometimes 8, 9, or 10 days, sometimes 14 days, sometimes 21 days, sometimes 28 days, sometimes 1 month or more after contact with

the candidate agent, e.g., 2 months, 4 months, 6 months or more. In some embodiments, the analysis includes analysis at multiple time points. The selection of the time point(s) for analysis will be based upon the type of analysis to be performed, as will be readily understood by the ordinarily skilled artisan.

[000232] The analysis may include measuring any of the parameters described herein or known in the art for measuring cell viability, cell proliferation, cell identity, cell morphology, and cell function, particularly as they may pertain to cells of the immune system, e.g., T cells and/or NK cells. For example, flow cytometry may be used to determine the total number of hematopoietic cells or the number of cells of a particular hematopoietic cell type. Histochemistry or immunohistochemistry may be performed to determine the apoptotic state of the cells, e.g. terminal deoxynucleotidyl transferase dUTP nick end labeling (TUNEL) to measure DNA fragmentation, or immunohistochemistry to detect Annexin V binding to phosphatidylserine on the cell surface. Flow cytometry may also be employed to assess the proportions of differentiated cells and differentiated cell types, e.g., to determine the ability of hematopoietic cells to differentiate in the presence of agent. ELISAs, Westerns, and Northern blots may be performed to determine the levels of cytokines, chemokines, immunoglobulins, etc., expressed in the engrafted humanized SIRP α -IL-15 non-human animal, e.g., mouse, e.g. to assess the function of the engrafted cells. In vivo assays to test the function of immune cells, as well as assays relevant to particular diseases or disorders of interest such as diabetes, autoimmune disease, graft v. host disease, AMD, etc., may also be performed. See, e.g. Current Protocols in Immunology (Richard Coico, ed. John Wiley & Sons, Inc. 2012) and Immunology Methods Manual (I. Lefkovits ed., Academic Press 1997), the disclosures of which are incorporated herein by reference.

[000233] So, for example, a method is provided for determining the effect of an agent on a human pathogen, including exposing an engrafted humanized SIRP α -IL-15 non-human animal, e.g., mouse, e.g., an engrafted *Rag2^{-/-}IL2rg^{Y/-}* hSIRP α hIL-15 mouse, to an effective amount of a human pathogen, the effective amount of a pathogen being the amount of pathogen required to produce an infection in the mouse; allowing the pathogen to infect the mouse; measuring a parameter of the infection over time in the presence of the agent; and comparing that measurement to the measurement from an engrafted humanized SIRP α -IL-15 non-human animal, e.g., mouse, not exposed to the agent. The agent is determined to be an antipathogenic

agent if it reduces the amount of the agent in blood or a tissue of the non-human animal, e.g., mouse, by at least half following a single administration or two or more administrations of the agent over a selected period of time.

[000234] As another example, a method is provided for determining if a pathogen isolate or strain of interest is drug resistant, e.g. multidrug resistant. In these methods, an engrafted humanized SIRP α -IL-15 non-human animal, e.g., mouse, e.g., an engrafted *Rag2^{-/-}IL2rg^{Y/-}* hSIRP α hIL-15 mouse, is exposed to an effective amount of a human pathogen isolate or strain of interest, the effective amount of the pathogen being the amount of pathogen required to produce an infection in the non-human animal, e.g., mouse; the pathogen is allowed to infect the non-human animal; a parameter of the infection, e.g., the titer of the isolate or strain of interest in the blood or tissue of the non-human animal, the ability of the isolate or strain of interest to maintain an infection in the non-human animal, or the ability of the isolate or strain of interest to reproduce in the non-human animal at a point in time after administration of the drug, is measured in the presence of the drug; and that measurement is compared to the measurement from an engrafted humanized SIRP α -IL-15 non-human animal, e.g., mouse infected with pathogen not exposed to the agent. Examples of drugs of interest include amoxicillin, ampicillin, cefotaxime, ceftriaxone, ceftazidime, chloramphenicol, ciprofloxacin, co-trimoxazole, ertapenem, imipenem, fluoroquinolones (e.g., ciprofloxacin, gatifloxacin, ofloxacin), streptomycin, sulfadiazine, sulfamethoxazole, tetracycline, and a combination thereof. In a specific embodiment, the administration of the drug or combination of drugs is at least a week, 10 days, two week, three weeks, or four weeks after an infection-producing exposure to the isolate or strain of interest.

[000235] In addition, humanized SIRP α -IL-15 non-human animals (e.g., mice) and humanized SIRP α -IL-15 non-human animals (e.g., mice) engrafted with human hematopoietic cells, e.g., engrafted *Rag2^{-/-}IL2rg^{Y/-}* hSIRP α hIL-15 mice, and optionally having other genetic modifications are useful in studying antibody-dependent cellular cytotoxicity (ADCC) mediated by NK cells (e.g., human NK cells). Such animals are also useful models for testing the ability of therapeutic drug candidates, e.g., antigen-binding proteins or antibodies, designed to target various cells (e.g., tumors or infected cells) or infectious agents, to activate NK cell pathways involved in killing such cells or infectious agents.

[000236] It is widely known that one of the mechanisms underlying monoclonal antibody therapy is its activation of NK cells through binding the NK cell Fc receptor CD16 (Fc gamma receptor IIIA). Attempts have been made to increase affinity of various known monoclonal candidates (e.g., rituximab) for Fc gamma RIII A in order to improve ADCC (e.g., *Bowles et al.* Blood 2006; 108:2648-2654; *Garff-Tavernier et al.* Leukemia 2011; 25:202-209). As demonstrated herein, the humanized SIRP α -IL-15 engrafted non-human animals produce human NK cells that are capable of mediating ADCC; and thus, these animals present a useful *in vivo* model for studying ADCC mechanisms and screening various therapeutic candidates.

[000237] Thus, engrafted humanized SIRP α -IL-15 non-human animals and cells, e.g., human NK cells, isolated therefrom, may be used in screening methods designed to identify agents which improve antibody dependent cellular cytotoxicity (ADCC) activity of an engrafted cell type in the humanized non-human animal or cells, e.g., human NK cells. For example, a suitable method may include administering an agent to an engrafted humanized SIRP α -IL-15 non-human animal and determining the effect of the agent on an antibody dependent cellular cytotoxicity (ADCC) activity of an engrafted cell type *in vivo* in the humanized non-human animal. In one embodiment, such effect results in improved tumor killing, e.g., of a transplanted tumor, e.g., of a human tumor. In another embodiment, such effect results in improved killing of infected cell, e.g., virally-infected cell or bacterially-infected cell. In yet another embodiment, such effect results in improved killing of a bacteria, a fungus or a parasite. In various embodiments the agent is an antibody or an antigen-binding protein. In some embodiments, the antibody or the antigen-binding protein is designed to target an antigen expressed on a human tumor cell. In some embodiments, the antibody or the antigen-binding protein is designed to target an antigen expressed on a virally-infected cell or a bacterially-infected cell. In some embodiments, the antibody or the antigen-binding protein is designed to target a bacterial, a fungal, or a parasitic antigen. In some embodiments, an *in vitro* method is provided wherein human cells, e.g., human NK cells, are isolated from an engrafted humanized SIRP α -IL-15 non-human animal and contacted *in vitro* with an agent such as an antibody or an antigen-binding protein, and a target cell (e.g., tumor cell) to determine the efficacy of the agent in mediating killing of the target cell. The effect of the agent on the cytolytic activity of the human cells, e.g., human NK cells, can then be determined.

[000238] Other examples of uses for the subject mice are provided elsewhere herein. Additional applications of the genetically modified and engrafted mice described in this disclosure will be apparent to those skilled in the art upon reading this disclosure.

METHODS OF MAKING THE SUBJECT GENETICALLY MODIFIED NON-HUMAN ANIMALS

[000239] In some aspects of the invention, methods are provided for making the subject non-human animals of the present disclosure. In practicing the subject methods, a non-human animal is generated which includes a nucleic acid sequence incorporated into the genome of the genetically modified non-human animal, which sequence encodes a human SIRP α protein and is operably linked to a SIRP α gene promoter, e.g., an endogenous non-human SIRP α gene promoter; and a nucleic acid sequence incorporated into the genome of the genetically modified non-human animal, which sequence encodes a human IL-15 protein and is operably linked to an IL-15 gene promoter, e.g., an endogenous non-human IL-15 gene promoter.

[000240] The generation of a non-human animal including a nucleic acid sequence that encodes a human SIRP α protein and is operably linked to a SIRP α promoter, and/or a nucleic acid sequence that encodes a human IL-15 protein and is operably linked to an IL-15 gene promoter, may be accomplished using any convenient method for the making genetically modified animals, e.g. as known in the art or as described herein.

[000241] For example, a nucleic acid encoding a human SIRP α protein or a human IL-15 protein may be incorporated into a recombinant vector in a form suitable for insertion into the genome of the host cell and expression of the human protein in a non-human host cell. In various embodiments, the recombinant vector includes the one or more regulatory sequences operatively linked to the nucleic acid encoding the human protein in a manner which allows for transcription of the nucleic acid into mRNA and translation of the mRNA into the human protein, as described above. It will be understood that the design of the vector may depend on such factors as the choice of the host cell to be transfected and/or the amount of human protein to be expressed.

[000242] Any of various methods may then be used to introduce the human nucleic acid sequence into an animal cell to produce a genetically modified animal that expresses the human gene. Such techniques are well-known in the art and include, but are not limited to, pronuclear microinjection, transformation of embryonic stem cells, homologous recombination and knock-in techniques. Methods for generating genetically modified animals that can be used include, but are not limited to, those described in Sundberg and Ichiki (2006, *Genetically Engineered Mice Handbook*, CRC Press), Hofker and van Deursen (2002, *Genetically modified Mouse Methods and Protocols*, Humana Press), Joyner (2000, *Gene Targeting: A Practical Approach*, Oxford University Press), Turksen (2002, *Embryonic stem cells: Methods and Protocols in Methods Mol Biol.*, Humana Press), Meyer et al. (2010, *Proc. Nat. Acad. Sci. USA* 107:15022-15026), and Gibson (2004, *A Primer of Genome Science* 2nd ed. Sunderland, Massachusetts: Sinauer), U.S. Pat. No. 6,586,251, Rathinam et al. (2011, *Blood* 118:3119-28), Willinger et al., (2011, *Proc Natl Acad Sci USA*, 108:2390-2395), Rongvaux et al., (2011, *Proc Natl Acad Sci USA*, 108:2378-83) and Valenzuela et al. (2003, *Nat Biot* 21:652-659).

[000243] For example, the subject genetically modified animals can be created by introducing the nucleic acid encoding the human protein into an oocyte, e.g., by microinjection, and allowing the oocyte to develop in a female foster animal. In preferred embodiments, the nucleic acid is injected into fertilized oocytes. Fertilized oocytes can be collected from superovulated females the day after mating and injected with the expression construct. The injected oocytes are either cultured overnight or transferred directly into oviducts of 0.5-day p.c. pseudopregnant females. Methods for superovulation, harvesting of oocytes, expression construct injection and embryo transfer are known in the art and described in *Manipulating the Mouse Embryo* (2002, *A Laboratory Manual*, 3rd edition, Cold Spring Harbor Laboratory Press). Offspring can be evaluated for the presence of the introduced nucleic acid by DNA analysis (e.g., PCR, Southern blot, DNA sequencing, etc.) or by protein analysis (e.g., ELISA, Western blot, etc.).

[000244] As another example, the construct including the nucleic acid sequence encoding the human protein may be transfected into stem cells (e.g., ES cells or iPS cells) using well-known methods, such as electroporation, calcium-phosphate precipitation, lipofection, etc. The cells can be evaluated for the presence of the introduced nucleic acid by DNA analysis (e.g., PCR, Southern blot, DNA sequencing,

etc.) or by protein analysis (e.g., ELISA, Western blot, etc.). Cells determined to have incorporated the expression construct can then be introduced into preimplantation embryos. For a detailed description of methods known in the art useful for the compositions and methods of the invention, see Nagy et al., (2002, *Manipulating the Mouse Embryo: A Laboratory Manual*, 3rd edition, Cold Spring Harbor Laboratory Press), Nagy et al. (1990, *Development* 110:815-821), U.S. Pat. No. 7,576,259, U.S. Pat. No. 7,659,442, U.S. Pat. No. 7,294,754, and Kraus et al. (2010, *Genesis* 48:394-399).

[000245] In a preferred embodiment, a method of generating a genetically modified animal described herein utilizes a targeting construct made using VELOCIGENE® technology, introducing the construct into ES cells, and introducing targeted ES cell clones into a mouse embryo using VELOCIMOUSE® technology, as described in the Examples.

[000246] Genetically modified founder animals can be bred to additional animals carrying the genetic modification. For example, humanized SIRP α non-human animals can be bred with humanized IL-15 non-human animals of the same species to produce the hSIRP α -hIL-15 non-human animals described herein. Genetically modified animals carrying a nucleic acid encoding the human protein(s) of the present disclosure can further be bred to knockout animals, e.g., a non-human animal that is deficient for one or more proteins, e.g. does not express one or more of its genes, e.g. a Rag2-deficient animal and/or an Il2rg-deficient animal.

[000247] As discussed above, in some embodiments, the subject genetically modified non-human animal is an immunodeficient animal. Genetically modified non-human animals that are immunodeficient and include one or more human proteins, e.g. hSIRP α and/or hIL-15, may be generated using any convenient method for the generation of genetically modified animals, e.g. as known in the art or as described herein. For example, the generation of the genetically modified immunodeficient animal can be achieved by introduction of the nucleic acid encoding the human protein into an oocyte or stem cells including a mutant SCID gene allele that, when homozygous, will result in immunodeficiency as described in greater detail above and in the working examples herein. Mice are then generated with the modified oocyte or ES cells using, e.g. methods described herein and known in the art, and mated to produce the immunodeficient mice including the desired genetic modification. As another example, genetically modified non-human animals can be generated in an

immunocompetent background, and crossed to an animal including a mutant gene allele that, when hemizygous or homozygous, will result in immunodeficiency, and the progeny mated to create an immunodeficient animal expressing the at least one human protein of interest.

[000248] In some embodiments, the genetically modified non-human animal is treated so as to eliminate endogenous hematopoietic cells that may exist in the genetically modified non-human animal. In one embodiment, the treatment includes irradiating the genetically modified non-human animal. In a specific embodiment, newborn genetically modified mouse pups are irradiated sublethally. In a specific embodiment, newborn pups are irradiated 2 x 200 cGy with a four hour interval.

[000249] Various embodiments of the invention provide genetically modified animals that include a human nucleic acid in substantially all of their cells, as well as genetically modified animals that include a human nucleic acid in some, but not all their cells. In some instances, e.g. targeted recombination, one copy of the human nucleic acid will be integrated into the genome of the genetically modified animals. In other instances, e.g. random integration, multiple copies, adjacent or distant to one another, of the human nucleic acid may be integrated into the genome of the genetically modified animals.

[000250] Thus, in some embodiments, the subject genetically modified non-human animal may be an immunodeficient animal including a genome that includes a nucleic acid encoding a human polypeptide operably linked to the corresponding non-human animal promoter, wherein the animal expresses the encoded human polypeptide. In other words, the subject genetically modified immunodeficient non-human animal includes a genome that includes a nucleic acid encoding at least one human polypeptide, wherein the nucleic acid is operably linked to the corresponding non-human promoter and a polyadenylation signal, and wherein the animal expresses the encoded human polypeptide.

REAGENTS, DEVICES AND KITS

[000251] Also provided are reagents, devices and kits thereof for practicing one or more of the above-described methods. The subject reagents, devices and kits thereof may vary greatly.

[000252] In some embodiments, the reagents or kits will include one or more agents for use in the methods described herein. For example, the kit may include a

humanized SIRP α -IL-15 non-human animal, e.g., mouse, e.g., a *Rag2^{-/-}IL2rg^{Y/-}* hSIRP α hIL-15 mouse. The kit may include reagents for breeding humanized SIRP α -IL-15 non-human animals, e.g., mice, e.g., primers and, in some instances, reagents for genotyping humanized SIRP α -IL-15 non-human animals, e.g., mice. The kit may include human hematopoietic cells or an enriched population of human hematopoietic progenitor cells for transplantation into the humanized SIRP α -IL-15 non-human animal, e.g., mouse, or reagents for preparing a population of hematopoietic cells or an enriched population of hematopoietic cells from a human for transplantation into a humanized SIRP α -IL-15 non-human animal, e.g., mouse. Other reagents may include reagents for determining the viability and/or function of hematopoietic cells or differentiated immune cells (e.g., T cells and/or NK cells), e.g. in the presence/absence of candidate agent, e.g., one or more antibodies that are specific for markers expressed by different types of hematopoietic cells or differentiated immune cells (e.g., T cells and/or NK cells), or reagents for detecting particular cytokines, chemokine, etc. Other reagents may include culture media, culture supplements, matrix compositions, and the like.

[000253] In addition to the above components, the subject kits will further include instructions for practicing the subject methods. These instructions may be present in the subject kits in a variety of forms, one or more of which may be present in the kit. One form in which these instructions may be present is as printed information on a suitable medium or substrate, e.g., a piece or pieces of paper on which the information is printed, in the packaging of the kit, in a package insert, etc. Yet another means would be a computer readable medium, e.g., diskette, CD, etc., on which the information has been recorded. Yet another means that may be present is a website address which may be used via the internet to access the information at a remote site. Any convenient means may be present in the kits.

EXEMPLARY NON-LIMITING ASPECTS OF THE DISCLOSURE

[000254] Aspects, including embodiments, of the present subject matter described above may be beneficial alone or in combination, with one or more other aspects or embodiments. Without limiting the foregoing description, certain non-limiting aspects of the disclosure numbered 1-167 are provided below. As will be apparent to those of skill in the art upon reading this disclosure, each of the individually numbered aspects may be used or combined with any of the preceding or

following individually numbered aspects. This is intended to provide support for all such combinations of aspects and is not limited to combinations of aspects explicitly provided below:

1. A genetically modified non-human animal, comprising:

a nucleic acid sequence incorporated into the genome of the genetically modified non-human animal, which sequence encodes a human SIRP α protein and is operably linked to a SIRP α gene promoter; and

a nucleic acid sequence incorporated into the genome of the genetically modified non-human animal, which sequence encodes a human IL-15 protein and is operably linked to an IL-15 gene promoter, wherein the genetically modified non-human animal expresses the human SIRP α protein and the human IL-15 protein.

2. The genetically modified non-human animal according to 1, wherein the SIRP α gene promoter is an endogenous non-human SIRP α gene promoter.
3. The genetically modified non-human animal according to 2, wherein the SIRP α gene promoter is the endogenous non-human SIRP α gene promoter at the non-human animal SIRP α gene locus.
4. The genetically modified non-human animal according to 3, comprising a null mutation in the non-human SIRP α gene at the non-human animal SIRP α gene locus.
5. The genetically modified non-human animal according to 4, wherein the genetically modified non-human animal is a mouse and the null mutation is a deletion of at least mouse SIRP α exons 2-4.
6. The genetically modified non-human animal according to 4, wherein the genetically modified non-human animal is heterozygous for the allele comprising the nucleic acid sequence that encodes the human SIRP α protein.
7. The genetically modified non-human animal according to 4, wherein the genetically modified non-human animal is homozygous for the allele comprising the nucleic acid sequence that encodes the human SIRP α protein.

8. The genetically modified non-human animal according to any one of 1-7, wherein the nucleic acid sequence that encodes the human SIRP α protein comprises human SIRP α genomic coding and non-coding sequence.
9. The genetically modified non-human animal according to any one of 1-8, wherein the human SIRP α protein is a functional fragment of a full length human SIRP α protein.
10. The genetically modified non-human animal according to 9, wherein the functional fragment comprises an extracellular domain of human SIRP α .
11. The genetically modified non-human animal according to 10, wherein the extracellular domain comprises amino acids 28-362 of SEQ ID NO:12.
12. The genetically modified non-human animal according to any one of 1-11, wherein the IL-15 gene promoter is an endogenous non-human IL-15 gene promoter.
13. The genetically modified non-human animal according to 12, wherein the IL-15 gene promoter is the endogenous non-human IL-15 gene promoter at the non-human animal IL-15 gene locus.
14. The genetically modified non-human animal according to 13, comprising a null mutation in the non-human IL-15 gene at the non-human animal IL-15 gene locus.
15. The genetically modified non-human animal according to 14, wherein the genetically modified non-human animal is a mouse and the null mutation is a deletion of at least mouse IL-15 exons 5-8.
16. The genetically modified non-human animal according to 14, wherein the genetically modified non-human animal is heterozygous for the allele comprising the nucleic acid sequence that encodes the human IL-15 protein.
17. The genetically modified non-human animal according to 14, wherein the genetically modified non-human animal is homozygous for the allele comprising the nucleic acid sequence that encodes the human IL-15 protein.
18. The genetically modified non-human animal according to any one of 1-17, wherein the nucleic acid sequence that encodes the human IL-15 protein comprises human IL-15 genomic coding and non-coding sequence.

19. The genetically modified non-human animal according to any one of 1-18, wherein the human IL-15 protein is a functional fragment of a full length human IL-15 protein.
20. The genetically modified non-human animal according to any one of 1-19, wherein the genetically modified non-human animal is immunodeficient.
21. The genetically modified non-human animal according to 20, wherein the genetically modified non-human animal comprises a Rag2 gene knock-out.
22. The genetically modified non-human animal according to 20 or 21, wherein the genetically modified non-human animal comprises an IL2rg gene knock-out.
23. The genetically modified non-human animal according to any one of 1-22, wherein the non-human animal is a mammal.
24. The genetically modified non-human animal according to 23, wherein the mammal is a rodent.
25. The genetically modified non-human animal according to 24, wherein the rodent is a mouse.
26. The genetically modified non-human animal according to any one of 1-25, wherein the genetically modified non-human animal comprises an engraftment of human hematopoietic cells.
27. The genetically modified non-human animal according to 26, wherein the genetically modified non-human animal comprises an infection with a human pathogen.
28. The genetically modified non-human animal according to 27, wherein the human pathogen activates, induces and/or targets T cells and/or natural killer (NK) cells.
29. The genetically modified non-human animal according to 27, wherein the human pathogen is a pathogen that infects human intestine.
30. The genetically modified non-human animal according to 29, wherein the human pathogen is a human rotavirus.
31. The genetically modified non-human animal according to 27, wherein the pathogen infects human lung.
32. The genetically modified non-human animal according to 31, wherein the human pathogen is an influenza virus.

33. An animal engraftment model, comprising a genetically modified non-human animal comprising:

a nucleic acid sequence incorporated into the genome of the genetically modified non-human animal, which sequence encodes a human SIRP α protein and is operably linked to a SIRP α gene promoter;

a nucleic acid sequence incorporated into the genome of the genetically modified non-human animal, which sequence encodes a human IL-15 protein and is operably linked to an IL-15 gene promoter; and

an engraftment of human hematopoietic cells, wherein the genetically modified non-human animal (i) expresses the human SIRP α protein and the human IL-15 protein, and (ii) comprises human intraepithelial lymphocytes (IELs) in the small intestine and Peyer's patches of the genetically modified non-human animal.

34. The model according to 33, wherein the genetically modified non-human animal comprises an infection with a human pathogen.

35. The model according to 34, wherein the human pathogen is an intestinal pathogen.

36. The model according to 35, wherein the intestinal pathogen is selected from: *Campylobacter jejuni*, *Clostridium difficile*, *Enterococcus faecalis*, *Enterococcus faecium*, *Escherichia coli*, Human Rotavirus, *Listeria monocytogenes*, Norwalk Virus, *Salmonella enterica*, *Shigella flexneri*, *Shigella sonnei*, *Shigella dysenteriae*, *Yersinia pestis*, *Yersinia enterocolitica*, and *Helicobacter pylori*.

37. The model according to any one of 33-36, wherein the SIRP α gene promoter is an endogenous non-human SIRP α gene promoter.

38. The model according to 37, wherein the SIRP α gene promoter is the endogenous non-human SIRP α gene promoter at the non-human animal SIRP α gene locus.

39. The model according to 38, wherein the genetically modified non-human animal comprises a null mutation in the non-human SIRP α gene at the non-human animal SIRP α gene locus.

40. The model according to 39, wherein the genetically modified non-human animal is a mouse and the null mutation is a deletion of at least mouse SIRP α exons 2-4.
41. The model according to 39, wherein the genetically modified non-human animal is heterozygous for the allele comprising the nucleic acid sequence that encodes the human SIRP α protein.
42. The model according to 39, wherein the genetically modified non-human animal is homozygous for the allele comprising the nucleic acid sequence that encodes the human SIRP α protein.
43. The model according to any one of 33-42, wherein the nucleic acid sequence that encodes the human SIRP α protein comprises human SIRP α genomic coding and non-coding sequence.
44. The model according to any one of 33-43, wherein the human SIRP α protein is a functional fragment of a full length human SIRP α protein.
45. The model according to 44, wherein the functional fragment comprises an extracellular domain of human SIRP α .
46. The model according to 45, wherein the extracellular domain comprises amino acids 28-362 of SEQ ID NO:12.
47. The model according to any one of 33-46, wherein the IL-15 gene promoter is an endogenous non-human IL-15 gene promoter.
48. The model according to 47, wherein the IL-15 gene promoter is the endogenous non-human IL-15 gene promoter at the non-human animal IL-15 gene locus.
49. The model according to 48, wherein the genetically modified non-human animal comprises a null mutation in the non-human IL-15 gene at the non-human animal IL-15 gene locus.
50. The model according to 49, wherein the genetically modified non-human animal is a mouse and the null mutation is a deletion of at least mouse IL-15 exons 5-8.
51. The model according to 48, wherein the genetically modified non-human animal is heterozygous for the allele comprising the nucleic acid sequence that encodes the human IL-15 protein.

52. The model according to 48, wherein the genetically modified non-human animal is homozygous for the allele comprising the nucleic acid sequence that encodes the human IL-15 protein.
53. The model according to any one of 33-52, wherein the nucleic acid sequence that encodes the human IL-15 protein comprises human IL-15 genomic coding and non-coding sequence.
54. The model according to any one of 33-53, wherein the human IL-15 protein is a functional fragment of a full length human IL-15 protein.
55. The model according to any one of 33-54, wherein the genetically modified non-human animal is immunodeficient.
56. The model according to 55, wherein the genetically modified non-human animal comprises a Rag2 gene knock-out.
57. The model according to 55 or 56, wherein the genetically modified non-human animal comprises an IL2rg gene knock-out.
58. The model according to any one of 33-57, wherein the non-human animal is a mammal.
59. The model according to 58, wherein the mammal is a rodent.
60. The model according to 59, wherein the rodent is a mouse.
61. An animal engraftment model, comprising a genetically modified non-human animal comprising:
 - a nucleic acid sequence incorporated into the genome of the genetically modified non-human animal, which sequence encodes a human SIRP α protein and is operably linked to a SIRP α gene promoter;
 - a nucleic acid sequence incorporated into the genome of the genetically modified non-human animal, which sequence encodes a human IL-15 protein and is operably linked to an IL-15 gene promoter; and
 - an engraftment of human hematopoietic cells, wherein the genetically modified non-human animal (i) expresses the human SIRP α protein and the human IL-15 protein, and (ii) comprises human intraepithelial lymphocytes (IELs) in the lung of the genetically modified non-human animal.
62. The model according to 61, wherein the genetically modified non-human animal comprises an infection with a human pathogen.
63. The model according to 62, wherein the human pathogen is lung pathogen.

64. The model according to 63, wherein the lung pathogen is selected from:
Streptococcus pyogenes, *Haemophilus influenza*, *Corynebacterium diphtheria*, *SARS coronavirus*, *Bordetella pertussis*, *Moraxella catarrhalis*, Influenza virus (A, B, C), Coronavirus, Adenovirus, Respiratory Syncytial Virus, Parainfluenza virus, Mumps virus, *Streptococcus pneumoniae*, *Staphylococcus aureus*, *Legionella pneumophila*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, *Mycoplasma pneumonia*, *Mycobacterium tuberculosis*, *Chlamydia Pneumoniae*, *Blastomyces dermatitidis*, *Cryptococcus neoformans*, and *Aspergillus fumigatus*.
65. The model according to any one of 61-64, wherein the SIRP α gene promoter is an endogenous non-human SIRP α gene promoter.
66. The model according to 65, wherein the SIRP α gene promoter is the endogenous non-human SIRP α gene promoter at the non-human animal SIRP α gene locus.
67. The model according to 66, wherein the genetically modified non-human animal comprises a null mutation in the non-human SIRP α gene at the non-human animal SIRP α gene locus.
68. The model according to 67, wherein the genetically modified non-human animal is a mouse and the null mutation is a deletion of at least mouse SIRP α exons 2-4.
69. The model according to 67, wherein the genetically modified non-human animal is heterozygous for the allele comprising the nucleic acid sequence that encodes the human SIRP α protein.
70. The model according to 67, wherein the genetically modified non-human animal is homozygous for the allele comprising the nucleic acid sequence that encodes the human SIRP α protein.
71. The model according to any one of 61-70, wherein the nucleic acid sequence that encodes the human SIRP α protein comprises human SIRP α genomic coding and non-coding sequence.
72. The model according to any one of 61-71, wherein the human SIRP α protein is a functional fragment of a full length human SIRP α protein.
73. The model according to 72, wherein the functional fragment comprises an extracellular domain of human SIRP α .

74. The model according to 73, wherein the extracellular domain comprises amino acids 28-362 of SEQ ID NO:12.
75. The model according to any one of 61-74, wherein the IL-15 gene promoter is an endogenous non-human IL-15 gene promoter.
76. The model according to 75, wherein the IL-15 gene promoter is the endogenous non-human IL-15 gene promoter at the non-human animal IL-15 gene locus.
77. The model according to 76, wherein the genetically modified non-human animal comprises a null mutation in the non-human IL-15 gene at the non-human animal IL-15 gene locus.
78. The model according to 77, wherein the genetically modified non-human animal is a mouse and the null mutation is a deletion of at least mouse IL-15 exons 5-8.
79. The model according to 77, wherein the genetically modified non-human animal is heterozygous for the allele comprising the nucleic acid sequence that encodes the human IL-15 protein.
80. The model according to 77, wherein the genetically modified non-human animal is homozygous for the allele comprising the nucleic acid sequence that encodes the human IL-15 protein.
81. The model according to any one of 61-80, wherein the nucleic acid sequence that encodes the human IL-15 protein comprises human IL-15 genomic coding and non-coding sequence.
82. The model according to any one of 61-80, wherein the human IL-15 protein is a functional fragment of a full length human IL-15 protein.
83. The model according to any one of 61-82, wherein the genetically modified non-human animal is immunodeficient.
84. The model according to 83, wherein the genetically modified non-human animal comprises a Rag2 gene knock-out.
85. The model according to 83 or 84, wherein the genetically modified non-human animal comprises an IL2rg gene knock-out.
86. The model according to any one of 61-85, wherein the non-human animal is a mammal.
87. The model according to 86, wherein the mammal is a rodent.
88. The model according to 87, wherein the rodent is a mouse.

89. A method of determining the efficacy of a candidate T-cell inducing vaccine, the method comprising:
- administering a candidate T-cell inducing vaccine to a genetically modified non-human animal, wherein the genetically modified non-human animal is deficient for an endogenous immune system and comprises:
 - (i) a nucleic acid sequence incorporated into the genome of the genetically modified non-human animal, which sequence encodes a human SIRP α protein and is operably linked to a SIRP α gene promoter,
 - (ii) a nucleic acid sequence incorporated into the genome of the genetically modified non-human animal, which sequence encodes a human IL-15 protein and is operably linked to an IL-15 gene promoter, and
 - (iii) an engraftment of human hematopoietic cells, wherein the genetically modified non-human animal expresses the human SIRP α protein and the human IL-15 protein;
 - challenging the genetically modified non-human animal with a human pathogen; and
 - determining whether the candidate T-cell inducing vaccine induces a T cell mediated immune response in the genetically modified non-human animal.
90. The method according to 89, wherein the SIRP α gene promoter is an endogenous non-human SIRP α gene promoter.
91. The method according to 90, wherein the SIRP α gene promoter is the endogenous non-human SIRP α gene promoter at the non-human animal SIRP α gene locus.
92. The method according to 91, wherein the genetically modified non-human animal comprises a null mutation in the non-human SIRP α gene at the non-human animal SIRP α gene locus.
93. The method according to 92, wherein the genetically modified non-human animal is a mouse and the null mutation is a deletion of at least mouse SIRP α exons 2-4.

94. The method according to 92, wherein the genetically modified non-human animal is heterozygous for the allele comprising the nucleic acid sequence that encodes the human SIRP α protein.
95. The method according to 92, wherein the genetically modified non-human animal is homozygous for the allele comprising the nucleic acid sequence that encodes the human SIRP α protein.
96. The method according to any one of 89-95, wherein the nucleic acid sequence that encodes the human SIRP α protein comprises human SIRP α genomic coding and non-coding sequence.
97. The method according to any one of 89-96, wherein the human SIRP α protein is a functional fragment of a full length human SIRP α protein.
98. The method according to 97, wherein the functional fragment comprises an extracellular domain of human SIRP α .
99. The method according to 98, wherein the extracellular domain comprises amino acids 28-362 of SEQ ID NO:12.
100. The method according to any one of 89-99, wherein the IL-15 gene promoter is an endogenous non-human IL-15 gene promoter.
101. The method according to 100, wherein the IL-15 gene promoter is the endogenous non-human IL-15 gene promoter at the non-human animal IL-15 gene locus.
102. The method according to 101, wherein the genetically modified non-human animal comprises a null mutation in the non-human IL-15 gene at the non-human animal IL-15 gene locus.
103. The method according to 102, wherein the genetically modified non-human animal is a mouse and the null mutation is a deletion of at least mouse IL-15 exons 5-8.
104. The method according to 101, wherein the genetically modified non-human animal is heterozygous for the allele comprising the nucleic acid sequence that encodes the human IL-15 protein.
105. The method according to 101, wherein the genetically modified non-human animal is homozygous for the allele comprising the nucleic acid sequence that encodes the human IL-15 protein.

106. The method according to any one of 89-105, wherein the nucleic acid sequence that encodes the human IL-15 protein comprises human IL-15 genomic coding and non-coding sequence.
107. The method according to any one of 89-106, wherein the human IL-15 protein is a functional fragment of a full length human IL-15 protein.
108. The method according to any one of 89-107, wherein the genetically modified non-human animal comprises a Rag2 gene knock-out.
109. The method according to any one of 89-108, wherein the genetically modified non-human animal comprises an IL2rg gene knock-out.
110. The method according to any one of 89-109, wherein the genetically modified non-human animal is a mammal.
111. The method according to 110, wherein the mammal is a rodent.
112. The method according to 111, wherein the rodent is a mouse.
113. A method of identifying an agent that inhibits an infection by a pathogen that activates, induces and/or targets human T cells and/or natural killer (NK) cells, the method comprising:
- administering an agent to an genetically modified non-human animal, wherein the genetically modified non-human animal is deficient for an endogenous immune system and comprises:
- (i) a nucleic acid sequence incorporated into the genome of the genetically modified non-human animal, which sequence encodes a human SIRP α protein and is operably linked to a SIRP α gene promoter,
- (ii) a nucleic acid sequence incorporated into the genome of the genetically modified non-human animal, which sequence encodes a human IL-15 protein and is operably linked to an IL-15 gene promoter,
- (iii) an engraftment of human hematopoietic cells, and
- (iv) an infection by a pathogen that activates, induces and/or targets human T cells and/or natural killer cells, wherein the genetically modified non-human animal expresses the human SIRP α protein and the human IL-15 protein; and
- determining whether the agent reduces the amount of the pathogen in the pathogen-infected non-human animal.

114. The method according to 113, wherein the SIRP α gene promoter is an endogenous non-human SIRP α gene promoter.
115. The method according to 114, wherein the SIRP α gene promoter is the endogenous non-human SIRP α gene promoter at the non-human animal SIRP α gene locus.
116. The method according to 115, wherein the genetically modified non-human animal comprises a null mutation in the non-human SIRP α gene at the non-human animal SIRP α gene locus.
117. The method according to 116, wherein the genetically modified non-human animal is a mouse and the null mutation is a deletion of at least mouse SIRP α exons 2-4.
118. The method according to 116, wherein the genetically modified non-human animal is heterozygous for the allele comprising the nucleic acid sequence that encodes the human SIRP α protein.
119. The method according to 116, wherein the genetically modified non-human animal is homozygous for the allele comprising the nucleic acid sequence that encodes the human SIRP α protein.
120. The method according to any one of 113-119, wherein the nucleic acid sequence that encodes the human SIRP α protein comprises human SIRP α genomic coding and non-coding sequence.
121. The method according to any one of 113-120, wherein the human SIRP α protein is a functional fragment of a full length human SIRP α protein.
122. The method according to 121, wherein the functional fragment comprises an extracellular domain of human SIRP α .
123. The method according to 122, wherein the extracellular domain comprises amino acids 28-362 of SEQ ID NO:12.
124. The method according to any one of 113-123, wherein the IL-15 gene promoter is an endogenous non-human IL-15 gene promoter.
125. The method according to 124, wherein the IL-15 gene promoter is the endogenous non-human IL-15 gene promoter at the non-human animal IL-15 gene locus.

126. The method according to 125, the genetically modified non-human animal comprises a null mutation in the non-human IL-15 gene at the non-human animal IL-15 gene locus.
127. The method according to 126, wherein the genetically modified non-human animal is a mouse and the null mutation is a deletion of at least mouse IL-15 exons 5-8.
128. The method according to 125, wherein the genetically modified non-human animal is heterozygous for the allele comprising the nucleic acid sequence that encodes the human IL-15 protein.
129. The method according to 125, wherein the genetically modified non-human animal is homozygous for the allele comprising the nucleic acid sequence that encodes the human IL-15 protein.
130. The method according to any one of 113-129, wherein the nucleic acid sequence that encodes the human IL-15 protein comprises human IL-15 genomic coding and non-coding sequence.
131. The method according to any one of 113-130, wherein the human IL-15 protein is a functional fragment of a full length human IL-15 protein.
132. The method according to any one of 113-131, wherein the genetically modified non-human animal comprises a Rag2 gene knock-out.
133. The method according to any one of 113-132, wherein the genetically modified non-human animal comprises an IL2rg gene knock-out.
134. The method according to any one of 113-133, wherein the genetically modified non-human animal is a mammal.
135. The method according to 134, wherein the mammal is a rodent.
136. The method according to 135, wherein the rodent is a mouse.
137. A method of making a non-human animal expressing a human IL-15 protein and a human SIRP α protein, comprising:
introducing into a genome of a first non-human animal a nucleic acid sequence encoding a human SIRP α protein, wherein the sequence encoding the human SIRP α protein is operably linked to an SIRP α gene promoter sequence;
introducing into a genome of a second non-human animal a nucleic acid sequence encoding a human IL-15 protein, wherein the sequence

encoding the human IL-15 protein is operably linked to a IL-15 promoter sequence; and

making a third non-human animal that comprises the nucleic acid sequence encoding the human IL-15 protein and the nucleic acid sequence encoding the human SIRP α protein, wherein the third non-human animal expresses the human IL-15 protein and the human SIRP α protein.

138. The method of 137, wherein the steps of introducing comprise generating a non-human animal from a pluripotent stem cell comprising the nucleic acid encoding human IL-15 or human SIRP α .
139. The method of 137 or 138, wherein the first animal is a different animal than the second animal, and the step of making the third animal comprises breeding the first and the second animal.
140. The method of 137, wherein the first animal and the second animal are the same, the step of introducing into the genome of the first animal comprises contacting a first pluripotent stem cell with the nucleic acid sequence encoding the human SIRP α protein to obtain a second pluripotent stem cell, the step of introducing into the genome of the second animal comprises contacting the second pluripotent stem cell with the nucleic acid sequence encoding the human SIRP α protein to obtain a third pluripotent stem cell, and the third non-human animal is made from the third pluripotent stem cell.
141. The method according to any one of 137-140, wherein the pluripotent stem cell is an ES cell or an iPS cell.
142. The method according to any one of 137-140, wherein the pluripotent stem cell is deficient for Rag2.
143. The method according to any one of 137-142, wherein the pluripotent stem cell is deficient for IL2rg.
144. The method according to any one of 137-143, wherein the third non-human animal is deficient in one or both of Rag2 and IL2rg.
145. The method according to any one of 137-144, wherein the IL-15 promoter sequence is a human IL-15 promoter sequence.

146. The method according to any one of 137-144, wherein the IL-15 promoter sequence is an endogenous non-human animal IL-15 promoter sequence.
147. The method according to any one of 137-144, wherein the integration results in a replacement of the non-human IL-15 gene at the non-human IL-15 gene locus.
148. The method according to any one of 137-147, wherein the nucleic acid sequence that encodes the human IL-15 protein comprises human IL-15 genomic coding and non-coding sequence.
149. A method of engrafting a genetically modified non-human animal expressing a human IL-15 protein, comprising:
transplanting a population of cells comprising human hematopoietic cells into the genetically modified non-human animal made by a method according to any one of 137-148.
150. The method according to 149, wherein the transplanting comprises tail-vein injection, fetal liver injection, or retro-orbital injection.
151. The method according to 149 or 150, wherein the genetically modified non-human animal is sublethally irradiated prior to transplantation.
152. The method according to any one of 149-151, wherein the human hematopoietic cells are CD34+ cells.
153. The method according to any one of 149-151, wherein the human hematopoietic cells are from fetal liver, adult bone marrow, or umbilical cord blood.
154. A method of determining the efficacy of a candidate therapeutic antibody or antigen-binding protein in killing a target cell, the method comprising:
administering the candidate therapeutic antibody or antigen-binding protein to a genetically modified non-human animal, wherein the genetically modified non-human animal is deficient for an endogenous immune system and comprises:
(i) a nucleic acid sequence incorporated into the genome of the genetically modified non-human animal, which sequence encodes a

human SIRP α protein and is operably linked to a SIRP α gene promoter,

(ii) a nucleic acid sequence incorporated into the genome of the genetically modified non-human animal, which sequence encodes a human IL-15 protein and is operably linked to an IL-15 gene promoter, and

(iii) an engraftment of human hematopoietic cells, wherein the genetically modified non-human animal expresses the human SIRP α protein and the human IL-15 protein; and

determining whether the candidate therapeutic antibody or antigen-binding protein modulates an NK cell mediated antibody-dependent cellular cytotoxicity against the target cell in the genetically modified non-human animal.

155. A method of determining the efficacy of a candidate therapeutic antibody or antigen-binding protein in killing a target cell, the method comprising:

isolating an NK cell from a genetically modified non-human animal, wherein the genetically modified non-human animal is deficient for an endogenous immune system and comprises:

(i) a nucleic acid sequence incorporated into the genome of the genetically modified non-human animal, which sequence encodes a human SIRP α protein and is operably linked to a SIRP α gene promoter,

(ii) a nucleic acid sequence incorporated into the genome of the genetically modified non-human animal, which sequence encodes a human IL-15 protein and is operably linked to an IL-15 gene promoter, and

(iii) an engraftment of human hematopoietic cells, wherein the genetically modified non-human animal expresses the human SIRP α protein and the human IL-15 protein;

contacting the isolated NK cell with the candidate therapeutic antibody or antigen-binding protein and the target cell; and

determining the antibody- or the antigen-binding protein-dependent cytolytic activity of the isolated NK cell against the target cell.

156. A method of screening a candidate therapeutic antibody or antigen-binding protein for improved efficacy in killing a target cell comprising:
administering the candidate therapeutic antibody or antigen-binding protein to a genetically modified non-human animal, wherein the genetically modified non-human animal is deficient for an endogenous immune system and comprises:

(i) a nucleic acid sequence incorporated into the genome of the genetically modified non-human animal, which sequence encodes a human SIRP α protein and is operably linked to a SIRP α gene promoter,

(ii) a nucleic acid sequence incorporated into the genome of the genetically modified non-human animal, which sequence encodes a human IL-15 protein and is operably linked to an IL-15 gene promoter, and

(iii) an engraftment of human hematopoietic cells, wherein the genetically modified non-human animal expresses the human SIRP α protein and the human IL-15 protein; and

determining whether the candidate therapeutic antibody or antigen-binding protein displays improved efficacy in killing the target cell in the genetically modified non-human animal.

157. The method of any one of 154-156, wherein the target cell is selected from the group consisting of a tumor cell, a virally-infected cell, a bacterially-infected cell, a bacterial cell, a fungal cell, and a parasitic cell.

158. A method of determining the efficacy a candidate therapeutic antibody or antigen-binding protein in NK-cell mediated killing of a target cell, comprising:

administering the candidate therapeutic antibody or antigen-binding protein to a genetically modified non-human animal, wherein the genetically modified non-human animal is deficient for an endogenous immune system and comprises:

(i) a nucleic acid sequence incorporated into the genome of the genetically modified non-human animal, which sequence encodes a human SIRP α protein and is operably linked to a SIRP α gene promoter,

(ii) a nucleic acid sequence incorporated into the genome of the genetically modified non-human animal, which sequence encodes a human IL-15 protein and is operably linked to an IL-15 gene promoter, and

(iii) an engraftment of human hematopoietic cells, wherein the genetically modified non-human animal expresses the human SIRP α protein and the human IL-15 protein; and

determining whether the candidate therapeutic antibody or antigen-binding protein modulates (e.g., activates) NK cell antibody-dependent cellular cytotoxicity against the target cell in the genetically modified non-human animal.

159. The method of 158, wherein the target cell is selected from the group consisting of a tumor cell, a virally-infected cell, a bacterially-infected cell, a bacterial cell, a fungal cell, and a parasitic cell.

160. The method of claim 159, wherein the target cell is a tumor cell.

161. The method of claim 160, wherein the tumor cell is a B-cell lymphoma cell.

162. A model of NK cell mediated antibody-dependent cellular cytotoxicity, comprising a genetically modified non-human animal, wherein the genetically

modified non-human animal is deficient for an endogenous immune system and comprises:

a nucleic acid sequence incorporated into the genome of the genetically modified non-human animal, which sequence encodes a human SIRP α protein and is operably linked to a SIRP α gene promoter;

a nucleic acid sequence incorporated into the genome of the genetically modified non-human animal, which sequence encodes a human IL-15 protein and is operably linked to an IL-15 gene promoter; and

an engraftment of human hematopoietic cells, wherein the genetically modified non-human animal (i) expresses the human SIRP α protein and the human IL-15 protein, (ii) comprises human lymphocytes, and (iii) comprises a target cell selected from the group consisting of a tumor cell, a virally-infected cell, a bacterially-infected cell, a bacterial cell, a fungal cell, and a parasitic cell.

- 163. The model of claim 162, wherein the target cell is a tumor cell.
- 164. The model of claim 163, wherein the tumor cell is a B-cell lymphoma cell.
- 165. The model of claim 163 or claim 164, wherein the model comprises an exogenous candidate therapeutic antibody or antigen-binding protein.
- 166. The model of any one of claims 162-165, wherein the genetically modified non-human animal comprises human intraepithelial lymphocytes (IELs) in the small intestine and Peyer's patches of the genetically modified non-human animal.
- 167. The model of any one of claims 162-166, wherein the genetically modified non-human animal comprises human intraepithelial lymphocytes (IELs) in the lung of the genetically modified non-human animal.

EXAMPLES

[000255] 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 present invention, and are not intended to limit the scope of what the inventors regard as their invention nor are they intended to represent that the experiments below are all or the only experiments performed. Efforts have been made to ensure accuracy with respect to numbers used (*e.g.* amounts, temperature, *etc.*) but some experimental errors and deviations should be accounted for. Unless indicated otherwise, parts are parts by weight, molecular weight is weight average molecular weight, temperature is in degrees Centigrade, and pressure is at or near atmospheric.

Example 1: Generation of Humanized SIRP α (SRG) Knock-In Mice

[000256] A human SIRP α knock-in mouse was generated, which expresses the extracellular domain of human SIRP α operably linked to the mouse SIRP α promoter (see FIG. 1). Human SIRP α is known to exist in at least 10 allelic forms. In this particular example, human SIRP α variant 1 is employed for humanizing an endogenous SIRP α gene of a mouse.

Materials and Methods

[000257] The generation of knock-in mice encoding human SIRP α into the Rag2^{-/-} Il2rg^{Y/-} 129xBalb/c (N2) genetic background was performed using VELOCIGENE® technology as described in greater detail below. The mice were maintained under specific pathogen-free conditions and with continuous treatment of enrofloxacin in the drinking water (Baytril; 0.27 mg/mL).

[000258] A targeting vector for humanization of an extracellular region of a SIRP (e.g., SIRP α) gene was constructed using VELOCIGENE® technology (see, e.g., U.S. Pat. No. 6,586,251 and Valenzuela et al. (2003) High-throughput engineering of the mouse genome coupled with high-resolution expression analysis, *Nature Biotech.* 21(6):652-659).

[000259] Briefly, mouse bacterial artificial chromosome (BAC) clone bMQ-261H14 was modified to delete the sequence containing exons 2 to 4 of an endogenous SIRP α gene and insert exons 2 to 4 of a human SIRP α gene using human BAC clone CTD-3035H21. The genomic DNA corresponding to exons 2 to 4 of an endogenous SIRP α gene (~8555 bp) was replaced in BAC clone bMQ-261H14 with a ~8581 bp DNA fragment containing exons 2 to 4 of a human SIRP α gene from BAC clone CTD-3035H21. Sequence analysis of the human SIRP α allele contained in BAC clone CTD-3035H21 revealed the allele to correspond to human variant 1. A neomycin cassette flanked by *loxP* sites was added to the end of the ~8581 bp human DNA fragment containing exons 2 to 4 of the human SIRP α gene (FIG. 1(bottom)).

[000260] Upstream and downstream homology arms were obtained from mouse BAC DNA at positions 5' and 3' of exons 2 and 4, respectively, and added to the ~8581 bp human fragment-neomycin cassette to create the final targeting vector for humanization of an endogenous SIRP α gene, which contained from 5' to 3' a 5' homology arm containing 19 kb of mouse DNA 5' of exon 2 of the endogenous

SIRP α gene, a ~8581 bp DNA fragment containing exons 2 to 4 of a human SIRP α gene, a neomycin cassette flanked by *loxP* sites, and a 3' homology arm containing 21 kb of mouse DNA 3' of exon 4 of an endogenous SIRP α gene. Targeted insertion of the targeting vector positioned the neomycin cassette in the fifth intron of a mouse SIRP α gene between exons 4 and 5. The targeting vector was linearized by digesting with *SwaI* and then used in homologous recombination in bacterial cells to achieve a targeted replacement of exons 2 to 4 in a mouse SIRP α gene with exons 2 to 4 of a human SIRP α gene (FIG. 1(bottom)).

[000261] The targeted BAC DNA (described above) was used to electroporate Rag2^{-/-} IL2rg^{Y/-} mouse ES cells to create modified ES cells including a replacement of exons 2 to 4 in an endogenous mouse SIRP α gene with a genomic fragment including exons 2 to 4 of a human SIRP α gene. Positive ES cells containing a genomic fragment including exons 2 to 4 of a human SIRP α gene were identified by quantitative PCR using TAQMAN™ probes (Lie and Petropoulos, 1998. *Curr. Opin. Biotechnology* 9:43-48). The nucleotide sequence across the upstream insertion point included the following, which indicates endogenous mouse sequence upstream of the insertion point (contained within the parentheses below) linked contiguously to a human SIRP α genomic sequence present at the insertion point:

(AGCTCTCCTACCACTAGACTGCTGAGACCCGCTGCTCTGCTCAGGACTCG
 ATTTCCAGTACACAATCTCCCTCTTTGAAAAGTACCACACATCCTGGGGT)
 GCTCTTGCATTTGTGTGACACTTTGCTAGCCAGGCTCAGTCCTGGGTTCCA
 GGTGGGGACTCAAACACACTGGCACGAGTCTACATTGGATATTCTTGGT
 (SEQ ID NO:1). The nucleotide sequence across the downstream insertion point at

the 5' end of the neomycin cassette included the following, which indicates human SIRP α genomic sequence contiguous with cassette sequence downstream of the insertion point (contained within the parentheses below with *loxP* sequence italicized):

GCTCCCCATTCCTCACTGGCCCAGCCCCTCTTCCCTACTCTTTCTAGCCCCT
 GCCTCATCTCCCTGGCTGCCATTGGGAGCCTGCCCCACTGGAAGCCAG(TC
 GAGATAACTTCGTATAATGTATGCTATACGAAGTTATATGCATGGCCTCCGCGC
 CGGGTTTTGGCGCCTCCCGCGGGCGCCCCCTCCTCACGGCGA) (SEQ ID

NO:2). The nucleotide sequence across the downstream insertion point at the 3' end of the neomycin cassette included the following, which indicates cassette sequence

contiguous with mouse genomic sequence 3' of exon 4 of an endogenous SIRP α gene (contained within the parentheses below):

CATTCTCAGTATTGTTTTGCCAAGTTCTAATTCCATCAGACCTCGACCTGC
AGCCCCTAGATAACTTCGTATAATGTATGCTATACGAAGTTATGCTAGC(T
GTCTCATAGAGGCTGGCGATCTGGCTCAGGGACAGCCAGTACTGCAAAGA
GTATCCTTGTTTCATACCTTCTCCTAGTGGCCATCTCCCTGGGACAGTCA)

(SEQ ID NO:3). Positive ES cell clones were then used to implant female mice using the VELOCIMOUSE® method (see, e.g., U.S. Pat. No. 7,294,754 and Poueymirou et al. 2007, F0 generation mice that are essentially fully derived from the donor gene-targeted ES cells allowing immediate phenotypic analyses, Nature Biotech. 25(1):91-99) to generate a litter of pups containing an insertion of exons 2 to 4 of a human SIRP α gene into an endogenous SIRP α gene of a mouse.

[000262] Targeted ES cells described above were used as donor ES cells and introduced into an 8-cell stage mouse embryo by the VELOCIMOUSE® method (supra). Mice bearing the humanization of exons 2 to 4 of an endogenous SIRP α gene were identified by genotyping using a modification of allele assay (Valenzuela et al., supra) that detected the presence of the human SIRP α gene sequences.

[000263] Mice bearing the humanized SIRP α gene construct (i.e., containing human SIRP α exons 2 to 4 in a mouse SIRP α gene) can be bred to a Cre deleter mouse strain (see, e.g., International Patent Application Publication No. WO 2009/114400) in order to remove any loxed neomycin cassette introduced by the targeting vector that is not removed, e.g., at the ES cell stage or in the embryo. Optionally, the neomycin cassette is retained in the mice. To obtain homozygous Sirp α mice heterozygotes are bred.

Results

[000264] Mice including a nucleic acid encoding a humanized version of the mouse SIRP α gene as described above (SRG mice) exhibit physiological expression of a humanized SIRP α protein (data not shown). These mice also exhibit human immune cell engraftment in the spleen, peripheral lymph nodes (LN) and thymus comparable to NOD scid gamma (NSG) mice (data not shown).

Example 2: Generation of Humanized SRG IL-15^{h/h} (SRG-15) Knock-In Mice

[000265] The cytokine IL-15 has been shown to be important for mouse NK cell development and memory CD8⁺ T cell differentiation and maintenance. To study the effects of human IL-15 on the development, differentiation and maintenance of human immune cells in the context of an animal model, human IL-15 human SIRP α knock-in mice were generated as described in greater detail below. FIG. 2 shows a schematic representation of the IL-15 knock-in construct.

Materials and Methods

[000266] Mouse ES cells were modified to replace mouse IL-15 gene sequence with human IL-15 gene sequence at the endogenous mouse IL-15 locus, under control of mouse IL-15 regulatory elements, using VELOCIGENE® genetic engineering technology, to produce a humanized locus as shown in FIG. 2. Knock-in mice comprising human IL-15 were generated on Rag2^{-/-} Il2rg^{Y/-} 129xBalb/c genetic background. FIG. 2 does not show upstream (with respect to direction of transcription of the IL-15 gene) the 5' untranslated exons of the mouse gene (exons 1 and 2); coding exon 1 (exon 3) of FIG. 2 shows a small untranslated region (unfilled) upstream of the coding exon. Except as discussed below for mouse 1, as shown in the humanization at the bottom of FIG. 2, mouse coding exons 1 and 2 (exons 3 and 4) were retained, whereas mouse coding exons 3 through 6 (exons 5-8) were replaced with human coding exons 3 through 6 (exons 5-8). At the downstream end, human coding exon 6 (exon 8) is followed by a stop codon and a human 3'-UTR, and further by human sequence found downstream of the human 3'UTR. For selection purposes, a selection cassette (floxed for removal by Cre) was included. The humanized locus of FIG. 2 expresses a mature IL-15 protein that is fully human.

[000267] Specifically, bacterial homologous recombination (BHR) was performed to construct a large targeting vector (LTVEC) containing sequences of the human IL-15 gene for targeting to the mouse IL-15 locus using standard BHR techniques (see, *e.g.*, Valenzuela *et al.* (2003), *supra*) and gap repair BHR. Linear fragments were generated by ligating PCR-generated homology boxes to cloned cassettes followed by gel isolation of ligation products and electroporation into BHR-competent bacteria harboring the target bacterial artificial chromosome (BAC). Mouse BAC PRCI23-203P7 is used as the source of mouse sequence; human BAC

RP11-103B12 is used as the source of human IL-15 gene sequence. Following a selection step, correctly recombined clones are identified by PCR across novel junctions, and by restriction analysis. An LTVEC containing homology arms and human IL-15 gene sequences was made.

[000268] The mouse IL-15 gene (mouse GeneID: 103014; RefSeq transcript: NM_008357.2; ensemble eID:16168) is modified by using genomic coordinates for deletion GRCM38: ch 8: 82331173-82343471 (minus strand); genomic coordinates for replacement GRCh37: ch4: 142642924-142655819 (plus strand). 12299 nucleotides of mouse sequence were replaced by 12896 nucleotides of human sequence. The replacement of mouse IL-15 sequence as described above is graphically presented in FIG. 2.

[000269] The LTVEC including the humanized IL-15 gene had about 13 kb of upstream mouse targeting arm flanked upstream with a MluI site, and a 27 kb downstream mouse targeting arm flanked downstream with an AscI site. The LTVEC was linearized with MluI and AscI for electroporation.

[000270] Following construction of the LTVEC, nucleotide sequence of the LTVEC across the mouse/human 5' junction, and human/mouse 3' junction is as shown in Table 1 below. **SEQ ID NO:4** depicts the upstream (with respect to direction of transcription of the IL-15 gene) junction between mouse sequence and human sequence; the sequence shown begins with mouse sequence in uppercase, followed by an AsisI restriction site in lowercase, followed by human IL-15 nucleic acid sequence in uppercase. **SEQ ID NO:5** indicates downstream human IL-15 coding and noncoding sequence in uppercase (human 3'UTR ***bolded italics***), followed by an XhoI site in lowercase, followed by a lox site (uppercase, ***bolded italics***), followed by sequence of the downstream neo selection cassette (uppercase), which extends 2.6 kb downstream (not shown). **SEQ ID NO:6** is a nucleic acid sequence that depicts the junction between the downstream portion of the neo selection cassette (uppercase), with lox site (uppercase and ***bolded italics***), followed by an NheI site (lowercase), which is followed by mouse sequence downstream of the humanization (uppercase); the selection cassette extends 2.6 kb further upstream.

Table 1: Junction Sequences of Humanized IL-15 Locus

SEQ ID NO	Sequence
SEQ ID NO:4	ATCCATTTAGCCTTTCTCTGATCACTAAGTTGGACAGTTGGA CAGTCTTCCTCAAATTAGCTTAGACTATCAAAATTATACTGT ATTTTTGGTATTTCCAgcgatcgcTTCAGTTACAAGGCTGTTGAA TGCACAGAAGCAAGGATAACACTGATTTTTTCACTGGTCAG AATAAAAATTATTGATTGCTCTTTTGCTTATAGTATTC
SEQ ID NO:5	AATGTAACAGAATCTGGATGCAAAGAATGTGAGGAACTGG AGGAAAAAATATTAAGAATTTTTGCAGAGTTTTGTACAT ATTGTCCAAATGTTTCATCAACACTTCTTGATTGCAATTGATT <i>CTTTTAAAGTGTTTCTGTTATTAACAAACATCACTCTGCTG</i> <i>CTTAGACATAACAAACACTCGGCATTTCAAATGTGCTGTCA</i> <i>AAACAAGTTTTTCTGTCAAGAAGATGATCAGACCTTGGATCA</i> <i>GATGAACTCTTAGAAATGAAGGCAGAAAAATGTCATTGAGTA</i> <i>ATATAGTGACTATGAACTTCTCTCAGACTTACTTTACTCATTT</i> <i>TTTAAATTTATTATTGAAATTGTACATATTTGTGGAATAATGT</i> <i>AAAATGTTGAATAAAAAATATGTACAAGTGTTGTTTTTAAAGTT</i> <i>GCACTGATATTTTACCTCTTATTGCAAAATAGCATTTGTTTAA</i> <i>GGGTGATAGTCAAATTATGTATTGGTGGGGCTGGGTACCAAT</i> <i>GCTGCAGGTCAACAGCTATGCTGGTAGGCTCCTGCCAGTGTG</i> <i>GAACCACTGACTACTGGCTCTCATTGACTTCCTTACTAAGCAT</i> <i>AGCAAACAGAGGAAGAATTTGTTATCAGTAAGAAAAAGAAGA</i> <i>ACTATATGTGAATCCTCTTCTTTATACTGTAATTTAGTTATTG</i> <i>ATGTATAAAGCAACTGTTATGAAATAAAGAAATTGCAATAACT</i> <i>GGCATATAATGTCCATCAGTAAATCTTGGTGGTGGTGGCAA</i> <i>TAATAAACTTCTACTGATAGGTAGAATGGTGTGCAAGCTTG</i> <i>TCCAATCACGGATTGCAGGCCACATGCGGCCCAGGACAAC</i> <i>TTGAATGTGGCCCAACACAAATTCATAAACTTTCATACATCT</i> <i>CGTTTTTAGCTCATCAGCTATCATTAGCGGTAGTGTATTTAA</i> <i>AGTGTGGCCCAAGACAATTCTTCTTATTCCAATGTGGCCCA</i> <i>GGGAAATCAAAAGATTGGATGCCCCTGGTATAGAAAATA</i> <i>ATAGTGACAGTGTTTCATATTTTCATGCTTTCCCAAATACAGGT</i>

Table 1 Cont. SEQ ID NO:5 Cont.	ATTTTATTTTCACATTCTTTTTGCCATGTTTATATAATAATAA AGAAAAACCCTGTTGATTTGTTGGAGCCATTGTTATCTGAC AGAAAATAATTGTTTATATTTTTTGCCTACACTGTCTAAAA TTAGCAAGCTCTCTTCTAATGGAAGTGTAAAGAAAGATGAAA TATTTTTGTTTTATTATAAAATTTATTTTACCTTAATTCTGGTA ATACTCACTGAGTGACTGTGGGGTGGGAAATGATCTCTTAA GAATTTGATTTCTTTCTATTCCATAGTACAAACTCGTTCTCT GTTGAAACATTCTTCTATCACCCAGTGCCCTATCCATGTAC ATGTGTTCTTATTGCTCTAGTCAAACGGTGCTTATAAATATC TTTCAGAAAGTTTAGGAGAAATCTGTATCCTATTTGACTTCC AATAATCATGTATTGGCTGTCAGCTTCTTACCTACTCTCAGT CCAGAGAAATAGTATTTGGCAGCCACTCTTTAAAGTTTATG GGTTGTGGATTGTGGCGGTTGATTTATTTTTTTTATTTCAATT GGGATAGAATTTTTTAATATACCTGTATTTTTGTTTTGTTTTA TGTAGCTTTTCTATTAGGGAGAGTAGGAAAAGTGCACCATT TTCTTCTCTAAATTTCCAGTCCAGTCTTTAGGGGAATGTTAG TCTTCCTGAGATGGGGGAAGGAAAATCATAATGCCAGTCAC TTTGCAAATAATATTTTATAGTGATAAATGGTTCATTTTGGT TACATAGGCATACAAGTGGGCTTAAAACTTGGAATTTACCA GGGCTCAAATTAATAATTCTTACATTAGTTACTCGATATGG ATCGCTTCAGTTGATCTTAGAAAACTCAAGGCATAGATCTG CAACcctcgag ATAACTTCGTATAATGTATGCTATACGAAGTTATA TGCATGGCCTCCGCGCCGGGTTTTGGCGCCTCCCGCGGGCG CCCCCCTCCTCACGGCG
SEQ ID NO:6	CATTCTCAGTATTGTTTTGCCAAGTTCTAATTCCATCAG ACCTCGACCTGCAGCCCCTAG ATAACTTCGTATAATGT ATGCTATACGAAGTTAT _{gctagc} GTGATAGTCCTTCACG GAAAGTACAAGAATACACAGAAACTGCTGTTTACATT AGTCTTTCACGTTTTTATTTTATTCTCACAAATTTAATGCAA TAC

[000271] Mouse ES cells were electroporated with the LTVEC constructs, grown on selection medium, and used as donor ES cells to make humanized IL-15

mice including a replacement at the endogenous mouse IL-15 locus with human sequence as depicted in FIG. 2. Following electroporation of the ES cell, a loss of native allele assay (see, e.g., *Valenzuela et al.* (2003), *supra*) is performed to detect loss of endogenous IL-15 sequence due to the targeting.

[000272] Correctly targeted ES cells were further electroporated with a transient Cre-expressing vector to remove the Neo drug selection cassette.

[000273] Donor mouse ES cells including a humanized IL-15 locus were introduced into early stage mouse embryos by the VELOCIMOUSE® method (Poueymirou *et al.* (2007) F0 generation mice fully derived from gene-targeted embryonic stem cells allowing immediate phenotypic analyses, *Nat Biotechnol* 25:91-99). Heterozygous mice were obtained, and heterozygotes were bred to obtain homozygotes with respect to humanized IL-15. Two versions of humanized IL-15 mice were generated (referred to herein as mouse 1 and mouse 2). Following further analysis, the mouse 1 version was found to contain an exon duplication in its genome. In mouse 2 the endogenous mouse IL-15 locus was replaced with human sequence as depicted in FIG. 2.

[000274] Human IL-15mRNA levels were determined as follows. Reverse transcription (RT)-qPCR was performed using a 7500 Fast Real-Time PCR System (Applied Biosystems) and a SYBR® FAST universal qPCR kit (KAPA Biosystems). Sequence-specific oligonucleotide primers were designed using Primer3 software and synthesized by Sigma-Aldrich. The following primers were used: mouse *Hprt* forward: 5'-AGGGATTGGAATCACGTTTG-3'(SEQ ID NO:7), mouse *Hprt* reverse: 5'-TTTACTGGCAACATCAACAG-3'(SEQ ID NO:8); human *Il15* forward: 5'-GCCCAGGGAAATCAAAAGAT-3'(SEQ ID NO:9), human *Il15* reverse: 5'-TGGCTCCAACAAATCAACAG-3'(SEQ ID NO:10). Relative expression values were calculated using the comparative threshold cycle method and normalized to mouse *Hprt*.

[000275] SRG-15 mice are generated either by (1) breeding mice comprising human SIRPα replacement to mice comprising human IL-15 replacement, both on Rag2^{-/-} Il2rg^{Y/-} background, or by (2) introducing a large targeting vector comprising human IL-15 into an ES cell harboring human SIRPα replacement on Rag2^{-/-} Il2rg^{Y/-} background (described in Example 1) and generating mice from ES cells harboring both human IL-15 and SIRPα gene replacements as well as Rag2^{-/-} Il2rg^{Y/-} using the

VELOCIMOUSE® method. Heterozygous mice are bred to homozygosity.

Results

[000276] As illustrated in FIGs. 3A and 3B, high levels of expression of human IL-15 mRNA were found in the liver, lung, bone marrow (BM), small intestine (SI) and colon of non-engrafted SRG-15 mouse 1. Similarly high levels of human IL-15 mRNA were found in the liver, lung and small intestine of non-engrafted SRG-15 mouse 2 (FIG. 3B). As shown in FIG. 4, upon stimulation by poly (I:C), high levels of human IL-15 protein could also be detected in the serum of SRG-15 mouse 2, wherein human exons 5-8 replace the endogenous mouse exons.

Example 3: Engraftment of SRG-15 Mice

Materials and Methods

[000277] SRG and SRG-15 mice are engrafted as described below. Neonate mice are irradiated sub-lethally without anesthesia 3-5 days post birth with 160cGy and returned to their mothers for rest. 4-12 hours post irradiation these neonates are transplanted with CD34⁺ huHSCs in 25 µl PBS intrahepatically (i.h.) using a 30G needle.

Results

[000278] To assess the impact of human IL-15 on immune cell development, human CD45⁺ cell engraftment in NSG, SRG and SRG-15 mice was compared. Efficient engraftment of human hematopoietic cells in the blood of NSG, SRG and SRG-15 (mouse 2) mice was seen 12-14 weeks post engraftment as shown in FIG. 5A. A comparison showing engraftment as evidenced by human CD45⁺ cell numbers in the BM, spleen, LN, liver and lung of SRG and SRG-15 (mouse 2) 14 weeks post engraftment is provided in FIG. 5B.

[000279] In mouse 1, although human CD45⁺ cell engraftment was not different, a higher percentage and number of human NK cells was found in various tissues in SRG-15 mice compared to SRG mice, as illustrated by FIGS. 6A and 6B. IL-15 is not only important for NK cell development and survival but also for their maturation. As shown in FIG. 6C, human NK cells in the liver of SRG-15 mice (mouse 1) had a higher expression level of CD16 and CD56, indicating increased NK cell maturation in SRG-15 mice compared to SRG mice. Both human NK cell subsets, CD56^{bright}CD16⁻ and CD56^{dim}CD16⁺, were found to be present in the blood, spleen

and liver of SRG-15 mice, as shown in FIG. 6D (spleen) (and data not shown). In addition, as shown in FIG. 6D, analysis of the two human NK cell subsets in the spleen of SRG-15 mice (mouse 1) showed that they had a distinct expression level of killer inhibitory receptors, with the CD56^{dim}CD16⁺ NK cell population including the higher percentage of CD158-expressing cells. This resembles what is found for NK cell subsets in the blood of humans (data not shown).

[000280] For SRG-15 mouse 2, efficient human NK cell engraftment in lymphoid and non-lymphoid tissues was seen as shown in FIGs. 7A – 7D. FIGs. 7A and 7B show percentage of NK cells in blood and spleen, respectively. FIGs. 7C and 7D show the frequency of human NK cells in the blood, spleen (SP), liver and lung of SRG and SRG-15 (mouse 2) mice 14 weeks post engraftment. Additional data showing NK cell distribution and percentage in blood and spleen of SRG and SRG-15 (mouse 2) mice from different experiments is provided in FIGs. 8 and 9A respectively. An increase in the hNKp46 fragment of hCD45⁺ cells in the blood of SRG-15 mice (mouse 2) is shown in FIG. 9B. FIGs. 9C – 9E show relative numbers, distribution and composition of hCD45⁺ cells in the thymus of SRG and SRG-15 (mouse 2) mice.

[000281] The NK cell subsets in humans and SRG-15 mice (mouse 2) were characterized. As shown in FIGs. 10A and 10B, increased levels of both hCD56^{bright} hCD16⁻ and hCD56^{dim} hCD16⁺ were seen in the blood and spleen of SRG-15 mice relative to SRG mice. As in human, expression of killer inhibitory receptors (KIRs) was seen on NK cell subsets in SRG-15 mice (mouse 2) (FIG. 10C). FIG. 10C shows CD56^{bright} CD16⁻ NK cells (left box for each plot) and CD56^{dim} CD16⁺ NK cells (right box for each plot). The histogram below shows CD158 expression in those subsets. CD158 (KIR2D) on NK cell subsets in SRG-15 mice is similar to what is observed in human PBMC-derived NK cells.

[000282] Human NK cell distribution in the blood of SRG-15 mice was compared to that of blood obtained from two healthy human donors. Peripheral blood mononuclear cells (PBMCs) were isolated from buffy coats of two individual donors (obtained from BioreclamationIVT, Westbury, NY) over Ficoll-Paque; although greater percentage of blood NK cells was observed in engrafted SRG-15 mice than in PBMCs from human donors, a physiologically comparable distribution of cytotoxic (CD16⁺) NK cells versus IFN-g producing (CD16⁻) NK cells was observed (FIG. 11).

[000283] Finally, an analysis of the bone marrow of SRG and SRG-15 (mouse

2) showed increased human NK cell development in SRG-15 mice relative to SRG mice (FIG. 12).

[000284] The impact of human IL-15 on human T cell development in SRG-15 mice was also assessed. A comparison of SRG-15 (mouse 1) mice relative to SRG mice showed that the effect of human IL-15 on the percentage, number and/or ratio of T cells varied depending on the tissue (FIG. 13A). The size and number of lymph nodes at week 16 post engraftment did not differ between SRG and SRG-15 mice, confirming the results that the numbers of human T cells in the lymph nodes of SRG and SRG-15 (mouse 1) mice were similar (FIG. 13A). FIG. 13B shows a human CD8⁺ T cell phenotype in blood and liver for SRG and SRG-15 mice (mouse 1), with an increase in hCD62L⁻ cells in SRG-15 mice (mouse 1) relative to SRG mice for both blood and liver. Additional data characterizing the T cells of the SRG-15 mice (mouse 1) relative to the SRG mice is provided in FIGs. 14A and 14B, which shows expression of the tissue-resident marker CD69 in the CD8⁺ T cells of lung (14A) and liver (14B) of SRG and SRG-15 mice. The above data provides evidence of an increase in effector tissue-resident T cells in SRG-15 mice.

[000285] For mouse 2, the frequency of hCD3⁺ T cells in the spleen, lung and liver relative to SRG mice was assessed 16 weeks post engraftment, as shown in FIGs. 15A and 15B.

Example 4: Development of Human Tissue-Resident Lymphocytes in SRG-15 Mice

[000286] Because IL-15 has been shown to be produced by epithelial cells in the gut and the lung and may play an important role for the development and survival of human tissue-resident T and NK cells, human tissue-resident T and NK cells were analyzed in SRG and SRG-15 mice.

Materials and Methods

[000287] Neonate mice are irradiated sub-lethally without anesthesia 3-5 days post birth with 160cGy and returned to their mothers for rest. 4-12 hours post irradiation these neonates are transplanted with CD34⁺ huHSCs in 25 μ l PBS intrahepatically (i.h.) using a 30G needle.

Results

[000288] As shown in FIG. 17A, isolation of the intraepithelial lymphocyte

population from the small intestine during steady state conditions in mouse 1 revealed a higher frequency of human CD45⁺ cells in SRG-15 mice compared to SRG mice. Immunohistochemical analysis, as illustrated in FIG. 17B, demonstrated that the human CD45⁺ NK cells were located in the epithelial cell layer of the small intestine of SRG-15 mice (mouse 1) (as designated by the arrows in FIG. 17B), while very few intraepithelial lymphocytes were found in SRG mice. Human CD8⁺ IELs in SRG-15 mice showed high expression of CD69, the typical marker of tissue-resident T cells. In contrast to human IELs (Sathaliyawala T, Kubota M, Yudanin N *et al. Immunity* 2013; 38:187-197), only a subpopulation of human CD8⁺ IELs in the SRG-15 mice expressed the tissue-resident marker CD103 (FIG. 17C). As shown in FIGS. 16A and 16B, the phenotype of increased human CD8⁺ IELs in SRG-15 mice (mouse 1) was specific as there was little difference in the number of lamina propria cells in the colon during steady state between SRG and SRG-15 mice. In addition to the increased number of human T cells in the lung of SRG-15 mouse 1 as shown in FIG. 13A, higher expression of CD69 on human CD8⁺ T cells in the lung of SRG-15 mice compared to SRG mice was also found as shown by FIG. 14A. In addition, FIG. 14B shows a higher level of hCD69 expressing CD8⁺ T cells in the liver of SRG-15 mouse 1 compared to the SRG mouse.

[000289] Similar to the SRG-15 engrafted mouse 1, in SRG-15 engrafted mouse 2, FACS analysis revealed a higher proportion of human CD45⁺ cells in the IEL fraction of SRG-15 mice compared to SRG mice (FIG. 18A). In addition, while the number of LPLs was not significantly changed between SRG and SRG-15 (mouse 2) mice, a significant increase in IELs was seen in SRG-15 (mouse 2) mice relative to SRG mice (FIG. 18B). The composition of hCD3⁺ cells in the small intestine of SRG-15 mice (mouse 2) is provided in FIG. 18C and shows a greater proportion of hCD8⁺ relative to hCD4⁺ cells. The phenotypic characteristics of hCD3⁺ hCD8⁺ T cells in the spleen and small intestine of SRG-15 mice (mouse 2) are provided in FIG. 18D. Immunohistochemical analysis, as illustrated in FIG. 18E, demonstrated that the human CD8⁺ IELs were located in the epithelial cell layer of the small intestine of SRG-15 mice (mouse 2) (as designated by the arrows in FIG. 18E), while very few intraepithelial lymphocytes were found in SRG mice.

[000290] As discussed above with respect to FIGs. 18A and 18B, in SRG-15 engrafted mouse 2, greater gut-associated lymphoid tissue (GALT) resident intraepithelial human lymphocyte reconstitution (IELs) was observed compared to

SRG mice (FIG. 19A and 19C). Interestingly, the majority of the human lymphocytes observed were human NK cells. As expected for normal human GALT physiology, the majority of NK cells in the SRG-15 mouse 2 in both blood and spleen were cytotoxic NK cells (CD16⁺), while in IEL, there was a comparable distribution of CD16⁺ versus CD16⁻ NK cells (FIG. 19B). There were no changes in the number of lamina propria lymphocytes between the engrafted SRG and SRG-15 mice (FIG. 19C). Unlike engrafted SRG-15 mouse 1, in engrafted SRG-15 mouse 2 a greater proportion of human CD3⁺ CD8⁺ IELs expressed human CD103 marker. Peyer's patches were completely absent in SRG mice but they were present in the SRG-15 mouse 2 and were populated with human lymphocytes as shown in FIG. 20A and 20B.

Example 5: Determining the Functional Role of Human Tissue-Resident T Cells in SRG-15 Mice During Viral Infections

[000291] To test whether tissue-resident T cells in SRG-15 mice have a functional relevance during homeostasis, it was determined whether the increased number of human CD8⁺ IELs in SRG-15 mice induces characteristic changes in the composition of the mouse gut microbiota.

Materials and Methods

[000292] Neonate mice are irradiated sub-lethally without anesthesia 3-5 days post birth with 160cGy and returned to their mothers for rest. 4-12 hours post irradiation these neonates are transplanted with CD34⁺ huHSCs in 25 μ l PBS intrahepatically (i.h.) using a 30G needle.

[000293] Four weeks post engraftment, SRG-15 mice were cohoused for four weeks with SRG and donor Balb/c mice to equalize the gut microbiota between the different strains. The mice were then separated and fecal samples were collected and analyzed by 16S rRNA sequencing. FIG. 21A provides a timeline for cohousing and feces sample collection for gut microbiota sequencing.

Results

[000294] As illustrated in 21B, for mouse 1, the results show that there were no significant changes between engrafted SRG-15 and SRG mice after cohousing, indicating that the developing human CD8⁺ IELs do not induce major changes during steady state conditions. Additional experiments were conducted to determine whether

CD8⁺ IELs, which are sufficient to clear acute rotavirus infection, can clear rotavirus infection in engrafted SRG-15 mice. As shown in FIG. 22, the results indicated that acute rotavirus infection can be cleared in engrafted SRG-15 mice but not in non-engrafted SRG mice.

Example 6: Analysis of NK cell subsets in SRG-15 mice (mouse 2) and humans

[000295] NK cell subsets in SRG-15 (mouse 2) mice were characterized for various phenotypic markers and compared with humans.

Materials and Methods

[000296] NK cell subsets were detected via Cytometry by Time-of-Flight (CyTOF), as described generally in Yao et al. *J. of Immunological Methods* 415 (2014) 1-5, and analyzed using ViSNE (el-AD et al. *Nat. Biotechnol.* 2013 Jun; 31(6):545-52doi: 10.1038/nbt.2594. Epub 2013 May 19.

Results

[000297] FIG. 23A provides ViSNE plots showing CyTOF-based analysis of 33 parameters of CD56^{bright} CD16⁻ and CD56^{dim} CD16⁺ NK cell subsets in humans (n=20) and SRG-15 mice (mouse 2) (n=9). Each dot represents a single cell.

[000298] FIG. 23B provides ViSNE plots showing the expression intensity of eight selected markers on CD56^{bright} CD16⁻ NK cells in humans (n=20) and SRG-15 mice (mouse 2) (n=9).

[000299] FIG. 23C ViSNE plots showing the expression intensity of eight selected markers on CD56^{dim} CD16⁺ NK cells in humans (n=20) and SRG-15 mice (n=9). This multi-dimensional single-cell analysis of 33 key molecules of human NK cells indicate that the human NK cells that develop in SRG-15 mice are highly comparable to human NK cells in healthy individuals.

Example 7: Cytotoxic Capacity of NK Cells from SRG-15 mice

Materials and Methods

[000300] For *in vitro* NK cytotoxicity studies, isolated splenic NK cells from human HSC-engrafted SRG and SRG-15 mice (mouse 2) were treated overnight with human IL-2. The next day, NK cells were cultured with CFSE-labeled, NK-susceptible K562 target cells at varying effector to target ratios (E:T). After 5hr co-culture, killing of K562 cells was measured by FACS analysis of viability dye Topro3 uptake by K562 cells (gated on CFSE⁺ cells to distinguish K562 and then analysis of

percent positive for Topro3).

[000301] Additionally, for *in vitro* antibody-dependent cellular cytotoxicity (ADCC) studies, isolated splenic NK cells from human HSC-engrafted SRG and SRG-15 mice were treated overnight with human IL-2. The next day, NK cells were cultured with CFSE-labeled Raji target cells at varying effector to target ratios (E:T). Raji cells were pre-treated with anti-CD20 (Rituximab) or control IgG. After 5hr co-culture, killing of Raji cells was measured by FACS analysis of viability dye Topro3 uptake by Raji cells (gated on CFSE+ cells and then analysis of percent positive for Topro3).

[000302] For *in vivo* NK cell activation studies, human HSC-engrafted SRG and SRG-15 mice (mouse 2) were injected intra-peritoneally with 50µg poly IC. Mice were pre-bled (before poly IC injection) and 18 hours after poly IC injection. Human CD45+ NKp46+ (NK cells) were analyzed for activation marker CD69 expression by FACS pre- and post-poly IC administration.

Results

[000303] In a classical NK cytotoxicity study, classical NK target HLA class I deficient K562 cells were subject to killing by activated NK cells from SRG or SRG-15 mice (mouse 2). As shown in FIG. 24C (left) splenic NK cells from SRG and SRG-15 mice showed comparable cytolytic capacity with respect to K562 cells when normalized for number.

[000304] NK cells are typically responsible for anti-CD20 antibody mediated ADCC against B cell leukemias and lymphomas (*see, e.g., J. Golay et al. Haematologica* 2003; 88:1002-12). In order to demonstrate the ability of NK cells from SRG-15 engrafted mice to facilitate anti-CD20 mediated ADCC, splenic NK cells from both SRG and SRG-15 mice were tested and shown to exhibit comparable antibody-dependent cellular toxicity (ADCC) activity against anti-CD20 treated Raji cells when normalized for cell number (FIG. 24C (right)).

[000305] As depicted, e.g., in FIGs. 8 and 9, there is a significant upregulation of NK cells in both spleen and blood of SRG-15 animals. The capacity for activation of NK cells in SRG-15 mice was tested by measuring CD69 marker activation after a poly-IC injection. As shown in FIG. 24A, the percentage of NK cells positive for the activation marker CD69 was increased in SRG-15 mice relative to SRG mice. As SRG-15 NK cells were shown to mediate ADCC comparable to SRG NK cells *in vitro* under normalized conditions, the ability of SRG-15 NK cells to exhibit a greater

activated phenotype *in vivo*, as well as greater numbers of NK cells in SRG-15 mice, suggests that SRG-15 mice may be a suitable *in vivo* model to study human NK cell ADCC.

Example 8: IFN γ production from SRG and SRG-15 derived NK cells

Materials and Methods

[000306] NK cells were isolated from pooled splenocytes of SRG or SRG-15 mice (3 spleens per group) and NK cells were isolated using EasySep Human NK enrichment kit (StemCell Technologies; Cat #19055).

[000307] NK cells were also isolated from healthy human PBMCs. NK cells were treated overnight with 10ng/mL human IL-2. The next day, cells were stimulated overnight with 10ng/mL human IL-12p70 or 2mg/mL poly I:C or left untreated. The next day, supernatant was harvested and IFN γ levels assessed using Human IFN γ Quantikine ELISA kit (R&D systems; Cat # DIF50). NK cell purity was analyzed by FACS and IFN γ levels normalized as picograms (pg) produced by individual NK cells. Statistical analysis was performed using ANOVA test.

Results

[000308] As shown in FIG. 24B, SRG and SRG-15 derived NK cells have comparable IFN γ secretion, but less than human PBMC-derived NK cells upon IL-12p70 treatment.

Example 9: Human NK Cells Inhibit Tumor Growth in SRG-15 Mice

[000309] The ability of human NK cells to infiltrate human tumor xenographs and inhibit tumor growth in SRG-15 mice (mouse 2) was tested.

Materials and Methods

[000310] Rituximab was injected i.p. every other day (started at day 14 post s.c. injection of 5 million Raji cells). Tumor growth was assessed by caliper measurement and the volume was calculated using the following formula: tumor volume = $0.5 \times (\text{length} \times \text{width}^2)$. Data were pooled from 2 independent experiments. Statistical analysis was performed using unpaired, two-tailed Mann-Whitney *U*-test comparing engrafted, untreated SRG-15 and engrafted, RTX-treated SRG-15 mice (* $P < 0.05$).

[000311] The s.c. tumor was crushed and digested using Collagenase D (1 hour, 37 C). The recovered cells, including tumor and immune cells were analyzed by an LSRII flow cytometer.

Results

[000312] As shown in FIG. 25A, human NK cells in SRG-15 mice inhibit tumor growth following treatment with rituximab (RTX). FIG. 25B, shows the frequency of human NK cells and T cells in human tumor xenografts of untreated (n=5) and RTX-treated SRG-15 mice (n=1). FIG. 25C, shows human NK cell subsets in the blood and tumor of untreated (n=2) and RTX-treated SRG-15 mice (n=1).

Example 10: Additional Materials and Methods Utilized in Connection with the Above Examples

[000313] Human CD34⁺ cell isolation and injection. Human CD34⁺ cell isolation and injection was performed according to the methods described, for example, in Rongvaux A, Willinger T, Martinek J *et al. Nat Biotechnol* 2014; **32**:364-372.

[000314] Flow cytometric analysis of human cell populations. Flow cytometric analysis of human cell populations was performed as described in Strowig T, Rongvaux A, Rathinam C *et al. Proc Natl Acad Sci U S A* 2011; **108**:13218-13223, and in Rongvaux A, Willinger T, Martinek J *et al. Nat Biotechnol* 2014; **32**:364-372.

[000315] Histology. Tissue was fixed overnight in 4% paraformaldehyde, transferred to 70% ethanol and embedded in paraffin.

[000316] Quantitative RT-PCR. Quantitative RT-PCR was performed as described in Rongvaux A, Willinger T, Martinek J *et al. Nat Biotechnol* 2014; **32**:364-372.

[000317] 16S rRNA sequencing. 16S rRNA sequencing was performed as described in Palm NW, de Zoete MR, Cullen TW *et al. Cell* 2014; **158**:1000-1010.

[000318] Viral infections. Rotavirus and influenza virus were obtained and applied in the subject methods.

[000319] Statistical analysis. Statistical significance was performed with Prism 6 software (GraphPad), using two-tailed unpaired Student's *t*-test.

[000320] FACS antibodies were obtained BD Biosciences and BioLegend.

[000321] The preceding merely illustrates the principles of the invention. It will be appreciated that those skilled in the art will be able to devise various arrangements which, although not explicitly described or shown herein, embody the principles of the invention and are included within its spirit and scope. Furthermore, all examples

and conditional language recited herein are principally intended to aid the reader in understanding the principles of the invention and the concepts contributed by the inventors to furthering the art, and are to be construed as being without limitation to such specifically recited examples and conditions. Moreover, all statements herein reciting principles, aspects, and embodiments of the invention as well as specific examples thereof, are intended to encompass both structural and functional equivalents thereof. Additionally, it is intended that such equivalents include both currently known equivalents and equivalents developed in the future, i.e., any elements developed that perform the same function, regardless of structure. The scope of the present invention, therefore, is not intended to be limited to the exemplary embodiments shown and described herein. Rather, the scope and spirit of present invention is embodied by the appended claims.

ADDITIONAL SEQUENCE INFORMATION

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ACCESSION	NM_001040022
VERSION	NM_001040022.1 GI:91105763
SOURCE	Homo sapiens (human)

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[SEQ ID NO:12]

Translation = MEPAGPAPGRLGPLLCLLLAASCAWSGVAGEEELQVIQPKSVL
VAAGETATLRCTATSLIPVGPIQWFRGAGPGRELIYNQKEGHFPRVTTVSDLTKRNNM
DFSIRIGNITPADAGTYCYVKFRKGSPPDVEFKSGAGTELSVRAKPSAPVVS GPAARA
TPQHTVSFTCESHGFSRPDITLKWFKNGNELSDFQTNVDPVGESVSYSIHSTAKVVL
REDVHSQVICEVAHVTLQGDPLRGTANLSETIRVPPTLEVTQQPVRAENQVNVTCQVR
KFYPQRLQLTWLENGNVSRTEASTVTENKDGTYNWMSWLLVNVSAHRDDVKLTCQVE
HDGQPAVSKSHDLKVS AHPKEQGSNTAAENTGSNERNIYIVGVVCTLLVALLMAALY
LVRIRQKKAQGSTSSTRLHEPEKNAREITQDTNDITYADLNLPKGKKPAPQAAEPNNH
TEYASIQTSPPASEDTLTYADLDMVHLNRTPKQPAPKPEPSFSEYASVQVPRK

LOCUS	NM_080792 3868 bp mRNA linear PRI 15-MAR-2015
DEFINITION	Homo sapiens signal-regulatory protein alpha (SIRPA), Transcript variant 3, mRNA.
ACCESSION	NM_080792 NM_004648
VERSION	NM_080792.2 GI:91105786
SOURCE	Homo sapiens (human)

[SEQ ID NO:14]

1 cgctcgctcg cagagaagcc gcggcccatg gagcccgccg gcccgggccc
cggcgcctc

61 gggccgctgc tctgcctgct gctcgccgcg tcttgcgcct ggtcaggagt
ggcgggtgag

121 gaggagctgc aggtgattca gcctgacaag tccgtgttgg ttgcagctgg
agagacagcc

181 actctgcgct gcactgcgac ctctctgac cctgtggggc ccatccagtg
gttcagagga

241 gctggaccag gccgggaatt aatctacaat caaaaagaag gccacttccc
ccgggtaaca

301 actgtttcag acctcacaaa gagaaacaac atggactttt ccatccgcat
cggtaacatc

361 accccagcag atgccggcac ctactactgt gtgaagttcc ggaaaggag
ccccgatgac

421 gtggagttta agtctggagc aggcactgag ctgtctgtgc gcgccaaacc
 ctctgcccc

481 gtggtatcgg gccctgcggc gagggccaca cctcagcaca cagtgaagctt
 cacctgcgag

541 tcccacggct tctcaccag agacatcacc ctgaaatggt tcaaaaatgg
 gaatgagctc

601 tcagacttcc agaccaacgt ggaccccgta ggagagagcg tgcctacag
 catccacagc

661 acagccaagg tgggtgctgac ccgcgaggac gttcactctc aagtcatctg
 cgaggtggcc

721 cacgtcacct tgcaggggga ccctcttcgt gggactgcca acttgtctga
 gaccatccga

781 gttccacca cttggaggt tactcaacag cccgtgaggg cagagaacca
 ggtgaatgtc

841 acctgccagg tgaggaagtt ctacccccag agactacagc tgacctggtt
 ggagaatgga

901 aacgtgtccc ggacagaaac ggctcaacc gttacagaga acaaggatgg
 tacctacaac

961 tggatgagct ggctcctggt gaatgtatct gccacaggg atgatgtgaa
 gctcacctgc

1021 caggtggagc atgacgggca gccagcggtc agcaaaagcc atgacctgaa
 ggtctcagcc

1081 cccccgaagg agcagggctc aaataccgcc gctgagaaca ctggatctaa
 tgaacggaac

1141 atctatatattg tgggtgggtgt ggtgtgcacc ttgctggtgg ccctactgat
 ggcggccctc

1201 tacctcgtcc gaatcagaca gaagaaagcc cagggctcca cttcttctac
 aaggttgcat

1261 gagcccgaga agaatgccag agaaataaca caggacacaa atgatatcac
 atatgcagac

1321 ctgaacctgc ccaaggggaa gaagcctgct cccagggctg cggagcccaa
 caaccacag

1381 gagtatgcca gcattcagac cagcccgcag cccgcgtcgg aggacaccct
 cacctatgct

1441 gacctggaca tgggtccact caaccggacc cccaagcagc cggcccccaa
 gcctgagccg

1501 tccttctcag agtacgccag cgtccaggtc ccgaggaagt gaatgggacc
 gtggtttgct

1561 ctagcaccca tctctacgcg ctttcttgtc ccacagggag ccgccgtgat
 gagcacagcc

1621 aaccaggttc ccggagggct ggggcggtgc aggtctctggg acccaggggc
 caggggtggct
 1681 cttctctccc caccctcct tggctctcca gcacttctg ggcagccacg
 gccccctccc
 1741 ccacattgc cacatacctg gaggtgacg ttgccaaacc agccagggaa
 ccaacctggg
 1801 aagtggccag aactgcctgg ggtccaagaa ctcttggtgcc tccgtccatc
 accatgtggg
 1861 ttttgaagac cctcgactgc ctccccgatg ctccgaagcc tgatcttcca
 ggggtggggag
 1921 gagaaaatcc cacctcccct gacctccacc acctccacca ccaccaccac
 caccaccacc
 1981 accactacca ccaccacca actggggcta gagtggggaa gatttcccct
 ttagatcaaa
 2041 ctgccccttc catggaaaag ctggaaaaaa actctggaac ccatatccag
 gcttggtgag
 2101 gttgctgcca acagtcctgg cctcccccat ccctaggcta aagagccatg
 agtcctggag
 2161 gaggagagga cccctcccaa aggactggag acaaaaccct ctgcttcctt
 gggtcctcc
 2221 aagactccct ggggcccac tgtgttgctc caccggacc catctctccc
 ttctagacct
 2281 gagcttgccc ctccagctag cactaagcaa catctcgctg tggacgcctg
 taaattactg
 2341 agaaatgtga aacgtgcaat cttgaaactg aggtgttaga aaacttgatc
 tgtggtgttt
 2401 tgttttggtt tttttcttaa aacaacagca acgtgatctt ggctgtctgt
 catgtgttga
 2461 agtccatggt tgggtcttgt gaagtctgag gtttaacagt ttgttgctct
 ggagggttt
 2521 tcttacagcg aagacttgag ttctccaag tcccagaacc ccaagaatgg
 gcaagaagga
 2581 tcaggtcagc cactccctgg agacacagcc ttctggctgg gactgacttg
 gccatgttct
 2641 cagctgagcc acgcggctgg tagtgcagcc ttctgtgacc ccgctgtggt
 aagtccagcc
 2701 tgcccagggc tgctgagggc tgcctcttga cagtgcagtc ttatcgagac
 ccaatgcctc
 2761 agtctgctca tccgtaaagt ggggatagtg aagatgacac ccctccccac
 cacctctcat

2821 aagcacttta ggaacacaca gagggtaggg atagtggccc tggccgtcta
 tcctaccctt
 2881 ttagtgaccg ccccatccc ggctttctga gctgacctt gaagaagaaa
 tcttccattt
 2941 ctgctctcaa accctactgg gatcaaactg gaataaattg aagacagcca
 ggggatggg
 3001 gcagctgtga agctcgggct gattccccct ctgtcccaga aggttgcca
 gaggtgtga
 3061 ccagttacc ctttaacccc cacccttcca gtcgggtgtg agggcctgac
 cgggccagg
 3121 gcaagcagat gtcgaagcc ctatttattc agtcttctact ataactctta
 gagttgagac
 3181 gctaattgttc atgactcctg gccttgggat gcccaaggga tttctggctc
 aggctgtaaa
 3241 agtagctgag ccatcctgcc cattcctgga ggtcctacag gtgaaactgc
 aggagctcag
 3301 catagacca gctctctggg ggatgggtcac ctggtgattt caatgatggc
 atccaggaat
 3361 tagctgagcc aacagaccat gtggacagct ttggccagag ctcccggtg
 gcatctggga
 3421 gccacagtga ccagccacc tggctcaggc tagttccaaa ttccaaaaga
 ttggcttgta
 3481 aaccttcgtc tccctctctt ttaccagag acagcacata cgtgtgcaca
 cgcattgcaca
 3541 cacacattca gtattttaaa agaattgttt ctgggtgcca ttttcatttt
 attttatttt
 3601 ttaattcttg gagggggaaa taagggaata aggccaagga agatgtatag
 ctttagcttt
 3661 agcctggcaa cctggagaat ccacatacct tgtgtattga accccaggaa
 aaggaagagg
 3721 tcgaaccaac cctgcggaag gagcatgggt tcaggagttt attttaagac
 tgctgggaag
 3781 gaaacaggcc ccattttgta tatagttgca acttaaaactt tttggcttgc
 aaaatatttt
 3841 tgtaataaag atttctgggt aataatga

[SEQ ID NO:12]

Translation = MEPAGPAPGRLGPLLCLLLAASCAWSGVAGEEELQVIQPKSVL
 VAAGETATLRCTATSLIPVGPIQWFRGAGPGRELIYNQKEGHFPRVTTVSDLTKRNNM
 DFSIRIGNITPADAGTYCYVKFRKGSPDDVEFKSGAGTELSVRAKPSAPVVSGPAARA

TPQHTVSFTCESHGFSPRDITLKWFKNGNELSDFQTNVDPVGESVSYSIHSTAKVVL
REDVHSQVICEVAHVTLQGDPLRGTANLSETIRVPPTLEVTQQPVRAENQVNVTCQVR
KFYPQRLQLTWLENGVSRTEASTVTENKDGTYNWSWLLVNVSAHRDDVKLTCQVE
HDGQPAVSKSHDLKVS AHPKEQGSNTAAENTGSNERNIYIVGVVCTLLVALLMAALY
LVRI RQKKAQGSTSSTRLHEPEKNAREITQDTNDITYADLNLPKGKKPAPQAAEPNNH
TEYASIQTSQPASEDTLTYADLDMVHLNRTPKQPAPKPEPSFSEYASVQVPRK

LOCUS NM_007547 4031 bp mRNA linear ROD 15-FEB-2015
DEFINITION Mus musculus signal-regulatory protein alpha (Sirpa),
Transcript variant 1, mRNA.
ACCESSION NM_007547 NM_011208
VERSION NM_007547.4 GI:597084939
SOURCE Mus musculus (house mouse)

[SEQ ID NO:15]

1 cggaaggtg cgggcgcgag gagggggcgc tcggccgggc cgccctcgcg
ctggcctcgc

61 gacggctccg cacagccgc actcgctctg cgagctgtcc ccgctcgcgc
ttgctctccg

121 atctccgtcc ccgctccctc tccctcttcc tctccccctc tttccttctc
cctcgctatc

181 cgctcccccg ccccggtgcc tctggctctg cgcttggtc cctcgggtcc
gctccccttt

241 ccgcgcggcc tggcccggcg tcacgctccc ggagtctccc cgctcggcgg
cgtctcattg

301 tgggaggggg tcagatcacc ccgcggggcg gtggcgctgg ggggcagcgg
agggggaggg

361 gccttagtgc ttcgcccgcg ccgcccgcc gcctgccgag cgcgctcacc
gccgctctcc

421 ctcttgctc tgcagccgcg gcccatggag ccgcccggcc cggcccctgg
ccgcctaggg

481 ccgctgctgc tctgcctgct gctctccgcg tcctgtttct gtacaggagc
cacggggaag

541 gaactgaagg tgactcagcc tgagaaatca gtgtctgttg ctgctgggga
ttcgaccgtt

601 ctgaactgca ctttgacctc cttgttgccg gtgggaccca ttaggtggta
cagaggagta

661 gggccaagcc ggctgttgat ctacagtttc gcaggagaat acgttcctcg
aattagaaat

721 gtttcagata ctactaagag aaacaatatg gactttttcca tccgtatcag
 taatgtcacc

781 ccagcagatg ctggcatcta ctactgtgtg aagttccaga aaggatcatc
 agagcctgac

841 acagaaatac aatctggagg gggaacagag gtctatgtac tcgccaaacc
 ttctccaccg

901 gaggtatccg gcccagcaga caggggcata cctgaccaga aagtgaactt
 cacctgcaag

961 tctcatggct tctctccccg gaatatcacc ctgaagtggc tcaaagatgg
 gcaagaactc

1021 cacccttgg agaccaccgt gaaccctagt ggaaagaatg tctcctacaa
 catctccagc

1081 acagtcaggg tggactaaa ctccatggat gttaattcta aggtcatctg
 cgaggtagcc

1141 cacatcacct tggatagaag ccctcttcgt gggattgcta acctgtctaa
 cttcatccga

1201 gtttcaccca ccgtgaaggc cacccaacag tccccgacgt caatgaacca
 ggtgaacctc

1261 acctgccggg ctgagagggt ctaccccgag gatctccagc tgatctggct
 ggagaatgga

1321 aacgtatcac ggaatgacac gcccaagaat ctacaaaaga acacggatgg
 gacctataat

1381 tacacaagct tgttcctggc gaactcatct gctcatagag aggacgtggc
 gttcacgtgc

1441 caggtgaagc acgaccaaca gccagcgatc acccgaaacc ataccgtgct
 gggatttgcc

1501 cactcgagtg atcaaggag catgcaaacc ttccctgata ataatgctac
 ccacaactgg

1561 aatgtcttca tcggtgtggg cgtggcgtgt gctttgctcg tagtcctgct
 gatggctgct

1621 ctctacctcc tccgatcaa acagaagaaa gccaaagggc caacatcttc
 cacacggttg

1681 cacgagcccg agaagaacgc cagggaata acccagatcc aggacacaaa
 tgacatcaac

1741 gacatcacat acgcagacct gaatctgccc aaagagaaga agcccgacc
 ccgggcccct

1801 gagcctaaca accacacaga atatgcaagc attgagacag gcaaagtgcc
 taggccagag

1861 gataccctca cctatgctga cctggacatg gtccacctca gccgggcaca
 gccagcccc

1921 aagcctgagc catctttctc agagtatgct agtgtccagg tccagaggaa
 gtgaatgggg

1981 ctgtgggtctg tactaggccc catccccaca agttttcttg tctacatgg
 agtggccatg

2041 acgaggacat ccagccagcc aatcctgtcc ccagaaggcc aggtggcacg
 ggtcctagga

2101 ccaggggtaa ggggtggcctt tgtcttcctt ccgtggctct tcaacacctc
 ttgggcaccc

2161 acgtccctt cttccggagg ctgggtgttg cagaaccaga gggcgaactg
 gagaaagctg

2221 cctggaatcc aagaagtgtt gtgcctcggc ccatcactcg tgggtctgga
 tcttggtctt

2281 ggcaacccca ggttgcgctc ttgatgttcc agagcttggt cttctgtgtg
 gagaagagct

2341 caccatctct acccaacttg agctttggga ccagactccc tttagatcaa
 accgccccat

2401 ctgtggaaga actacaccag aagtcagcaa gttttcagcc aacagtgtg
 gcctccccac

2461 ctcccaggct gactagccct ggggagaagg aaccctctcc tcctagacca
 gcagagactc

2521 cctgggcatg ttcagtgtgg cccacctcc cttccagtcc cagcttgctt
 cctccagcta

2581 gcactaactc agcagcatcg ctctgtggac gcctgtaaat tattgagaaa
 tgtgaactgt

2641 gcagtcttaa agctaagggtg ttagaaaatt tgatttatgc tgtttagttg
 ttgttggtt

2701 tcttttcttt ttaatttctt tttctttttt gatttttttt cttccctta
 aaacaacagc

2761 agcagcatct tggctctttg tcatgtgttg aatggttggg tcttgtgaag
 tctgaggtct

2821 aacagtttat tgtcctggaa ggattttctt acagcagaaa cagatttttt
 tcaaattccc

2881 agaatcctga ggaccaagaa ggatccctca gctgctactt ccagcaccca
 gcgtcactgg

2941 gacgaaccag gccctgttct tacaaggcca catggctggc cctttgcctc
 catggctact

3001 gtggtaagtg cagccttgtc tgaccaaatg ctgacctaat gttggccatt
 ccacattgag

3061 gggacaaggt cagtgatgcc ccccttcact cacaagcact tcagaggcat
 gcagagagaa

3121 gggacactcg gccagctctc tgaggtaatc agtgcaagga ggagtcggtt
 ttttgccagc
 3181 aaacctcagc aggatcacac tggaacagaa cctggtcata cctgtgacaa
 cacagctgtg
 3241 agccagggca aaccacccac tgtcactggc tcgagagtct gggcagaggc
 tctgaccctc
 3301 caccctttaa actggatgcc ggggcctggc tgggcccaat gccaagtggc
 tatggcaacc
 3361 ctgactatct ggtcttaaca tgtagctcag gaagtggagg cgctaattgc
 cccaatccct
 3421 ggggattcct gattccagct attcatgtaa gcagagccaa cctgcctatt
 tctgtaggtg
 3481 cgactgggat gttaggagca cagcaaggac ccagctctgt agggctgggt
 acctgatact
 3541 tctcataatg gcatctagaa gttaggctga gttggcctca ctggcccagc
 aaaccagaac
 3601 ttgtctttgt ccgggccatg ttcttgggct gtcttctaata tccaaagggc
 tggttggtgta
 3661 agctccaccc ccttctcctc tgcctaaaga catcacatgt gtatacacac
 acgggtgtat
 3721 agatgagtta aaagaatgtc ctcgctggca tcctaatttt gtcttaagtt
 tttttggagg
 3781 gagaaaggaa caaggcaagg gaagatgtgt agctttggct ttaaccaggc
 agcctggggg
 3841 ctccaagcc tatggaaccc tggtaaaaag aagagaacag aagcgccctg
 tgaggagtgg
 3901 gatttgtttt tctgtagacc agatgagaag gaaacaggcc ctgttttgta
 catagttgca
 3961 acttaaaatt tttggcttgc aaaatatatt tgtaataaag atttctgggt
 aacaataaaa
 4021 aaaaaaaaaa a

[SEQ ID NO:16]

Translation = MEPAGPAPGRLGPLLLCLLLSASCFCCTGATGKELKVTQPEKSVS
 VAAGDSTVLNCTLTSLLPVGPIRWYRGVGPSRLLIYSFAGEYVPRIRNVSDTTKRNNM
 DFSIRISNVTPADAGIYYCVKFQKGSSEPDETIQSGGGTEVYVLAKPSPPEVSGPADR
 GIPDQKVNFTCKSHGFSPRNITLKWFKDQQLHPLETTVNP SGKNVSYNISSTVRVVL
 NSMDVNSKVICEVAHITLDRSPLRGIANLSNFIRVSPTVKVTQQSPTSMNQVNLCRA
 ERFYPEDLQLIWLGNVSRNDTPKNLTKNTDGTNYTSLFLVNSSAHREDVVFTCQV

KHDQQPAITRNHTVLGFAHSSDQGSMTFFDNNATHNWNVFIGVGVACALLVLLMAA

LYLLRIKQKKAKGSTSSTRLHEPEKNAREITQIQDTNDINDITYADLNLPKEKKPAPR

APEPNNHTEYASIIETGKVPREDTLTYADLDMVHLSRAQPAPKPEPSFSEYASVQVQR
K

LOCUS NM_001177647 3377 bp mRNA linear ROD 15-FEB-2015
DEFINITION Mus musculus signal-regulatory protein alpha (Sirpa),
Transcript variant 3, mRNA.
ACCESSION NM_001177647
VERSION NM_001177647.2 GI:597436949
SOURCE Mus musculus (house mouse)

[SEQ ID NO:17]

1 cgggaaggtg cgggcgcgag gagggggcgc tcggccgggc cgccctcgcg
ctggcctcgc

61 gacggctccg cacagccgc actcgctctg cgagctgtcc ccgctcgcgc
ttgctctccg

121 atctccgtcc ccgctccctc tccctcttcc tctccccctc tttccttctc
cctcgctatc

181 cgctcccccg cccccgtgcc tctggctctg cgcttggtc cctcgggtcc
gtccccctt

241 cccgccggcc tggcccgcg tcacgtccc ggagtctccc cgctcggcgg
cgtctcattg

301 tgggaggggg tcagatcacc ccgccgggcg gtggcgctgg ggggcagcgg
agggggaggg

361 gccttagtgc ttgcggcgcg ccgccgccc gcctgccgag cgcgctcacc
gccgctctcc

421 ctcttgctc tgcagccgc gcccatggag cccgccggcc cggcccctgg
ccgcctaggg

481 ccgctgctgc tctgcctgct gctctccgcy tctgttttct gtacaggagc
cacggggaag

541 gaactgaagg tgactcagcc tgagaaatca gtgtctgttg ctgctgggga
ttcgaccgtt

601 ctgaactgca ctttgacctc cttgttgccg gtgggaccca ttaggtggta
cagaggagta

661 gggccaagcc ggctgttgat ctacagtttc gcaggagaat acgttcctcg
aattagaaat

721 gtttcagata ctactaagag aaacaatatg gacttttcca tccgtatcag
taatgtcacc

781 ccagcagatg ctggcatcta ctactgtgtg aagttccaga aaggatcatc
agagcctgac

841 acagaaatac aatctggagg gggaacagag gtctatgtac tcgataataa
 tgctaccac
 901 aactggaatg tcttcacg tgtgggcgtg gcgtgtgctt tgctcgtagt
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 961 gctgctctct acctcctccg gatcaaacag aagaaagcca aggggtcaac
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 1021 cggttgcacg agcccagaa gaacgccagg gaaataaccc agatccagga
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 1081 atcaacgaca tcacatacgc agacctgaat ctgcccagg agaagaagcc
 cgcaccccg
 1141 gccctgagc ctaacaacca cacagaatat gcaagcattg agacaggcaa
 agtgcctagg
 1201 ccagaggata cctcaccta tgctgacctg gacatggtcc acctcagccg
 ggcacagcca
 1261 gcccccaagc ctgagccatc tttctcagag tatgctagt tccaggcca
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 1621 ggtcttggca accccaggtt gcgtccttga tgttccagag cttggtcttc
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 1681 agagctcacc atctctacc aacttgagct ttgggaccag actccctta
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 gtgctggcct
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 1861 agactccctg ggcatttca gtgtggcccc acctcccttc cagtcccagc
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 1921 cagctagcac taactcagca gcatcgctct gtggacgcct gtaaattatt
 gagaaatgtg
 1981 aactgtgcag tcttaaagct aagggtgtag aaaatttgat ttatgctgtt
 tagttgttgt

2041 tgggttttctt ttctttttaa tttctttttc ttttttgatt ttttttcttt
 cccttaaaac
 2101 aacagcagca gcatcttggc tctttgtcat gtgttgaatg gttgggtctt
 gtgaagtctg
 2161 aggtctaaca gtttattgtc ctggaaggat tttcttacag cagaaacaga
 tttttttcaa
 2221 attcccagaa tcctgaggac caagaaggat ccctcagctg ctacttccag
 caccagcgt
 2281 cactgggacg aaccaggccc tgttcttaca aggccacatg gctggccctt
 tgccctcatg
 2341 gctactgtgg taagtgcagc cttgtctgac ccaatgctga cctaattgtg
 gccattccac
 2401 attgagggga caaggtcagt gatgcccccc ttactcaca agcacttcag
 aggcattcag
 2461 agagaaggga cactcggcca gctctctgag gtaatcagtg caaggaggag
 tccgtttttt
 2521 gccagcaaac ctcagcagga tcacactgga acagaacctg gtcatacctg
 tgacaacaca
 2581 gctgtgagcc agggcaaacc acccactgtc actggctcga gagtctgggc
 agaggctctg
 2641 accctccacc ctttaaactg gatgccgggg cctggctggg cccaatgcca
 agtggttatg
 2701 gcaaccctga ctatctggtc ttaacatgta gctcaggaag tggaggcgct
 aatgtcccca
 2761 atccctgggg attcctgatt ccagctattc atgtaagcag agccaacctg
 cctatttctg
 2821 taggtgcgac tgggatgtta ggagcacagc aaggacccag ctctgtaggg
 ctggtgacct
 2881 gatacttctc ataatggcat ctagaagtta ggctgagttg gcctcactgg
 ccagcaaac
 2941 cagaacttgt ctttgtccgg gccatgttct tgggctgtct tctaattcca
 aagggttgg
 3001 tggtaaagct ccacccccct ctcctctgcc taaagacatc acatgtgtat
 acacacacgg
 3061 gtgtatagat gagttaaaag aatgtcctcg ctggcatcct aattttgtct
 taagtttttt
 3121 tggagggaga aaggaacaag gcaagggaag atgtgtagct ttggctttaa
 ccaggcagcc
 3181 tgggggctcc caagcctatg gaaccctggg acaaagaaga gaacagaagc
 gccctgtgag

3241 gagtgggatt tgtttttctg tagaccagat gagaaggaaa caggccctgt
tttgtaata

3301 gttgcaactt aaaatTTTTtG gcttgcaaaa tatttttGta ataaagattt
ctgggtaaca

3361 ataaaaaaaa aaaaaaa

[SEQ ID NO:18]

Translation = MEPAGPAPGRLGFLLLCLLLSASCFCCTGATGKELKVTQPEKSVS
VAAGDSTVLNCTLTSLLPVGPIRWYRGVGPSRLLIYSFAGEYVPRIRNVSDTTRNNM
DFSIRISNVTPADAGIYYCVKFQKGSSEPDTEIQSGGGTEVYVLDNNATHNWNVFIGV
GVACALLVVLMAALYLLRIKQKKAKGSTSSSTRLHEPEKNAREITQIQDTNDINDITY
ADLNLPKEKKPAPRAPEPNNHTEYASIEETGKVPREPDTLTYADLDMVHLSRAQPAPKP
EPSFSEYASVQVQRK

LOCUS	NM_001291019 4043 bp mRNA linear ROD 15-FEB-2015
DEFINITION	Mus musculus signal-regulatory protein alpha (Sirpa), transcript variant 4, mRNA.
ACCESSION	NM_001291019 XM_006498985
VERSION	NM_001291019.1 GI:597436868
SOURCE	Mus musculus (house mouse)

[SEQ ID NO:19]

1 cggaaggtg cggcgcgag gagggggcgc tcggccgggc cgccctcgcg ctggcctcgc
61 gacggctccg cacagccgcg actcgctctg cgagctgtcc ccgctcgcgc ttgctctccg
121 atctccgtcc ccgctccctc tccctcttcc tctcccccctc tttccttctc cctcgctatc
181 cgctcccccg ccccggtgcc tctggtctg cgctggctc cctcgggtcc gctccccctt
241 cccgccggcc tggcccgcg tcacgctccc ggagtctccc cgctcggcgg cgtctcattg
301 tgggaggggg tcagatcacc ccgccggcg gtggcgctgg ggggcagcgg agggggaggg
361 gccttagtcg ttgcggcg cgcccgccc gcctgccgag cgcgctcacc gccgctctcc
421 ctcttgctc tgcagccgc gcccatggag cccgccggcc cggcccctgg ccgcctaggg
481 ccgctgctgc tctgcctgct gctctccgc tctgtttct gtacaggagc cacggggaag
541 gaactgaagg tgactcagcc tgagaaatca gtgtctgttg ctgctgggga ttcgaccgtt
601 ctgaactgca ctttgacctc cttgttgccg gtgggaccca ttaggtggta cagaggagta
661 gggccaagcc ggctgttgat ctacagtttc gcaggagaat acgttcctcg aattagaaat
721 gtttcagata ctactaagag aaacaatatg gacttttcca tccgtatcag taatgtcacc
781 ccagcagatg ctggcatcta ctactgtgtg aagttccaga aaggatcatc agagcctgac

841 acagaaatac aatctggagg gggaacagag gtctatgtac tcgccaaacc ttctccaccg
 901 gaggtatccg gccagcaga caggggcata cctgaccaga aagtgaactt cacctgcaag
 961 tctcatggct tctctccccg gaatatcacc ctgaagtggg tcaaagatgg gcaagaactc
 1021 cacccttgg agaccaccgt gaaccctagt ggaaagaatg tctcctacaa
 catctccagc
 1081 acagtcaggg tggactaaa ctccatggat gttaattcta aggtcatctg
 cgaggtagcc
 1141 cacatcacct tggatagaag ccctcttcgt gggattgcta acctgtctaa
 cttcatccga
 1201 gtttcaccca ccgtgaaggc caccacacag tccccgacgt caatgaacca
 ggtgaacctc
 1261 acctgccggg ctgagagggt ctaccccgag gatctccagc tgatctggct
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 1501 cactcgagtg atcaaggag catgcaaacc ttccctgata ataatgctac
 ccacaactgg
 1561 aatgtcttca tcgggtgtgg cgtggcgtgt gctttgctcg tagtcctgct
 gatggctgct
 1621 ctctacctcc tccgatcaa acagaagaaa gccaaagggt caacatcttc
 cacacggttg
 1681 cacgagcccg agaagaacgc cagggaaata acccaggtag agtctttgat
 ccaggacaca
 1741 aatgacatca acgacatcac atacgcagac ctgaatctgc ccaaagagaa
 gaagcccgca
 1801 ccccgggccc ctgagcctaa caaccacaca gaatatgcaa gcattgagac
 aggcaaagtg
 1861 cctaggccag aggataccct cacctatgct gacctggaca tggccacct
 cagccgggca
 1921 cagccagccc ccaagcctga gccatctttc tcagagtatg ctagtgtcca
 ggtccagagg
 1981 aagtgaatgg ggctgtgggc tgtactaggc cccatcccca caagttttct
 tgcctacat
 2041 ggagtggcca tgacgaggac atccagccag ccaatcctgt cccagaagg
 ccaggtggca

2101 cgggtcctag gaccaggggt aagggtggcc tttgtcttcc ctccgtggct
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 2161 tcttgggcac ccacgtcccc ttcttccgga ggctgggtgt tgcagaacca
 gagggcgaac
 2221 tggagaaagc tgcttgaat ccaagaagtg ttgtgcctcg gccatcact
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 2281 gatcctggtc ttggcaaccc caggttgcgt ccttgatgtt ccagagcttg
 gtcttctgtg
 2341 tggagaagag ctcaccatct ctacccaact tgagctttgg gaccagactc
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 ccagcttgc
 2581 ttctccagc tagcactaac tcagcagcat cgctctgtgg acgcctgtaa
 attattgaga
 2641 aatgtgaact gtgcagtctt aaagctaagg tgtagaaaaa tttgatttat
 gctgtttagt
 2701 tgttgttggg tttcttttct ttttaatttc tttttctttt ttgatttttt
 ttctttccct
 2761 taaaacaaca gcagcagcat cttggctctt tgtcatgtgt tgaatggttg
 ggtcttgtga
 2821 agtctgaggt ctaacagttt attgtcctgg aaggattttc ttacagcaga
 aacagatttt
 2881 tttcaaattc ccagaatcct gaggaccaag aaggatccct cagctgctac
 ttccagacc
 2941 cagcgtcact gggacgaacc aggccctgtt cttacaaggc cacatggctg
 gccctttgcc
 3001 tccatggcta ctgtggtaag tgcagccttg tctgaccaa tgctgaccta
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 3061 ttccacattg aggggacaag gtcagtgatg ccccccttca ctcacaagca
 cttcagaggc
 3121 atgcagagag aagggacact cggccagctc tctgaggtaa tcagtgaag
 gaggagtccg
 3181 ttttttgcca gcaaacctca gcaggatcac actggaacag aacctggtca
 tacctgtgac
 3241 aacacagctg tgagccaggg caaaccaccc actgtcactg gctcgagagt
 ctgggcagag

3301 gctctgaccc tccacccttt aaactggatg ccggggcctg gctgggccc
 atgccaagtg
 3361 gttatggcaa ccctgactat ctggtcttaa catgtagctc aggaagtgga
 ggcgctaag
 3421 tccccaatcc ctggggattc ctgattccag ctattcatgt aagcagagcc
 aacctgccta
 3481 tttctgtagg tgcgactggg atgtaggag cacagcaagg acccagctct
 gtagggctgg
 3541 tgacctgata cttctcataa tggcatctag aagttaggct gagttggcct
 cactggccca
 3601 gcaaaccaga acttgtcttt gtccgggcca tggtcttggg ctgtcttcta
 attccaaagg
 3661 gttggttggg aaagctccac ccccttctcc tctgcctaaa gacatcacat
 gtgtatacac
 3721 acacgggtgt atagatgagt taaaagaatg tcctcgctgg catcctaatt
 ttgtcttaag
 3781 tttttttgga gggagaaagg aacaaggcaa gggaagatgt gtagctttgg
 ctttaaccag
 3841 gcagcctggg ggctcccaag cctatggaac cctggtacaa agaagagaac
 agaagcgccc
 3901 tgtgaggagt gggatttggt tttctgtaga ccagatgaga aggaaacagg
 ccctgttttg
 3961 tacatagttg caacttaaaa tttttggctt gcaaaaatatt tttgtaataa
 agatttctgg
 4021 gtaacaataa aaaaaaaaaa aaa

[SEQ ID NO:20]

Translation = MEPAGPAPGRLGPLLLCLLLSASCFCCTGATGKELKVTQPEKSVS
 VAAGDSTVLNCTLTSLLPVGPIRWYRGVGPSRLLIYSFAGEYVPRI RNVS DTTKRNNM
 DFSIRISNVTPADAGIYYCVKFQKGSSEPDTEIQSGGGTEVYVLAKPSPPEVSGPADR
 GIPDQKVNFTCKSHGFSPRNITLKWFKDGQELHPLETTVNPSGKNVSYNISSTVRVVL
 NSMDVNSKVICEVAHITLDRSPLRGIANLSNFIRVSPTVKVTQQSPTSMNQVNLT CRA
 ERFYPEDLQLIWLENGNVSRNDTPKNLTKNTDGTNYTSLFLVNSSAHREDVVFTCQV
 KHDQQPAITRNHTVLGFHSSDQGSMTFPDNNATHNWNVFIGVG VACALLVLLMAA
 LYLLRIKQKKAKGSTSSTRLHEPEKNAREITQVQSLIQDTNDINDITYADLNLPEKK
 PAPRAPEPNNHTEYAS IETGKVPRPEDTLTYADLDMVHLSRAQPAPKPEPSFSEYASV
 QVQRK

LOCUS NM_001291020 3845 bp mRNA linear ROD
 15-FEB-2015
 DEFINITION Mus musculus signal-regulatory protein alpha (Sirpa),
 transcript
 variant 5, mRNA.
 ACCESSION NM_001291020 XM_006498984
 VERSION NM_001291020.1 GI:597436945
 KEYWORDS RefSeq.
 SOURCE Mus musculus (house mouse)

[SEQ ID NO:21]

1 aagctccctt gccgcgggca gcctcttgcc cactggagtc taaggactgg ccgggtgaga
 61 ggccgagacc agggggcgat cggccgccac ttcccagtc caccttaaga ggaccaagta
 121 gccagcccg cgcgccgacc tcagaaaaac aagtttgccg aaagtgggtg gcggccagcc
 181 tctgggcaga gggagcgggtg cttccaccgc ctggcagccc tgcgcgcggc ggcgcagccg
 241 cggcccatgg agcccgccgg cccggcccct ggccgcctag ggccgctgct gctctgcctg
 301 ctgctctccg cgtcctgttt ctgtacagga gccacgggga aggaactgaa ggtgactcag
 361 cctgagaaat cagtgtctgt tgctgctggg gattcgaccg ttctgaactg cactttgacc
 421 tccttggttg cgggtgggacc cattaggtgg tacagaggag tagggccaag ccggctgttg
 481 atctacagtt tcgcaggaga atacgttcct cgaattagaa atgtttcaga tactactaag
 541 agaaacaata tggacttttc catccgtatc agtaatgtca cccagcaga tgctggcatc
 601 tactactgtg tgaagttcca gaaaggatca tcagagcctg acacagaaat acaatctgga
 661 gggggaacag aggtctatgt actcgccaaa ccttctccac cggaggtatc cggcccagca
 721 gacaggggca tacctgacca gaaagtgaac ttcacctgca agtctcatgg cttctctccc
 781 cggaatatca ccctgaagtg gttcaaagat gggcaagaac tccacccctt ggagaccacc
 841 gtgaacccta gtggaagaa tgtctcctac aacatctcca gcacagtcag ggtggtacta
 901 aactccatgg atgttaattc taaggatcatc tgcgaggtag cccacatcac cttggataga
 961 agccctcttc gtgggattgc taacctgtct aacttcatcc gagtttcacc caccgtgaag
 1021 gtcacccaac agtccccgac gtcaatgaac caggtgaacc tcacctgccg
 ggctgagagg
 1081 ttctaccccg aggatctcca gctgatctgg ctggagaatg gaaacgtatc
 acggaatgac
 1141 acgccaaga atctcacaaa gaacacggat gggacctata attacacaag
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 1261 cagccagcga tcacccgaaa ccataccgtg ctgggatttg cccactcgag
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1321 agcatgcaaa ccttcctga taataatgct acccacaact ggaatgtctt
 catcggtgtg
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 cctccggatc
 1441 aaacagaaga aagccaagggt gtcaacatct tccacacggt tgcacgagcc
 cgagaagaac
 1501 gccagggaaa taaccaggt acagtctttg atccaggaca caaatgacat
 caacgacatc
 1561 acatacgag acctgaatct gcccaaagag aagaagcccg caccgccggc
 ccctgagcct
 1621 aacaaccaca cagaatatgc aagcattgag acaggcaaag tgcctaggcc
 agaggatacc
 1681 ctacacctatg ctgacctgga catggtccac ctgagccggg cacagccagc
 cccaagcct
 1741 gagccatctt tctcagagta tgctagtgtc caggtccaga ggaagtgaat
 ggggctgtgg
 1801 tctgtactag gcccacccc cacaagtttt cttgtcctac atggagtggc
 catgacgagg
 1861 acatccagcc agccaatcct gtcccagaa gccaggtgg cacgggtcct
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 ccatctgtgg
 2221 aagaactaca ccagaagtca gcaagttttc agccaacagt gctggcctcc
 ccacctcca
 2281 ggctgactag ccctggggag aaggaaccct ctccctctag accagcagag
 actccctggg
 2341 catgttcagt gtggccccac ctcccttcca gtcccagctt gcttcctcca
 gctagcacta
 2401 actcagcagc atcgctctgt ggacgcctgt aaattattga gaaatgtgaa
 ctgtgcagtc
 2461 ttaaagctaa ggtgttagaa aatttgattt atgctgttta gttgttgttg
 ggtttctttt

2521 ctttttaatt tctttttctt ttttgatatt ttttctttcc cttaaaacaa
 cagcagcagc

2581 atcttggtct tttgtcatgt gttgaatggt tgggtcttgt gaagtctgag
 gtctaacagt

2641 ttattgtcct ggaaggattt tcttacagca gaaacagatt tttttcaaat
 tcccagaatc

2701 ctgaggacca agaaggatcc ctcagctgct acttcacagca cccagcgtca
 ctgggacgaa

2761 ccaggccctg ttcttacaag gccacatggc tggccctttg cctccatggc
 tactgtggta

2821 agtgcagcct tgtctgaccc aatgctgacc taatgttggc cattccacat
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2881 aggtcagtga tgccccctt cactcacaag cacttcagag gcatgcagag
 agaagggaca

2941 ctcgccagc tctctgaggt aatcagtgcaggaggagtc cgttttttgc
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3001 cagcaggatc aactggaac agaacctggt catacctgtg acaacacagc
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3061 ggcaaaccac cactgtcac tggctcgaga gtctgggcag aggctctgac
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3121 ttaaactgga tgccggggcc tggctgggccc caatgccaaag tggttatggc
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3181 atctggtctt aacatgtagc tcaggaagtg gaggcgctaa tgtccccaat
 ccctggggat

3241 tcttgattcc agctattcat gtaagcagag ccaacctgcc tatttctgta
 ggtgcgactg

3301 ggatgttagg agcacagcaa ggaccagct ctgtagggct ggtgacctga
 tacttctcat

3361 aatggcatct agaagttagg ctgagttggc ctactggcc cagcaaacca
 gaacttgtct

3421 ttgtccgggc catgttcttg ggctgtcttc taattccaaa gggttggttg
 gtaaagctcc

3481 acccccttct cctctgccta aagacatcac atgtgtatac acacacgggt
 gtatagatga

3541 gttaaaagaa tgtcctcgct ggcatcctaa ttttgtctta agtttttttg
 gagggagaaa

3601 ggaacaaggc aagggaagat gtgtagcttt ggctttaacc aggcagcctg
 ggggctcca

3661 agcctatgga accctggtac aaagaagaga acagaagcgc cctgtgagga
 gtgggatttg

3721 tttttctgta gaccagatga gaaggaaaca ggcctgttt tgtacatagt
tgcaacttaa

3781 aatttttggc ttgcaaaata tttttgtaat aaagatttct gggtaacaat
aaaaaaaaaa

3841 aaaaa

[SEQ ID NO:20]

Translation = MEPAGPAPGRLGPLLLCLLLSASCFCCTGATGKELKVTQPEKSVS
VAAGDSTVLNCTLTSLLPVGPIRWYRGVGPSRLLIYSFAGEYVPRIRNVSDTTKRNNM
DFSIRISNVTPADAGIYYCVKFQKGSSEPDTEIQSGGGTEVYVLAKPSPPEVSGPADR
GIPDQKVNFTCKSHGFSPRNITLKWFKDGQELHPLETTVNP SGKNVSYNISSTVRVVL
NSMDVNSKVICEVAHITLDRSPLRGIANLSNFIRVSPTVKVTQQSPTSMNQVNLT CRA
ERFYPEDLQLIWLENGNVSRNDTPKNLTKNTDGTNYTSLFLVNSSAHREDVVFTCQV
KHDQQPAITRNHTVLGFAHSSDQGSMTFPDNNATHNWNVFIGVGACALLVLLMAA
LYLLRIKQKKAKGSTSSTRLHEPEKNAREITQVQSLIQDTNDINDITYADLNLPKEKK
PAPRAPEPNNHTEYASIIETGKVPRPEDTLTYADLDMVHLSRAQPAPKPEPSFSEYASV
QVQRK

LOCUS	NM_001291021 3389 bp mRNA linear ROD 15-FEB-2015
DEFINITION	Mus musculus signal-regulatory protein alpha (Sirpa), Transcript variant 6, mRNA.
ACCESSION	NM_001291021 XM_006498987
VERSION	NM_001291021.1 GI:597436920
SOURCE	Mus musculus (house mouse)

[SEQ ID NO:22]

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ttgctctccg

121 atctccgtcc ccgctccctc tccctcttcc tctccccctc tttccttctc
cctcgtatc

181 cgctcccccg ccccggtgcc tctggctctg cgcttggtc cctcgggtcc
gctccccctt

241 ccgcgcggcc tggcccggcg tcacgtccc ggagtctccc cgctcggcgg
cgtctcattg

301 tgggaggggg tcagatcacc ccgcggggcg gtggcgctgg ggggcagcgg
agggggaggg

361 gccttagtcg ttgcggcgcg ccggccggcc gcctgccgag cgcgctcacc
gccgctctcc

421 ctctttgctc tgcagccgcg gcccatggag cccgccggcc cggccccctgg
 ccgcctaggg
 481 ccgctgctgc tctgcctgct gctctccgcg tctgttttct gtacaggagc
 cacgggggaag
 541 gaactgaagg tgactcagcc tgagaaatca gtgtctgttg ctgctgggga
 ttcgaccgtt
 601 ctgaactgca ctttgacctc cttgttgccg gtgggacca ttaggtggta
 cagaggagta
 661 gggccaagcc ggctgttgat ctacagtttc gcaggagaat acgttcctcg
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 taatgtcacc
 781 ccagcagatg ctggcatcta ctactgtgtg aagttccaga aaggatcatc
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 841 acagaaatac aatctggagg gggaacagag gtctatgtac tcgataataa
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 901 aactggaatg tcttcatcgg tgtgggcgtg gcgtgtgctt tgctcgtagt
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 1381 ctacatggag tggccatgac gaggacatcc agccagccaa tctgtcccc
 agaaggccag
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 1501 aacacctctt gggcacccac gtccccttct tccggaggct ggggtgttgca
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 1561 gcgaactgga gaaagctgcc tggaatccaa gaagtgttgt gcctcggccc
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1621 ggtctggatc ctggtcttgg caaccccagg ttgcgtcctt gatgttccag
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 1681 tctgtgtgga gaagagctca ccatctctac ccaacttgag ctttgggacc
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 1741 tagatcaaac cgccccatct gtggaagaac tacaccagaa gtcagcaagt
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 1981 ttgagaaatg tgaactgtgc agtcttaaag ctaagggtgtt agaaaatttg
 atttatgctg
 2041 tttagttggt gttgggtttc ttttcttttt aatttctttt tcttttttga
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 2101 ttcccttaaa acaacagcag cagcatcttg gctctttgtc atgtgttgaa
 tggttgggtc
 2161 ttgtgaagtc tgaggctctaa cagtttattg tcctggaagg attttcttac
 agcagaaaca
 2221 gatttttttc aaattcccag aatcctgagg accaagaagg atccctcagc
 tgctacttcc
 2281 agcaccagc gtcactggga cgaaccaggc cctgttctta caaggccaca
 tggctggccc
 2341 tttgcctcca tggctactgt ggtaagtga gccttgtctg acccaatgct
 gacctaatgt
 2401 tggccattcc acattgaggg gacaagggtca gtgatgcccc ccttactca
 caagcacttc
 2461 agaggcatgc agagagaagg gacactcggc cagctctctg aggtaatcag
 tgcaaggagg
 2521 agtccgtttt ttgccagcaa acctcagcag gatcacactg gaacagaacc
 tggtcatacc
 2581 tgtgacaaca cagctgtgag ccaggggcaaa ccaccactg tcaactggctc
 gagagtctgg
 2641 gcagaggctc tgaccctcca ccctttaaac tggatgccgg gccctggctg
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 2701 caagtgggtta tggcaaccct gactatctgg tcttaacatg tagctcagga
 agtggaggcg
 2761 ctaatgtccc caatccctgg ggattcctga ttccagctat tcatgtaagc
 agagccaacc

2821 tgcctatttc tgtagggtgcg actgggatgt taggagcaca gcaaggaccc
agctctgtag

2881 ggctgggtgac ctgatacttc tcataatggc atctagaagt taggctgagt
tggcctcact

2941 ggcccagcaa accagaactt gtctttgtcc gggccatgtt cttgggctgt
cttctaattc

3001 caaagggttg gttggtaaag ctccaccccc ttctcctctg cctaaagaca
tcacatgtgt

3061 atacacacac ggggtgtatag atgagttaaa agaattgtcct cgctggcatc
ctaattttgt

3121 ctttaagtttt tttggaggga gaaaggaaca aggcaaggga agatgtgtag
ctttggcttt

3181 aaccaggcag cctgggggct cccaagccta tggaaccctg gtacaaagaa
gagaacagaa

3241 gcgcctctgtg aggagtggga tttgtttttc tgtagaccag atgagaagga
aacaggccct

3301 gttttgtaca tagttgcaac ttaaaatttt tggcttgcaa aatatttttg
taataaagat

3361 ttctgggtaa caataaaaaa aaaaaaaaaa

[SEQ ID NO:23]

Translation = MEPAGPAPGRLGPLLLCLLLSASCFCCTGATGKELKVTQPEKSVS
VAAGDSTVLNCTLTSLLPVGPIRWYRGVGPSRLLIYSFAGEYVPRIRNVSDTTRNNM
DFSIRISNVTPADAGIYYCVKFQKGSSEPDTEIQSGGGTEVYVLDNNAHNWNVFIGV
GVACALLVLLMAALYLLRIKQKKAGSTSSSTRLHEPEKNAREITQVQSLIQDTNDIN
DITYADLNLPKEKKPAPRAPEPNNHTEYASIEETGKVPREPDTLTLYADLDMVHLSRAQP
APKPEPSFSEYASVQVQRK

LOCUS	NM_001291022 3020 bp mRNA linear ROD 15-FEB-2015
DEFINITION	Mus musculus signal-regulatory protein alpha (Sirpa), Transcript variant 7, mRNA.
ACCESSION	NM_001291022
VERSION	NM_001291022.1 GI:597436963
SOURCE	Mus musculus (house mouse)

[SEQ ID NO:24]

1 cggaaggtg cgggcgcgag gagggggcgc tcggccgggc cgccctcgcg
ctggcctcgc

61 gacggctccg cacagcccgc actcgctctg cgagctgtcc ccgctcgcgc
ttgctctccg

121 atctccgtcc ccgtccctc tccctcttcc tctccccctc tttccttctc
 cctcgctatc

181 cgctcccccg cccccgtgcc tctggctctg cgcttggtc cctcggtcc
 gctccccctt

241 cccgcgggcc tggccggcg tcacgtccc ggagtctccc cgctcggcgg
 cgtctcattg

301 tgggaggggg tcagatcacc ccgccggcg gtggcgctgg ggggcagcgg
 agggggaggg

361 gccttagtgc ttgcgccgcg ccgccgccc gcctgccgag cgcgtcacc
 gccgtctcc

421 ctcttgctc tgcagccgcg gcccatggag cccgccggcc cggccctgg
 ccgctaggg

481 ccgtgtctgc tctgcctgct gctctccgcg tcctgtttct gtacagataa
 taatgctacc

541 cacaactgga atgtcttcat cgggtgtggc gtggcgtgtg ctttgctcgt
 agtcctgctg

601 atggctgtc tctacctct ccgatcaaa cagaagaaag ccaaggggtc
 aacatcttcc

661 acacggttgc acgagcccga gaagaacgcc agggaaataa ccagatcca
 ggacacaaat

721 gacatcaacg acatcacata cgcagacctg aatctgcca aagagaagaa
 gccgcaccc

781 cgggccccctg agcctaaca ccacacagaa tatgcaagca ttgagacagg
 caaagtgcct

841 aggccagagg ataccctcac ctatgctgac ctggacatgg tccacctcag
 ccgggcacag

901 ccagccccca agcctgagcc atctttctca gagtatgcta gtgtccaggt
 ccagaggaag

961 tgaatggggc tgtggtctgt actaggcccc atccccacaa gttttcttgt
 cctacatgga

1021 gtggccatga cgaggacatc cagccagcca atcctgtccc cagaaggcca
 ggtggcacgg

1081 gtctaggac caggggtaag ggtggccttt gtcttccctc cgtggctctt
 caacacctct

1141 tgggcaccca cgtccccctc ttccggaggc tgggtgttgc agaaccagag
 ggcgaactgg

1201 agaaagctgc ctggaatcca agaagtgttg tgcctcgcc catcactcgt
 ggtctggat

1261 cctggctctg gcaaccccag gttgcgtcct tgatgttcca gagcttggtc
 ttctgtgtgg

1321 agaagagctc accatctcta cccaacttga gctttgggac cagactccct
 ttagatcaaa
 1381 cgcgcccatc tgtggaagaa ctacaccaga agtcagcaag ttttcagcca
 acagtgtctg
 1441 cctccccacc tcccaggctg actagccctg gggagaagga accctctcct
 cctagaccag
 1501 cagagactcc ctgggcatgt tcagtgtggc cccacctccc ttccagtccc
 agcttgcttc
 1561 ctccagctag cactaactca gcagcatcgc tctgtggacg cctgtaaatt
 attgagaaat
 1621 gtgaactgtg cagtcttaaa gctaagggtg tagaaaaattt gatttatgct
 gtttagttgt
 1681 tgttggggtt cttttctttt taatttcttt ttcttttttg attttttttc
 ttcccttaa
 1741 aacaacagca gcagcatctt ggctctttgt catgtgttga atggttgggt
 cttgtgaagt
 1801 ctgaggctta acagtttatt gtccctggaag gattttctta cagcagaaac
 agattttttt
 1861 caaattccca gaatcctgag gaccaagaag gatccctcag ctgctacttc
 cagcaccag
 1921 cgtcactggg acgaaccagg ccctgttctt acaaggccac atggctggcc
 ctttgctcc
 1981 atggctactg tggtaagtgc agccttgtct gacccaatgc tgacctaatg
 ttggccattc
 2041 cacattgagg ggacaaggtc agtgatgcc cccttcactc acaagcactt
 cagaggcatg
 2101 cagagagaag ggacactcgg ccagctctct gaggtaatca gtgcaaggag
 gagtccgttt
 2161 tttgccagca aacctcagca ggatcacact ggaacagAAC ctggtcatac
 ctgtgacaac
 2221 acagctgtga gccagggcaa accaccact gtcactggct cgagagtctg
 ggcagaggct
 2281 ctgacctcc accctttaa ctggatgccg gggcctggct gggcccaatg
 ccaagtgggt
 2341 atggcaaccc tgactatctg gtcttaacat gtagctcagg aagtggaggc
 gctaattgtc
 2401 ccaatccctg gggattcctg attccagcta ttcattgaag cagagccaac
 ctgcctatct
 2461 ctgtaggtgc gactgggatg ttaggagcac agcaaggacc cagctctgta
 gggctgggtg

2521 cctgatactt ctcataatgg catctagaag ttaggctgag ttggcctcac
tggcccagca

2581 aaccagaact tgtctttgtc cgggccatgt tcttgggctg tcttctaatt
ccaagggtt

2641 gggttgtaaa gctccacccc cttctcctct gcctaaagac atcacatgtg
tatacacaca

2701 cgggtgtata gatgagttaa aagaatgtcc tcgctggcat cctaattttg
tcttaagttt

2761 ttttggaggg agaaaggaac aaggcaaggg aagatgtgta gctttggcct
taaccaggca

2821 gcctgggggc tcccaagcct atggaaccct ggtacaaaga agagaacaga
agcgccctgt

2881 gaggagtggg atttgttttt ctgtagacca gatgagaagg aaacaggccc
tgttttgtac

2941 atagttgcaa cttaaaattt ttggcttgca aaatattttt gtaataaaga
tttctgggta

3001 acaataaaaa aaaaaaaaaa

[SEQ ID NO:25]

Translation = MEPAGPAPGRLGPLLLCLLLSASCFTDNNATHNWNVFIGVGVA
CALLVLLMAALYLLRIKQKKAKGSTSSTRLHEPEKNAREITQIQDTNDINDITYADL
NLPKEKKPAPRAPEPNNHTEYASJETGKVRPEDTLTYADLDMVHLSRAQPAPKPEPS
FSEYASVQVQRK

LOCUS	NM_009020 3393 bp mRNA linear ROD 15-FEB-2015
DEFINITION	Mus musculus recombination activating gene 2 (Rag2), mRNA.
ACCESSION	NM_009020
VERSION	NM_009020.3 GI:144227233
SOURCE	Mus musculus (house mouse)

[SEQ ID NO:26]

1 actctaccct gcagccttca gcttggcaca aactaaacag tgactcttcc
ccaagtgccg

61 agtttaattc ctggcttggc cgaaaggatt cagagagggg taagcagccc
ctctggcctt

121 cagtgcctaaa ataagaaaga gtatttcaca tccacaagca ggaagtacac
ttcatacctc

181 tctaagataa aagacctatt cacaatcaaa aatgtccctg cagatggtaa
cagtgggtca

241 taacatagcc ttaattcaac caggcttctc acttatgaat tttgatggcc
aagttttctt

301 ctttggccag aaaggctggc ctaagagatc ctgtcctact ggagtccttc
 attttgatat
 361 aaaacaaaat catctcaaac tgaagcctgc aatcttctct aaagattcct
 gctacctccc
 421 acctcttcgt tatccagcta cttgctcata caaaggcagc atagactctg
 acaagcatca
 481 atatatcatt cacggaggga aaacaccaa caatgagctt tccgataaga
 tttatatcat
 541 gtctgtcgct tgcaagaata acaaaaaagt tactttccgt tgcacagaga
 aagacttagt
 601 aggagatgtc cctgaaccca gatacggccca ttccattgac gtggtgtata
 gtcgaggga
 661 aagcatgggt gttctctttg gaggacgttc atacatgcct tctaccaga
 gaaccacaga
 721 aaaatggaat agtgtagctg actgcctacc ccatgttttc ttgatagatt
 ttgaatttgg
 781 gtgtgctaca tcatatatc tcccagaact tcaggatggg ctgtcttttc
 atgtttctat
 841 tgccagaaac gataccgttt atattttggg aggacactca cttgccagta
 atatacgccc
 901 tgctaacttg tatagaataa gagtggacct tcccctgggt accccagcag
 tgaattgcac
 961 agtcttgcca ggaggaatct ctgtctccag tgcaatcctc actcaaaca
 acaatgatga
 1021 atttgttatt gtgggtggtt atcagctgga aaatcagaaa aggatggtct
 gcagccttgt
 1081 ctctctaggg gacaacacga ttgaaatcag tgagatggag actcctgact
 ggacctcaga
 1141 tattaagcat agcaaatat ggtttggaag caacatggga aacgggacta
 ttttccttgg
 1201 cataccagga gacaataagc aggctatgtc agaagcattc tatttctata
 ctttgagatg
 1261 ctctgaagag gatttgagtg aagatcagaa aattgtctcc aacagtcaga
 catcaacaga
 1321 agatcctggg gactccactc ctttgaaga ctgagaggaa ttttgtttca
 gtgctgaagc
 1381 aaccagtttt gatggtgacg atgaatttga cacctacaat gaagatgatg
 aagatgacga
 1441 gtctgtaacc ggctactgga taacatgttg ccctacttgt gatgttgaca
 tcaataacctg

1501 gggtccgttc tattcaacgg agctcaataa acccgccatg atctattggt
 ctcatgggga
 1561 tgggcactgg gtacatgccc agtgcattgga tttggaagaa cgcacactca
 tccacttgtc
 1621 agaaggaagc aacaagtatt attgcaatga acatgtacag atagcaagag
 cattgcaaac
 1681 tcccaaaaaga aacccccct tacaaaaacc tccaatgaaa tccctccaca
 aaaaaggctc
 1741 tgggaaagtc ttgactcctg ccaagaaatc cttccttaga agactgtttg
 attaatntag
 1801 caaaagcccc tcagactcag gtatatgtct ctctgaatct actttcaatc
 ataaacatta
 1861 ttttgatgtt tgtttactga aatctctatg ttatgtttta gttatgtgaa
 ttaagtgtg
 1921 ttgtgattta ttgttaagta taactattct aatgtgtgtt ttttaacatc
 ttatccagga
 1981 atgtcttaaa tgagaaatgt tatacagttt tccattaagg atatcagtga
 taaagtatag
 2041 aactcttaca ttattttgta acaatctaca tattgaatag taactaaata
 ccaataaata
 2101 aactaatgca caaaaagtta agttcttttg tgtaataagt agcctatagt
 tggtttaaac
 2161 agttaaaaacc aacagctata tcccacacta ctgctgttta taaatttta
 ggtggcctct
 2221 gggtttatact tatgagcaga attatatata ttgggtcaata ccatgaagaa
 aaatttaatt
 2281 ctatatcaag ccaggcatgg tgatgggtgat acatgcctgt aatcctggca
 cttaggaagt
 2341 ggaagaagga agtttgtgag tttgatgctt gttgaggtat gaccttttgc
 tatgtattgt
 2401 agtgtatgag cccaagacc tgcttgacct agagacaaga gagtccacac
 atagatccaa
 2461 gtaatgctat gtgaccttgc cccccggtta cttgtgatta ggtgaataaa
 gatgtcaaca
 2521 gccaatagct gggcagaaga gccaaaagtg gggattgagg gtaccctggc
 ttgatgtagg
 2581 aggagaccat gaggaaagg gagaaaaag tgatggagga ggagaaagat
 gccatgagct
 2641 aggagttaag aaagcatggc catgagtgtt ggccaattgg agttaagagc
 agcccagatg

2701 aaacatagta agtaataact cagggttatc gatagaaaat agatttttagt
 gccgtactct
 2761 cccagccct agagctgact atggcttact gtaaataata agtttgtatg
 tgtcttttat
 2821 ccaggaacta aatgggtcaaa ggtggagtag aaactctgga ttgggattaa
 atttttctac
 2881 aacaaatgct ggcctgggct agattttatc tcatatccga aggctgacag
 aacacagagc
 2941 actggaataa ttgccacctg ccatgcacaa agacctgagt ctaatactgt
 ggacattttc
 3001 ttgaagtatc tacatgtact tctggagtga aaacatatc caacaatatg
 cttttgttta
 3061 aatcactcac tcactttggg ccctcacatt atatcctttc aaaatcaatg
 gttcacccct
 3121 ttgaaaatgc ttagccatag tccctcatct tccttaaaga cagttgtcat
 ctctggaaat
 3181 agtcacatgt cattcaaggc ccaatactgt gcagctctga agtatggcat
 taccacttta
 3241 agtgaaaagt gaaatatgaa catgagctca gacaaagggt tgggactatc
 actctcaagg
 3301 aggctctact gctaagtcct gaactgcttt cacatgaata cagaaattat
 aacaaaaaat
 3361 atgtaatcaa taaaaagaaa actttcatat tcc

[SEQ ID NO:27]

Translation = MSLQMVTVGHNIALIQPGFSLMNF DGQVFFFGQKGWPKRSCPTG
 VFHFDIKQNLHLKLPALFISKDSCYLPPLRYPATCSYKGSIDSKHQYIIHGKTPNNE
 LSDKIYIMSVACKNNKKVTFRCTEKDLVGDVPEPRYGHSIDVVYSRGKSMGVLFGGRS
 YMPSTQRTTEKWNSVADCLPHVFLIDFEFGCATSYILPELQDGLSFHVSIARNDTVYI
 LGGHSLASNIRPANLYRIRVDLPLGTPAVNCTVLPGGISVSSAILTQTNNDEFVIVGG
 YQLENQKRMVCSLVSLGDNTEISEMETPDWTS DIKHSKIWFSGSNMNGTIFLGIPGD
 NKQAMSEAFYFYTLRCSEEDLSEDQKIVSNSQTSTEDPGDSTPFEDSEEFCSAEATS
 FDGDDEFDTYNEDDEDESVTGYWITCCPTCDVDINTWVPFYSTELNKPAMIYCSHGD
 GHWVHAQCMDLEERTLIHLSEGSNKYYCNEHVQIARALQTPKRNPLQKPPMKSLHKK
 GSGKVLTPAKKSFLRRLFD

LOCUS NM_013563 1612 bp mRNA linear ROD 15-FEB-2015
 DEFINITION Mus musculus interleukin 2 receptor, gamma chain(IL2rg), mRNA.
 ACCESSION NM_013563
 VERSION NM_013563.3 GI:118129799
 SOURCE Mus musculus (house mouse)

[SEQ ID NO:28]

1 gacacagact acaccagag aaagaagagc aagcaccatg ttgaaactat
 tattgtcacc
 61 tagatccttc ttagtccttc agctgctcct gctgagggca ggggtggagct
 ccaaggtcct
 121 catgtccagt gcgaatgaag acatcaaagc tgatttgatc ctgacttcta
 cagcccctga
 181 acacctcagt gctcctactc tgcccccttc agaggttcag tgctttgtgt
 tcaacataga
 241 gtacatgaat tgcacttga atagcagttc tgagcctcag gcaaccaacc
 tcacgctgca
 301 ctataggtac aaggtatctg ataataatac attccaggag tgcagtcact
 atttgttctc
 361 caaagagatt acttctggct gtcagataca aaaagaagat atccagctct
 accagacatt
 421 tgttggtccag ctccaggacc ccagaaaacc ccagaggcga gctgtacaga
 agctaaacct
 481 acagaatctt gtgatccac gggctccaga aaatctaaca ctgagcaatc
 tgagtgaatc
 541 ccagctagag ctgagatgga aaagcagaca tattaagaa cgctgtttac
 aatacttggg
 601 gcagtaccgg agcaacagag atcgaagctg gacggaacta atagtgaatc
 atgaacctag
 661 attctccctg cctagtgtgg atgagctgaa acggtacaca tttcgggttc
 ggagccgcta
 721 taacccaatc tgtggaagtt ctcaacagtg gagtaaatgg agccagcctg
 tccactggg
 781 gagtcatact gtagaggaga atccttcctt gtttgactg gaagctgtgc
 ttatccctgt
 841 tggcaccatg gggttgatta ttaccctgat ctttgtgtac tgttggttg
 aacgaatgcc
 901 tccaattccc cccatcaaga atctagagga tctggttact gaataccaag
 ggaacttttc
 961 ggcttgaggt ggtgtgtcta aagggtgac tgagagtctg cagccagact
 acagtgaacg

1021 gttctgccac gtcagcgaga ttcccccaa aggaggggcc ctaggagagg
ggcctggagg

1081 ttctccttgc agcctgcata gcccttactg gcctcccca tgttattctc
tgaagccgga

1141 agcctgaaca tcaatccttt gatggaacct caaagtccta tagtcctaag
tgacgctaac

1201 ctcccctact caccttgga atctggatcc aatgctcact gccttcctt
ggggctaagt

1261 ttcgatttcc tgtcccatgt aactgctttt ctgttccata tgccctactt
gagagtgtcc

1321 cttgccctct ttccctgcac aagccctccc atgccagcc taacacctt
ccactttctt

1381 tgaagagagt cttaccctgt agccagggt ggctgggagc tcactatgta
ggccagggtg

1441 gcctccaact cacaggctat cctccacact ctgcctcata agagttggg
ttactggcat

1501 gcaccaccac acccagcatg gtccttctct tttataggat tctccctccc
tttttctacc

1561 tatgattcaa ctgtttccaa atcaacaaga aataaagttt ttaaccaatg at

[SEQ ID NO:29]

Translation = MLKLLSPRSFLVLQLLLLRAGWSSKVLMSANEDIKADLIITS
TAPEHLSAPTLPLPEVQCFVFNIEYMNCTWNSSEPQATNLTLYRYKVSDNNTFQEC
SHYLFKEITSGCQIQKEDIQLYQTFVVQLQDPQKPQRRVQKLNQLNVI PRAPENL
TLSNLSESQLELRWKSRIKERCLQYLQYRSNRDRSWTELIVNHEPRFSLPSVDELK
RYTFRVRSRYNPICGSSQQWSKWSQPVHWGSHTVEENPSLFALEAVLIPVGTMGIIIT
LIFVYCWLERMPPPIPIKNLEDLVTEYQGNFSAWSGVSKGLTESLQPDYSERFCHVSE
IPPKGGALGEGPGGSPCSLHSPYWPPPCYSLKPEA

LOCUS	NM_000585 2012 bp mRNA linear PRI 15-MAR-2015
DEFINITION	Homo sapiens interleukin 15 (IL15), transcript variant 3, mRNA.
ACCESSION	NM_000585
VERSION	NM_000585.4 GI:323098327
SOURCE	Homo sapiens (human)

[SEQ ID NO:30]

1 gttgggactc cgggtggcag gcgcccgggg gaatcccagc tgactcgctc
actgccttcg

61 aagtccggcg cccccggga gggaactggg tggccgcacc ctcccggctg
cggtggctgt

121 cgccccccac cctgcagcca ggactcgatg gagaatccat tccaatatat
 ggccatgtgg
 181 ctcttttgag caatgttcca tcatgttcca tgctgctgac gtcacatgga
 gcacagaaat
 241 caatgttagc agatagccag cccatacaag atcgtattgt attgtaggag
 gcattgtgga
 301 tggatggctg ctggaaaccc cttgccatag ccagctcttc ttcaatactt
 aaggatttac
 361 cgtggctttg agtaatgaga atttcgaaac cacatttgag aagtatttcc
 atccagtgt
 421 acttgtgttt acttctaaac agtcattttc taactgaagc tggcattcat
 gtcttcattt
 481 tgggctgttt cagtgcaggg cttcctaaaa cagaagccaa ctgggtgaat
 gtaataagtg
 541 atttgaaaaa aattgaagat cttattcaat ctatgcatat tgatgctact
 ttatatacgg
 601 aaagtgatgt tcaccccagt tgcaaagtaa cagcaatgaa gtgctttctc
 ttggagttac
 661 aagttatttc acttgagtcc ggagatgcaa gtattcatga tacagtagaa
 aatctgatca
 721 tcctagcaaa caacagtttg tcttctaatag ggaatgtaac agaactctgga
 tgcaaagaat
 781 gtgaggaact ggaggaaaaa aatattaaag aatttttgca gagttttgta
 catattgtcc
 841 aaatgttcat caacacttct tgattgcaat tgattctttt taaagtgttt
 ctgttattaa
 901 caaacatcac tctgctgctt agacataaca aaacactcgg catttcaaat
 gtgctgtcaa
 961 aacaagtttt tctgtcaaga agatgatcag accttggatc agatgaactc
 ttagaaatga
 1021 aggcagaaaa atgtcattga gtaatatagt gactatgaac ttctctcaga
 cttactttac
 1081 tcattttttt aatttattat tgaaattgta catatttggtg gaataatgta
 aaatgttgaa
 1141 taaaaatatg tacaagtgtt gttttttaag ttgcactgat attttacctc
 ttattgcaaa
 1201 atagcatttg tttaagggtg atagtcaa atgtatttg tggggctggg
 taccaatgct
 1261 gcaggatcaac agctatgctg gtaggctcct gccagtgtgg aaccactgac
 tactggctct

1321 cattgacttc cttactaagc atagcaaaca gaggaagaat ttgttatcag
taagaaaaag

1381 aagaactata tgtgaatcct cttctttata ctgtaattta gttattgatg
tataaagcaa

1441 ctgttatgaa ataaagaaat tgcaataact ggcatataat gtccatcagt
aatcttgggt

1501 ggtgggtggca ataataaact tctactgata ggtagaatgg tgtgcaagct
tgtccaatca

1561 cggattgcag gccacatgcg gcccaggaca actttgaaatg tggcccaaca
caaattcata

1621 aactttcata catctcgttt ttagctcatc agctatcatt agcggtagtg
tatttaaagt

1681 gtggcccaag acaattcttc ttattccaat gtggcccagg gaaatcaaaa
gattggatgc

1741 ccctgggtata gaaaactaat agtgacagtg ttcataatttc atgctttccc
aaatacaggt

1801 atttttatattt cacattcttt ttgccatggt tatataataa taaagaaaaa
ccctgttgat

1861 ttgttggagc cattgttatc tgacagaaaa taattgttta tattttttgc
actacactgt

1921 ctaaaattag caagctctct tctaattggaa ctgtaagaaa gatgaaatat
ttttgtttta

1981 ttataaattt atttcacctt aaaaaaaaaa aa

[SEQ ID NO:31]

Translation = MRISKPHLRISISIQCYLCLLLNSHFLTEAGIHVFI LGCF SAGLP
KTEANWVNVISDLKKIEDLIQSMHIDATLYTESDVHP SCKVTAMKCF LLELQVISLES
GDASIHDTV ENLIILANNSLSSNGNVTESGCKECEEELEEKNIKEFLQSFVHIVQMFIN
TS

LOCUS	NM_172175 2333 bp mRNA linear PRI 15-MAR-2015
DEFINITION	Homo sapiens interleukin 15 (IL15), transcript variant 2, mRNA.
ACCESSION	NM_172175
VERSION	NM_172175.2 GI:323098328
SOURCE	Homo sapiens (human)

[SEQ ID NO:32]

1 gttgggactc cgggtggcag gcgcccgggg gaatcccagc tgactcgctc
actgccttcg

61 aagtcgggcg cccccggga gggaactggg tggccgcacc ctcccggtg
cggtggctgt

121 cgccccccac cctgcagcca ggactcgatg gagaatccat tccaatatat
 ggccatgtgg
 181 ctcttttgag caatgttcca tcatgttcca tgctgctgac gtcacatgga
 gcacagaaat
 241 caatgttagc agatagccag cccatacaag atcgttttca actagtggcc
 ccactgtgtc
 301 cggaattgat gggttcttgg tctcactgac ttcaagaatg aagccgcgga
 ccctcgcggt
 361 gagtgttaca gctcttaagg tggcgcatct ggagtttggt ctttctgatg
 ttcggatgtg
 421 ttcggagttt cttccttctg gtgggttcgt ggtctcgctg gctcaggagt
 gaagctacag
 481 accttcgcgg aggcattgtg gatggatggc tgctggaaac cccttgccat
 agccagctct
 541 tcttcaatac ttaaggattt accgtggctt tgagtaatga gaatttcgaa
 accacatttg
 601 agaagtattt ccatccagtg ctacttgtgt ttacttctaa acagtcattt
 tctaactgaa
 661 gctggcattc atgtcttcat tttgggatgc agctaataa cccagttggc
 ccaaagcacc
 721 taacctatag ttatataatc tgactctcag ttcagtttta ctctactaat
 gccttcatgg
 781 tattgggaac catagatttg tgcagctggt tcagtgacagg gcttcctaaa
 acagaagcca
 841 actgggtgaa tgtaataagt gatttgaaaa aaattgaaga tcttattcaa
 tctatgcata
 901 ttgatgctac tttatatacg gaaagtgatg ttcaccccag ttgcaaagta
 acagcaatga
 961 agtgctttct cttggagtta caagttattt cacttgagtc cggagatgca
 agtattcatg
 1021 atacagtaga aaatctgatc atcctagcaa acaacagttt gtcttctaata
 gggaatgtaa
 1081 cagaatctgg atgcaaagaa tgtgaggaac tggaggaaaa aaatattaaa
 gaatttttgc
 1141 agagttttgt acatattgtc caaatgttca tcaacacttc ttgattgcaa
 ttgattcttt
 1201 ttaaagtgtt tctgttatta acaaactca ctctgctgct tagacataac
 aaaacactcg
 1261 gcatttcaaa tgtgctgtca aaacaagttt ttctgtcaag aagatgatca
 gaccttggat

1321 cagatgaact cttagaaatg aaggcagaaa aatgtcattg agtaatatag
 tgactatgaa
 1381 cttctctcag acttacttta ctcatTTTTT taatttatta ttgaaattgt
 acatatttgt
 1441 ggaataatgt aaaatgttga ataaaaatat gtacaagtgt tgTTTTTTaa
 gttgcactga
 1501 tattttacct cttattgcaa aatagcattt gtttaagggt gatagtcaaa
 ttatgtattg
 1561 gtggggctgg gtaccaatgc tgcaggtaa cagctatgct ggtaggctcc
 tgccagtgtg
 1621 gaaccactga ctactggctc tcattgactt cttactaag catagcaaac
 agaggaagaa
 1681 tttgttatca gtaagaaaaa gaagaactat atgtgaatcc tcttctttat
 actgtaattt
 1741 agttattgat gtataaagca actgttatga aataaagaaa ttgcaataac
 tggcatataa
 1801 tgtccatcag taaatcttgg tgggtggtggc aataataaac ttctactgat
 aggtagaatg
 1861 gtgtgcaagc ttgtccaatc acggattgca ggccacatgc ggcccaggac
 aactttgaat
 1921 gtggcccaac acaaattcat aaactttcat acatctcggt tttagctcat
 cagctatcat
 1981 tagcggtagt gtatttaaag tgtggcccaa gacaattctt cttattccaa
 tgtggcccag
 2041 ggaaatcaaa agattggatg cccctggtat agaaaactaa tagtgacagt
 gttcatattt
 2101 catgctttcc caaatacagg tattttattt tcacattctt ttgccatgt
 ttatataata
 2161 ataaagaaaa accctgttga tttgttgag ccattgttat ctgacagaaa
 ataattgttt
 2221 atattttttg cactacactg tctaaaatta gcaagctctc ttctaattga
 actgtaagaa
 2281 agatgaaata tttttgtttt attataaatt tatttcacct taaaaaaaaa aaa

[SEQ ID NO:33]

Translation = MVLGTIDLCSCFSAGLPKTEANWVNVISDLKKIEDLIQSMHIDA

TLYTESDVHPSCKVTAMKCFLLLELQVISLES GDASIHD TVENLIILANNSLSSNGNV

ESGCKECEEELEEKNIKEFLQSFVHIVQMFINTS

LOCUS NM_008357 1297 bp mRNA linear ROD 15-FEB-2015
 DEFINITION Mus musculus interleukin 15 (Il15), transcript
 variant 1, mRNA.
 ACCESSION NM_008357
 VERSION NM_008357.2 GI:363000959
 SOURCE Mus musculus (house mouse)

[SEQ ID NO:34]

1 ttcttgacca agacttcaat actcagtggc actgtattcc ctttctgtcc
 agccactctt
 61 cccagaggtt ctctttcttca tcctccccct tgcagagtag ggcagcttgc
 aggtcctcct
 121 gcaagtctct cccaattctc tgcgccccaa agacttgagc tgcattctct
 tacgcgctgc
 181 agggaccttg ccagggcagg actgcccccg ccagttgca gaggtagacg
 aagacgggat
 241 cctgctgtgt ttggaaggct gaggccaca tctaacagct cagagaggct
 aggaagaat
 301 ccaccttgac acatggccct ctggctcttc aaagcactgc ctcttcatgg
 tccttgctgg
 361 tgaggctcctt aagaacacag aaacccatgt cagcagataa ccagcctaca
 ggaggccaag
 421 aagagttctg gatggatggc agctggaagc ccatcgccat agccagctca
 tttcaacat
 481 tgaagctctt acctgggcat taagtaatga aaattttgaa accatatatg
 aggaatacat
 541 ccatctcgtg ctacttggtt ttccttctaa acagtcactt ttaactgag
 gctggcattc
 601 atgtcttcat tttgggctgt gtcagtgtag gtctccctaa aacagaggcc
 aactggatag
 661 atgtaagata tgacctggag aaaattgaaa gccttattca atctattcat
 attgacacca
 721 ctttatacac tgacagtgac tttcatccca gttgcaaagt tactgcaatg
 aactgctttc
 781 tcctggaatt gcagggttatt ttacatgagt acagtaacat gactcttaat
 gaaacagtaa
 841 gaaacgtgct ctaccttgca aacagcactc tgtcttctaa caagaatgta
 gcagaatctg
 901 gctgcaagga atgtgaggag ctggaggaga aaaccttcac agagtttttg
 caaagcttta
 961 tacgcattgt ccaaattgtc atcaacacgt cctgactgca tgcgagcctc
 ttccgtgttt

1021 ctgttatttaa ggtacctcca cctgctgctc agaggcagca cagctccatg
catttgaaat

1081 ctgctgggca aactaagctt cctaacaagg agataatgag ccacttggat
cacatgaaat

1141 cttggaaatg aagagaggaa aagagctcgt ctcagactta tttttgcttg
cttattttta

1201 atttattgct tcatttgtac atatttgtaa tataacagaa gatgtggaat
aaagttgtat

1261 ggatatttta tcaattgaaa tttaaaaaaaa aaaaaaa

[SEQ ID NO:35]

Translation = MKILKPYMRNTSISCYLCFLNSHFLTEAGIHVFI LGCVSVGLP
KTEANWIDVRYDLEKIESLIQSIHIDTTLYTDSDFHPSCKVTAMNCFLELQVILHEY
SNMTLNETVRNVLYLANSTLSSNKNVAESGCKECEEELEEKTFTEFLQSFIRIVQMFIN
TS

LOCUS	NM_001254747 1287 bp mRNA linear ROD 15-FEB-2015
DEFINITION	Mus musculus interleukin 15 (Il15), transcript variant 2, mRNA.
ACCESSION	NM_001254747
VERSION	NM_001254747.1 GI:363000983
SOURCE	Mus musculus (house mouse)

[SEQ ID NO:36]

1 ttcttgacca agacttcaat actcagtggc actgtattcc cttctgtcc
agccactctt

61 cccagaggtt ctctttcttca tcctccccct tgcagagtag ggcagcttgc
aggctcctct

121 gcaagtctct cccaattctc tgcgccccaa agacttgcag tgcattctct
tacgcgctgc

181 agggaccttg ccagggcagg actgcccccg ccagttgca gagttggacg
aagacgggat

241 cctgctgtgt ttggaaggct gagttccaca tctaacagct cagagagaat
ccaccttgac

301 acatggccct ctggctcttc aaagcactgc ctcttcatgg tccttgctgg
tgaggtcctt

361 aagaacacag aaacccatgt cagcagataa ccagcctaca ggaggccaag
aagagttctg

421 gatggatggc agctggaagc ccatcgccat agccagctca tcttcaacat
tgaagctctt

481 acctgggcat taagtaatga aaattttgaa accatatatg aggaatacat
ccatctcgtg

541 ctacttgtgt ttccttctaa acagtcactt tttaactgag gctggcattc
 atgtcttcat
 601 tttgggctgt gtcagtgtag gtctccctaa aacagaggcc aactggatag
 atgtaagata
 661 tgacctggag aaaattgaaa gccttattca atctattcat attgacacca
 ctttatacac
 721 tgacagtgac tttcatccca gttgcaaagt tactgcaatg aactgccttc
 tcctggaatt
 781 gcaggttatt ttacatgagt acagtaacat gactcttaat gaaacagtaa
 gaaacgtgct
 841 ctaccttgca aacagcactc tgtcttctaa caagaatgta gcagaatctg
 gctgcaagga
 901 atgtgaggag ctggaggaga aaaccttcac agagtttttg caaagcttta
 tacgcattgt
 961 ccaaattgttc atcaacacgt cctgactgca tgcgagcctc ttccgtgttt
 ctgttattaa
 1021 ggtacctcca cctgctgctc agaggcagca cagctccatg catttgaaat
 ctgctgggca
 1081 aactaagctt cctaacaagg agataatgag ccacttggat cacatgaaat
 ctgggaaatg
 1141 aagagaggaa aagagctcgt ctcagactta tttttgcttg cttattttta
 atttattgct
 1201 tcatttgtac atatttgtaa tataacagaa gatgtggaat aaagttgtat
 ggatatttta
 1261 tcaattgaaa tttaaaaaaa aaaaaa

[SEQ ID NO:35]

Translation = MKILKPYMRNTSISCYLCFLLSHFLTEAGIHVFILGCVSVGLP
 KTEANWIDVRYDLEKIESLIQSIHIDTTLYTDSDFHPSCKVTAMNCFLELQVILHEY
 SNMTLNETVRNVLYLANSTLSSNKNVAESGCKECELEEKTFTEFLQSFIRIVQMFIN
 TS

CLAIMS

1. A genetically modified mouse, comprising:

a nucleic acid sequence incorporated into the genome of the genetically modified mouse, which sequence encodes a human SIRP α protein and is operably linked to a SIRP α gene promoter; and

a nucleic acid sequence incorporated into the genome of the genetically modified mouse, which sequence encodes a human IL-15 protein and is operably linked to an IL-15 gene promoter, wherein the genetically modified mouse expresses the human SIRP α protein and the human IL-15 protein.

2. The genetically modified mouse according to claim 1, wherein the SIRP α gene promoter is an endogenous mouse SIRP α gene promoter at the mouse SIRP α gene locus.
3. The genetically modified mouse according to claim 1, wherein the genetically modified mouse is heterozygous for the allele comprising the nucleic acid sequence that encodes the human SIRP α protein.
4. The genetically modified mouse according to claim 1, wherein the genetically modified mouse is homozygous for the allele comprising the nucleic acid sequence that encodes the human SIRP α protein.
5. The genetically modified mouse according to claim 1, wherein the IL-15 gene promoter is an endogenous mouse IL-15 gene promoter at the mouse IL-15 gene locus.
6. The genetically modified mouse according to claim 5, wherein the genetically modified mouse is heterozygous for the allele comprising the nucleic acid sequence that encodes the human IL-15 protein.
7. The genetically modified mouse according to claim 5, wherein the genetically modified mouse is homozygous for the allele comprising the nucleic acid sequence that encodes the human IL-15 protein.
8. The genetically modified mouse according to claim 1, wherein the nucleic acid sequence that encodes the human IL-15 protein comprises human IL-15 genomic coding and non-coding sequence.

9. The genetically modified mouse according to claim 1, wherein the human IL-15 protein is a functional fragment of a full length human IL-15 protein.
10. The genetically modified mouse according to claim 1, wherein the genetically modified mouse is immunodeficient.
11. The genetically modified mouse according to claim 10, wherein the genetically modified mouse comprises a Rag2 gene knock-out.
12. The genetically modified mouse according to claim 10, wherein the genetically modified mouse comprises an IL2rg gene knock-out.
13. The genetically modified mouse according to claim 1, wherein the genetically modified mouse comprises an engraftment of human hematopoietic cells.
14. The genetically modified mouse according to claim 13, wherein the genetically modified mouse comprises an infection with a human pathogen.
15. The genetically modified mouse according to claim 14, wherein the human pathogen activates, induces and/or targets T cells and/or natural killer (NK) cells.
16. The genetically modified-mouse according to claim 14, wherein the human pathogen is a pathogen that infects human intestine.
17. The genetically modified mouse according to claim 14, wherein the pathogen infects human lung.
18. A method of making a mouse expressing a human IL-15 protein and a human SIRP α protein, comprising:

introducing into a genome of a first mouse a nucleic acid sequence encoding a human SIRP α protein, wherein the sequence encoding the human SIRP α protein is operably linked to an SIRP α gene promoter sequence;

introducing into a genome of a second mouse a nucleic acid sequence encoding a human IL-15 protein, wherein the sequence encoding the human IL-15 protein is operably linked to a IL-15 promoter sequence; and

breeding the first mouse and the second mouse to produce a third mouse that comprises the nucleic acid sequence encoding the human IL-15 protein and the nucleic acid sequence encoding the human SIRP α protein, wherein the third mouse expresses the human IL-15 protein and the human SIRP α protein.

19. The method of claim 18, wherein the steps of introducing comprise generating a mouse from a pluripotent stem cell comprising the nucleic acid encoding human IL-15 or human SIRP α .

20. An animal engraftment model, comprising a genetically modified mouse comprising:

a nucleic acid sequence incorporated into the genome of the genetically modified mouse, which sequence encodes a human SIRP α protein and is operably linked to a SIRP α gene promoter;

a nucleic acid sequence incorporated into the genome of the genetically modified mouse, which sequence encodes a human IL-15 protein and is operably linked to an IL-15 gene promoter; and

an engraftment of human hematopoietic cells, wherein the genetically modified mouse (i) expresses the human SIRP α protein and the human IL-15 protein, and (ii) comprises human intraepithelial lymphocytes (IELs) in the small intestine and Peyer's patches of the genetically modified mouse.

21. A method of identifying an agent that inhibits an infection by a pathogen that activates, induces and/or targets human T cells and/or natural killer (NK) cells, the method comprising:

administering an agent to an genetically modified mouse, wherein the genetically modified mouse is deficient for an endogenous immune system and comprises:

(i) a nucleic acid sequence incorporated into the genome of the genetically modified mouse, which sequence encodes a human SIRP α protein and is operably linked to a SIRP α gene promoter,

(ii) a nucleic acid sequence incorporated into the genome of the genetically modified mouse, which sequence encodes a human IL-15 protein and is operably linked to an IL-15 gene promoter,

- (iii) an engraftment of human hematopoietic cells, and
- (iv) an infection by a pathogen that activates, induces and/or targets human T cells and/or natural killer cells, wherein the genetically modified mouse expresses the human SIRP α protein and the human IL-15 protein; and

determining whether the agent reduces the amount of the pathogen in the pathogen-infected mouse.

22. A method of determining the efficacy a candidate therapeutic antibody or antigen-binding protein in NK-cell mediated killing of a target cell, comprising:

administering the candidate therapeutic antibody or antigen-binding protein to a genetically modified mouse, wherein the genetically modified mouse is deficient for an endogenous immune system and comprises:

- (i) a nucleic acid sequence incorporated into the genome of the genetically modified-mouse, which sequence encodes a human SIRP α protein and is operably linked to a SIRP α gene promoter,
- (ii) a nucleic acid sequence incorporated into the genome of the genetically modified mouse, which sequence encodes a human IL-15 protein and is operably linked to an IL-15 gene promoter, and
- (iii) an engraftment of human hematopoietic cells, wherein the genetically modified mouse expresses the human SIRP α protein and the human IL-15 protein; and

determining whether the candidate therapeutic antibody or antigen-binding protein activates NK cell antibody-dependent cellular cytotoxicity against the target cell in the genetically modified mouse.

23. The genetically modified mouse according to claim 2, comprising a null mutation in the mouse SIRP α gene at the mouse SIRP α gene locus.

24. The genetically modified mouse according to claim 23, wherein the null mutation is a deletion of at least mouse SIRP α exons 2-4.

25. The genetically modified mouse according to claim 1, wherein the human SIRP α protein is a functional fragment of a full length human SIRP α protein.
26. The genetically modified mouse according to claim 25, wherein the functional fragment comprises an extracellular domain of human SIRP α .
27. The genetically modified non-human animal according to claim 5, comprising a null mutation in the non-human IL-15 gene at the non-human animal IL-15 gene locus.
28. The genetically modified mouse according to claim 27, wherein the null mutation is a deletion of at least mouse IL-15 exons 5-8.