

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization  
International Bureau



(43) International Publication Date  
24 February 2011 (24.02.2011)

PCT

(10) International Publication Number  
**WO 2011/022334 A1**

(51) International Patent Classification:

*A61K 38/17* (2006.01)    *A61P 3/00* (2006.01)  
*A61K 39/395* (2006.01)    *A61P 9/00* (2006.01)  
*A61P 3/10* (2006.01)    *A61P 29/00* (2006.01)

(21) International Application Number:

PCT/US2010/045627

(22) International Filing Date:

16 August 2010 (16.08.2010)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

61/234,425    17 August 2009 (17.08.2009)    US  
61/304,113    12 February 2010 (12.02.2010)    US

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

- with international search report (Art. 21(3))
- with sequence listing part of description (Rule 5.2(a))



WO 2011/022334 A1

(54) Title: USE OF NKG2D INHIBITORS FOR TREATING CARDIOVASCULAR AND METABOLIC DISEASES, SUCH AS TYPE 2 DIABETES

(57) Abstract: The present invention provides methods, compositions and kits for treating and detecting type 2 diabetes and/or conditions that may be regulated or normalised via inhibition of NKG2D, such as cardiovascular diseases.

## USE OF NKG2D INHIBITORS FOR TREATING CARDIOVASCULAR AND METABOLIC DISEASES, SUCH AS TYPE 2 DIABETES

### FEDERALLY SPONSORED RESEARCH

5 [0001] This invention was made with government support under Grant No. PEN04143, awarded by The United States Department of Agriculture and Grant No. CA093678, awarded by the National Institutes of Health (NIH). The Government has certain rights in the invention.

### 10 REFERENCE TO RELATED APPLICATIONS

[0002] This application claims the benefit of and priority under 35 U. S. C. § 119(e) to U.S. Provisional Application Serial No. 61/234,425, filed August 17, 2009 and U.S. Provisional Application Serial No. 61/304,113, filed February 12, 2010, which are incorporated by reference in their entirety.

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### FIELD OF THE INVENTION

[0003] The present invention relates to methods of treating type 2 diabetes and/or conditions that may be regulated or normalised via inhibition of NKG2D, such as cardiovascular diseases.

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### BACKGROUND OF THE INVENTION

[0004] A large and growing number of people suffer from diabetes mellitus. Diabetes mellitus, also commonly known as diabetes, is a metabolic disorder that results in elevation of the blood glucose level because of relative or absolute  
25 deficiency in the pancreatic hormone insulin. Insulin is secreted from the pancreas into the blood in response to the blood glucose level and a major function is to direct blood glucose into body stores, whereby the blood glucose level is controlled.

**[0005]** Diabetes is known in the Type 1 and Type 2 forms. Type 1 diabetes is characterized by a progressive loss of pancreatic beta cells due to an unfavourable balance between the destructive autoimmune processes targeting the beta cells on one side and the regenerative capacity of these cells on the other side. This imbalance eventually leads to total loss of beta cells and endogenous insulin secretion. Type 1 diabetes accounts for 5-10 % of diabetes. Type 2 diabetes is characterized by insulin resistance and impaired beta cell function, which includes impaired first phase insulin release, reduced beta cell pulse mass and insulin deficiency. Type 2 diabetes is the most common form of the disease, accounting for 90-95 % of diabetes.

**[0006]** People with diabetes are two to four times more likely to develop cardiovascular disease than people without diabetes. Cardiovascular disease is the major complication and leading cause of death in people with type 2 diabetes despite considerable improvements in therapy over the past decades. An increased risk of heart attack, stroke and amputation of the lower limbs are the major causes of premature death in people with diabetes. A higher prevalence of cardiovascular disease risk factors including obesity, hypertension, dyslipidemia and physical inactivity are usually present in the presence of type 2 diabetes.

**[0007]** Cardiovascular diseases are the most serious human health concern and the number one cause of death in the United States (U.S.). According to the American Heart Association, the cost for cardiovascular disease prevention and therapy will be an astonishing \$448.5 billion for 2008 in the U.S. alone, resulting in a huge financial burden for the society. Atherosclerosis is a form of cardiovascular diseases in which plaques, composed of fatty substances and cellular components, build up in the inner lining of arterial vessels. The disease is initiated by abnormal metabolites deposited in susceptible regions of artery of patients with dysfunctional metabolic conditions, such as diabetes, and progresses with the involvement of multiple factors, including immune activation and inflammation.

**[0008]** Abnormal metabolic conditions, such as diabetes, cause various cellular stress responses that induce tissue inflammation and immune cell activation, which in turn exacerbates the metabolic dysfunction, creating a vicious cycle that sustains the downstream outcomes that underlie disorders such as cardiovascular

disease progression. However, molecular events linking these processes are not well understood, hindering efforts to modulate the immune system for the treatment of the metabolic dysfunction and cardiovascular disease complications.

[0009] Accordingly, there is a need for effective methods for the prediction,  
5 prevention and treatment of metabolic dysfunction-associated diseases, such as diabetes as well as cardiovascular diseases and disorders.

### SUMMARY OF THE INVENTION

[0010] The present invention concerns the discovery of a family of immune  
10 stimulatory molecules that are upregulated in patients and animals with type 2 diabetes and/or metabolic dysfunctions and that might play an important role in activation of the immune cells for vascular and liver inflammation, metabolic dysfunction and cardiovascular disease development. In particular, elevated levels of stimulatory ligands for NKG2D, a potent immune activating receptor, were  
15 detected in type 2 diabetic human patients as well as in animal models for dysfunctional lipid metabolism and atherosclerosis.

[0011] Accordingly, the present invention provides novel methods, compositions and kits for treating type 2 diabetes and conditions that may be regulated or normalized via inhibition of NKG2D, such as cardiovascular disease. The present  
20 invention also provides novel methods for detecting and diagnosing a predisposition to type 2 diabetes or cardiovascular disease development or the presence of type 2 diabetes or cardiovascular disease.

[0012] In one embodiment, the present invention provides a method of treating type 2 diabetes comprising administering to a subject in need thereof a  
25 therapeutically effective amount of an agent that inhibits NKG2D activation or signaling. In another embodiment, the present invention provides a method of treating type 2 diabetes comprising administering to a subject in need thereof a therapeutically effective amount of an agent that blocks the NKG2D ligand binding interaction. In another embodiment, the present invention provides a method of  
30 treating a condition that may be regulated or normalized via inhibition of NKG2D

comprising administering to a subject in need thereof a therapeutically effective amount of an agent that inhibits NKG2D activation or signaling, wherein the condition is selected from the group consisting of type 2 diabetes, cardiovascular disease, inflammatory disease and metabolic dysfunction-associated disease. In another embodiment, the present invention provides a method of treating a condition that may be regulated or normalized via inhibition of NKG2D comprising administering to a subject in need thereof a therapeutically effective amount of an agent that blocks the NKG2D ligand binding interaction, wherein the condition is selected from the group consisting of type 2 diabetes, cardiovascular disease, inflammatory disease and metabolic dysfunction-associated disease.

**[0013]** In another embodiment, the present invention relates to the use of a therapeutically effective amount of an agent that inhibits NKG2D activation or signaling in a subject for treating type 2 diabetes. In another embodiment, the present invention relates to the use of a therapeutically effective amount of an agent that blocks the NKG2D ligand binding interaction in a subject for treating type 2 diabetes. In another embodiment, the present invention relates to the use of a therapeutically effective amount of an agent that inhibits NKG2D activation or signaling in a subject for treating a condition that may be regulated or normalized via inhibition of NKG2D, wherein the condition is selected from the group consisting of type 2 diabetes, cardiovascular disease, inflammatory disease and metabolic dysfunction-associated diseases. In another embodiment, the present invention relates to the use of a therapeutically effective amount of an agent that blocks the NKG2D ligand binding interaction in a subject for treating a condition that may be regulated or normalized via inhibition of NKG2D, wherein the condition is selected from the group consisting of type 2 diabetes, cardiovascular disease, inflammatory disease and metabolic dysfunction-associated disease.

**[0014]** In some embodiments, the condition that may be regulated or normalized via inhibition of NKG2D is type 2 diabetes. In some embodiments, the condition is cardiovascular disease.

**[0015]** In some embodiments, the subject is human.

**[0016]** In some embodiments, the agent is selected from the group consisting of soluble NKG2D, an antibody or antigen-binding fragment thereof that specifically binds NKG2D, an NKG2D ligand and an inhibitor of NKG2D ligand activity or expression. In some embodiments, the agent is an antibody or antigen-binding  
5 fragment thereof that specifically binds NKG2D. In some embodiments, the antibody or antigen-binding fragment thereof is human or humanized. In some embodiments, the antibody or antigen-binding fragment thereof binds human NKG2D (hNKG2D). In some embodiments, the antibody or antigen-binding fragment thereof reduces NKG2D-mediated activation or signaling of an NKG2D-expressing cell. In some  
10 embodiments, the antibody or antigen-binding fragment thereof competes with at least one NKG2D ligand in binding to NKG2D. In some embodiments, the NKG2D ligand is MICA/B.

**[0017]** In some embodiments, administration of the agent results in at least one of the following in the subject: reduces blood glucose levels, improves glucose  
15 tolerance, lowers insulin resistance, reduces body weight, lowers blood pressure, lowers inflammation or reduces metabolic dysfunctions.

**[0018]** In some embodiments, the agent is administered intravenously, intraperitoneally or subcutaneously.

**[0019]** In some embodiments, the methods of the present invention further  
20 comprises at least one additional agent selected from the group consisting of antidiabetic agents, antiobesity agents, appetite regulating agents, antihypertensive agents, agents for the treatment and/or prevention of complications resulting from or associated with diabetes and agents for the treatment and/or prevention of complications and disorders resulting from or associated with obesity. In some  
25 embodiments, the additional agent is selected from the group consisting of (a) a blood glucose lowering agent selected from the group consisting of GLP-1 and GLP-1 derivatives and analogues, Exendin-4 and Exendin-4 derivatives and analogues, amylin and amylin derivatives and analogues, sulphonylureas, biguanides, meglitinides (such as nateglinide and repaglinide), glucosidase inhibitors, DPP-IV  
30 (dipeptidyl peptidase-IV) inhibitors, SGLT2 inhibitors, SGLT1 inhibitors or agonists, gastrin and gastrin analogues and derivatives, FGF-21 (fibroblast growth factor 21) and FGF-21 derivatives and analogues, proton pump inhibitors such as

lansoprazole, omeprazole, dexlansoprazole, esomeprazole, pantoprazole, and rabeprazole, RXR agonists, Cholestyramine, colestipol, probucol, dextrothyroxine, PPAR agonists, and adiponectin and adiponectin derivatives and analogues; (b) a blood lipid lowering or lipid metabolism modifying agent selected from the group consisting of antihyperlipidemic agents, HMG CoA inhibitors (statins) such as lovastatin, pravastatin and simvastatin, and fibrates such as gemfibrozil and clofibrate; (c) an agent that lowers food intake or increases energy expenditure selected from the group consisting of NPY (neuropeptide Y) antagonists, PYY (polypeptide YY) agonists, PP (pancreatic polypeptide) agonists, Y2 receptor agonists, Y4 receptor agonists, mixed Y2/Y4 receptor agonists, MC4 (melanocortin 4) agonists, orexin antagonists, glucagon and glucagon derivatives and analogues, CRF (corticotropin releasing factor) agonists, CRF BP (corticotropin releasing factor binding protein) antagonists, urocortin agonists,  $\beta$ 3 agonists, MSH (melanocyte-stimulating hormone) agonists, MCH (melanocyte-concentrating hormone) antagonists, CCK (cholecystokinin) agonists, serotonin re-uptake inhibitors, serotonin and noradrenaline re-uptake inhibitors, mixed serotonin and noradrenergic compounds, 5HT (serotonin) agonists, bombesin agonists, galanin antagonists, growth hormone, growth hormone releasing compounds, TRH (thyrotropin releasing hormone) agonists, UCP 2 or 3 (uncoupling protein 2 or 3) modulators, leptin agonists, DA agonists (bromocriptin, dorexin), lipase/amylase inhibitors, RXR (retinoid X receptor) modulators, histamine H3 antagonists, and CART (cocaine amphetamine regulated transcript) agonists; and (d) a blood pressure lowering agent selected from the group consisting of  $\beta$ -blockers such as alprenolol, atenolol, timolol, pindolol, propranolol and metoprolol, ACE (angiotensin converting enzyme) inhibitors such as benazepril, captopril, enalapril, fosinopril, lisinopril, alatriopril, quinapril and ramipril, calcium channel blockers such as nifedipine, felodipine, nicardipine, isradipine, nimodipine, diltiazem and verapamil, and  $\alpha$ -blockers such as doxazosin, urapidil, prazosin and terazosin.

**[0020]** In one embodiment, the present invention provides a composition comprising a therapeutically effective amount of an agent that inhibits NKG2D activation or signaling and a pharmaceutically acceptable carrier. In another embodiment, the present invention provides a composition comprising a

therapeutically effective amount of an agent that blocks the NKG2D ligand binding interaction and a pharmaceutically acceptable carrier.

**[0021]** In some embodiments, the agent is useful for treating type 2 diabetes. In some embodiments, the agent is useful for treating a condition that may be regulated  
5 or normalized via inhibition of NKG2D.

**[0022]** In some embodiments, the condition is selected from the group consisting of type 2 diabetes, cardiovascular disease, inflammatory disease and metabolic dysfunction-associated disease. In some embodiments, the condition is type 2 diabetes. In some embodiments, the condition is cardiovascular disease.

10 **[0023]** In some embodiments, the agent is selected from the group consisting of soluble NKG2D, an antibody or antigen-binding fragment thereof that specifically binds NKG2D, an NKG2D ligand and an inhibitor of NKG2D ligand activity or expression. In some embodiments, the agent is an antibody or antigen-binding  
15 or antigen-binding fragment thereof that specifically binds NKG2D. In some embodiments, the antibody or antigen-binding fragment thereof is human or humanized. In some embodiments, the antibody or antigen-binding fragment thereof binds human NKG2D (hNKG2D).

**[0024]** In some embodiments, the agent is an inhibitor of NKG2D ligand activity or expression. In some embodiments, the inhibitor of NKG2D ligand activity or expression is a MICA/B inhibitor. In some embodiments, the MICA/B inhibitor is  
20 MICA/B-specific siRNA.

**[0025]** In some embodiments, the compositions of the present invention further comprise at least one additional agent selected from the group consisting of antidiabetic agents, antiobesity agents, appetite regulating agents, antihypertensive agents, agents for the treatment and/or prevention of complications resulting from or  
25 associated with diabetes and agents for the treatment and/or prevention of complications and disorders resulting from or associated with obesity. In some embodiments, the additional agent is selected from the group consisting of (a) a blood glucose lowering agent selected from the group consisting of GLP-1 and GLP-1 derivatives and analogues, Exendin-4 and Exendin-4 derivatives and analogues,  
30 amylin and amylin derivatives and analogues, sulphonylureas, biguanides, meglitinides (such as nateglinide and repaglinide), glucosidase inhibitors, DPP-IV

(dipeptidyl peptidase-IV) inhibitors, SGLT2 inhibitors, SGLT1 inhibitors or agonists, gastrin and gastrin analogues and derivatives, FGF-21 (fibroblast growth factor 21) and FGF-21 derivatives and analogues, proton pump inhibitors such as lansoprazole, omeprazole, dexlansoprazole, esomeprazole, pantoprazole, and rabeprazole, RXR agonists, Cholestyramine, colestipol, probucol, dextrothyroxine, PPAR agonists, and adiponectin and adiponectin derivatives and analogues; (b) a blood lipid lowering or lipid metabolism modifying agent selected from the group consisting of antihyperlipidemic agents, HMG CoA inhibitors (statins) such as lovastatin, pravastatin and simvastatin, and fibrates such as gemfibrozil and clofibrate; (c) an agent that lowers food intake or increases energy expenditure selected from the group consisting of NPY (neuropeptide Y) antagonists, PYY (polypeptide YY) agonists, PP (pancreatic polypeptide) agonists, Y2 receptor agonists, Y4 receptor agonists, mixed Y2/Y4 receptor agonists, MC4 (melanocortin 4) agonists, orexin antagonists, glucagon and glucagon derivatives and analogues, CRF (corticotropin releasing factor) agonists, CRF BP (corticotropin releasing factor binding protein) antagonists, urocortin agonists,  $\beta$ 3 agonists, MSH (melanocyte-stimulating hormone) agonists, MCH (melanocyte-concentrating hormone) antagonists, CCK (cholecystokinin) agonists, serotonin re-uptake inhibitors, serotonin and noradrenaline re-uptake inhibitors, mixed serotonin and noradrenergic compounds, 5HT (serotonin) agonists, bombesin agonists, galanin antagonists, growth hormone, growth hormone releasing compounds, TRH (thyrotropin releasing hormone) agonists, UCP 2 or 3 (uncoupling protein 2 or 3) modulators, leptin agonists, DA agonists (bromocriptin, dorexin), lipase/amylase inhibitors, RXR (retinoid X receptor) modulators, histamine H3 antagonists, and CART (cocaine amphetamine regulated transcript) agonists; and (d) a blood pressure lowering agent selected from the group consisting of  $\beta$ -blockers such as alprenolol, atenolol, timolol, pindolol, propranolol and metoprolol, ACE (angiotensin converting enzyme) inhibitors such as benazepril, captopril, enalapril, fosinopril, lisinopril, alatriopril, quinapril and ramipril, calcium channel blockers such as nifedipine, felodipine, nifedipine, isradipine, nimodipine, diltiazem and verapamil, and  $\alpha$ -blockers such as doxazosin, urapidil, prazosin and terazosin.

**[0026]** In one embodiment, the present invention provides a kit comprising: (a) a therapeutically effective amount of an agent that inhibits NKG2D activation or

signaling combined with a pharmaceutically acceptable carrier; and (b) instructions for use. In another embodiment, the present invention provides a kit comprising: (a) a therapeutically effective amount of an agent that blocks the NKG2D ligand binding interaction combined with a pharmaceutically acceptable carrier; and (b) instructions for use.

**[0027]** In some embodiments, the agent is useful for treating type 2 diabetes.

**[0028]** In some embodiments, the agent is useful for treating a condition that may be regulated or normalized via inhibition of NKG2D.

**[0029]** In some embodiments, the condition is selected from the group consisting of type 2 diabetes, cardiovascular disease, inflammatory disease and metabolic-dysfunction associated disease. In some embodiments, the condition is type 2 diabetes. In some embodiments, the condition is cardiovascular disease.

**[0030]** In some embodiments, the agent is selected from the group consisting of soluble NKG2D, an antibody or antigen-binding fragment thereof that specifically binds NKG2D, an NKG2D ligand and an inhibitor of NKG2D ligand activity or expression. In some embodiments, the agent is an antibody or antigen-binding fragment thereof that specifically binds NKG2D. In some embodiments, the antibody or antigen-binding fragment thereof is human or humanized. In some embodiments, the antibody or antigen-binding fragment thereof binds human NKG2D (hNKG2D).

**[0031]** In some embodiments, the kits of the present invention further comprise at least one additional agent selected from the group consisting of antidiabetic agents, antiobesity agents, appetite regulating agents, antihypertensive agents, agents for the treatment and/or prevention of complications resulting from or associated with diabetes and agents for the treatment and/or prevention of complications and disorders resulting from or associated with obesity. In some embodiments, the additional agent is selected from the group consisting of (a) a blood glucose lowering agent selected from the group consisting of GLP-1 and GLP-1 derivatives and analogues, Exendin-4 and Exendin-4 derivatives and analogues, amylin and amylin derivatives and analogues, sulphonylureas, biguanides, meglitinides (such as nateglinide and repaglinide), glucosidase inhibitors, DPP-IV (dipeptidyl peptidase-IV) inhibitors, SGLT2 inhibitors, SGLT1 inhibitors or agonists, gastrin and gastrin

analogues and derivatives, FGF-21 (fibroblast growth factor 21) and FGF-21 derivatives and analogues, proton pump inhibitors such as lansoprazole, omeprazole, dexlansoprazole, esomeprazole, pantoprazole, and rabeprazole, RXR agonists, Cholestyramine, colestipol, probucol, dextrothyroxine, PPAR agonists, and adiponectin and adiponectin derivatives and analogues; (b) a blood lipid lowering or lipid metabolism modifying agent selected from the group consisting of antihyperlipidemic agents, HMG CoA inhibitors (statins) such as lovastatin, pravastatin and simvastatin, and fibrates such as gemfibrozil and clofibrate; (c) an agent that lowers food intake or increases energy expenditure selected from the group consisting of NPY (neuropeptide Y) antagonists, PYY (polypeptide YY) agonists, PP (pancreatic polypeptide) agonists, Y2 receptor agonists, Y4 receptor agonists, mixed Y2/Y4 receptor agonists, MC4 (melanocortin 4) agonists, orexin antagonists, glucagon and glucagon derivatives and analogues, CRF (corticotropin releasing factor) agonists, CRF BP (corticotropin releasing factor binding protein) antagonists, urocortin agonists,  $\beta$ 3 agonists, MSH (melanocyte-stimulating hormone) agonists, MCH (melanocyte-concentrating hormone) antagonists, CCK (cholecystokinin) agonists, serotonin re-uptake inhibitors, serotonin and noradrenaline re-uptake inhibitors, mixed serotonin and noradrenergic compounds, 5HT (serotonin) agonists, bombesin agonists, galanin antagonists, growth hormone, growth hormone releasing compounds, TRH (thyrotropin releasing hormone) agonists, UCP 2 or 3 (uncoupling protein 2 or 3) modulators, leptin agonists, DA agonists (bromocriptin, doprexin), lipase/amylase inhibitors, RXR (retinoid X receptor) modulators, histamine H3 antagonists, and CART (cocaine amphetamine regulated transcript) agonists; and (d) a blood pressure lowering agent selected from the group consisting of  $\beta$ -blockers such as alprenolol, atenolol, timolol, pindolol, propranolol and metoprolol, ACE (angiotensin converting enzyme) inhibitors such as benazepril, captopril, enalapril, fosinopril, lisinopril, alatriopril, quinapril and ramipril, calcium channel blockers such as nifedipine, felodipine, nifedipine, isradipine, nimodipine, diltiazem and verapamil, and  $\alpha$ -blockers such as doxazosin, urapidil, prazosin and terazosin..

**[0032]** In one embodiment, the present invention provides a method of detecting a predisposition to developing type 2 diabetes or the presence of type 2 diabetes in a subject comprising: (a) obtaining a sample from the subject; (b) contacting the

sample with at least one reagent that detects the presence of MICA/B expression; (c) measuring the level of MICA/B expression in the sample; and (d) correlating overexpression of MICA/B with a predisposition to type 2 diabetes development or the presence of type 2 diabetes in the subject. In another embodiment, the present invention provides a method of detecting a predisposition to developing cardiovascular disease or the presence of cardiovascular disease in a subject comprising: (a) obtaining a sample from the subject; (b) contacting the sample with at least one reagent that detects the presence of MICA/B expression; (c) measuring the level of MICA/B expression in the sample; and (d) correlating overexpression of MICA/B with a predisposition to cardiovascular disease development or the presence of cardiovascular disease in the subject.

[0033] In some embodiments, the reagent is a MICA/B antibody.

[0034] In some embodiments, the sample is serum.

[0035] In some embodiments, the subject is human.

[0036] In some embodiments, the methods of the present invention further comprise measuring the level of expression of a cardiovascular disease marker that is not MICA/B in the sample and correlating overexpression or underexpression of the cardiovascular disease marker with a predisposition to cardiovascular disease development or presence of cardiovascular disease in the subject.

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#### BRIEF DESCRIPTION OF THE DRAWINGS

[0037] **FIG. 1** is a series of graphs showing detection of soluble MICA proteins in sera of type 2 diabetic patients and its association with expression of other pro-inflammatory cytokines. **(A)** Detection of soluble MICA in the blood of type 2 diabetic patients. Sera of the diabetic patients were assayed for MICA proteins using an ELISA kit (R&D Systems, Minneapolis, MN). Recombinant MICA proteins were used as standards, based on which the serum MICA levels were calculated. On the x-axis, each number represents a patient. **(B and C)** IL-6 and TNF- $\alpha$  levels in the sera of the same patients, analyzed by a human pro-inflammatory 4-plex panel (IL-6,

TNF- $\alpha$ , IL-1 $\beta$  and IFN- $\gamma$ ) (Meso Scale Discovery, Gaithersburg, MD). **(D)** Sera levels of C-reactive protein (CRP) in the sera of the type 2 diabetic patients as analyzed by a CRP ELISA kit (Calbiotech Inc. Spring Valley, CA). **(E)** Diabetes patients on average have higher MICA levels in their sera than fifty cancer patients that were tested. Data for the type 2 diabetic patients is grouped and compared with the data from the fifty cancer patients.

**[0038]** **FIG. 2** is a series of micrographs of cryosections showing detection of MICA/B by immunohistochemical staining on human aortic plaques. Cryosections of the plaques were stained with anti-MICA/B antibodies **(A, C, E, G)**. Adjacent sections were stained with anti-Mac-3 or CD31 antibodies to reveal macrophages or endothelial cells **(B, D, F, H)**. A section of normal aorta was used as a control for MICA staining **(I)**.

**[0039]** **FIG. 3** is a series of photographs of electrophoretic gels and a series of photographs of immunohistochemical-stained cryosections demonstrating upregulation of NKG2D ligands in atherosclerotic plaques of ApoE<sup>-/-</sup> mice. **(A)** Semi-quantitative RT-PCR analysis of transcripts for NKG2D ligands Rae-1 $\delta$ , Rae-1 $\epsilon$  and H60b in RNAs of aortic plaque lesions. **(B)** Real-time RT-PCR analysis of Rae-1 $\delta$ , Rae-1 $\epsilon$  and H60b transcripts in RNA samples isolated from aortic arch regions of Western diet (WD)-fed ApoE<sup>-/-</sup> and age-matched Western diet and normal chow-fed wild type mice. The experiment was done twice. **(C)** Immunohistochemical staining of cryosections of plaques from ApoE<sup>-/-</sup> mice that developed the plaques naturally (right) or accelerated by STZ-induced diabetes (left). The sections were co-stained with anti-Rae-1 or H60 antibody (brown) and anti-CD68 antibody (blue). **(D)** Immunohistochemical staining of atherosclerotic aortae of Western diet-fed ApoE<sup>-/-</sup> mice for NKG2D ligands Rae-1 and H60. Cryosections of atherosclerotic aortic arch regions (top and middle) and "plaque-free" thoracic regions (bottom) of the same Western diet-fed ApoE<sup>-/-</sup> mice were stained with polyclonal goat anti-mouse anti-Rae-1 (R&D Systems) or H60 antibodies (Santa Cruz Biotechnology). The pictures in the middle were higher amplifications (400X) of the boxed areas of the top panels (100X). **(E)** Flow cytometric analysis of cell surface Rae-1 expression on macrophages and endothelial cells isolated from atherosclerotic aortae of ApoE<sup>-/-</sup> mice or normal aortae of wild type mice. The macrophages were gated on the

CD45<sup>+</sup>CD11b<sup>+</sup>CD16/32<sup>+</sup> population and endothelial cells were gated on the CD45<sup>-</sup>CD31<sup>+</sup> population. The gray areas indicated isotype-matched control antibody staining. **(F)** Western blot analysis for total Rae-1 proteins in the in vitro treated wild-type macrophages. **(G)** Semi-quantitative RT-PCR analysis for the different NKG2D ligand upregulation in wild-type macrophages cultured in medium only and in presence of additional oxLDL, natural LDL (nLDL) and LPS (as a control). **(H)** Flow cytometric analysis of Rae-1 expression on wild-type macrophages in vitro cultured in presence of oxidized LDL (oxLDL) or advanced glycation end products (AGE). Macrophages were isolated from peritoneal cavity and cultured in vitro for two days in media containing 5 µg/ml oxLDL or 200 µg/ml AGE before analyzed by flow cytometry similarly as in the panel E except that the dashed lines were of staining in the presence of 10-fold excess of unlabeled anti-pan-Rae-1 antibodies.

**[0040]** **FIG. 4** is a series of photographs of aorta from ApoE-null mice showing suppression of plaque formation by anti-NKG2D antibody in diabetic ApoE-null mice. **(A)** Plaque formation in aorta of representative anti-NKG2D or control antibody treated diabetic ApoE-null mice. Aortae were perfused with PBS and observed under a dissection microscope for apparent opaque plaques. Note the dramatically decreased sizes of the plaques in the anti-NKG2D antibody-treated mouse (circled areas). **(B)** En face Oil red O staining of aorta for deposition of lipid contents in anti-NKG2D (MI-6) and control antibody (control) treated ApoE<sup>-/-</sup> mice from one representative experiment. Aortae were opened up, fixed in 10% formalin and stained with Oil red O dye. Lipid contents stained dark red. Note significantly less Oil red O staining in aortic arch areas of the anti-NKG2D antibody treated mice.

**[0041]** **FIG. 5** is a series of graphs demonstrating that targeting the NKG2D/ligand interaction prevents atherosclerosis in various mouse models. **(A)** The effect of anti-NKG2D antibody blockage on the atherosclerosis development in streptozotocin-induced diabetic ApoE<sup>-/-</sup> mice. Sizes of plaques on aorta of control and anti-NKG2D treated diabetic ApoE<sup>-/-</sup> mice were calculated based on ratios of the Oil red O positive staining areas of total arch areas. **(B and C)** The effect of NKG2D knockout on atherosclerosis development in streptozotocin-induced diabetic **(B)** or Western diet-fed **(C)** KLRK1<sup>-/-</sup>ApoE<sup>-/-</sup> mice (the KLRK1 gene encodes the

NKG2D protein). The plaque sizes were calculated the same way as the panel A. ApoE<sup>-/-</sup> mice were used as controls.

[0042] FIG. 6 is a series of graphs showing reduced pro-inflammatory cytokines in the sera of anti-NKG2D antibody treated diabetic ApoE null mice. Sera of four  
5 anti-NKG2D (MI-6 Ab)-treated and three control antibody (Con Ab)-treated diabetic ApoE null mice, along with two each of age-matched wild type B6 (Wild Type), one month (Young ApoE) or eight month old (Old ApoE) ApoE<sup>-/-</sup> mice were analyzed directly on a mouse proInflammatory-7plex kit (IL-6, TNF- $\alpha$ , IFN- $\gamma$ , IL-12p70, IL-10, IL-1 $\beta$  and KC/CXCL1) (Meso Scale Discovery, Gaithersburg, MD). The star \*  
10 indicate statistically significant differences in the values between the anti-NKG2D antibody and control antibody treated diabetic ApoE<sup>-/-</sup> mice.

[0043] FIG. 7 is a series of graphs showing reduced pro-inflammatory cytokines in the sera of KLRK1<sup>-/-</sup>ApoE<sup>-/-</sup> mice (which have a defective NKG2D gene). Sera of western diet fed (12 mice/group) (**panel A**) or STZ-induced diabetic (4 mice/group)  
15 (**panel B**) KLRK1<sup>-/-</sup>ApoE<sup>-/-</sup> and ApoE<sup>-/-</sup> mice were analyzed directly by a mouse proInflammatory-7plex kit (IL-6, TNF- $\alpha$ , IFN- $\gamma$ , IL-12p70, IL-10, IL-1 $\beta$  and KC/CXCL1) (Meso Scale Discovery, Gaithersburg, MD) as in Figure 6. The stars indicate statistically significant differences in the values between the anti-NKG2D antibody and control antibody treated diabetic ApoE<sup>-/-</sup> mice (\*\*p<0.01; \*p<0.05).

[0044] FIG. 8 displays a pair of photographs of sera and a pair of graphs showing alleviated metabolic conditions in KLRK1<sup>-/-</sup>ApoE<sup>-/-</sup> mice. (**A**) Clearer appearance of sera of western diet fed KLRK1<sup>-/-</sup>ApoE<sup>-/-</sup> than the similarly fed ApoE<sup>-/-</sup> mice. (**B**)  
20 Reduced cholesterol and triglyceride levels in blood of KLRK1<sup>-/-</sup>ApoE<sup>-/-</sup> mice. Sera of the panel A were analyzed for total cholesterol and triglyceride. The stars \*\* indicate statistically significant differences in the values between the KLRK1/ApoE  
25 double knockout and ApoE-knockout mice (\*\*p<0.05). For each group, at least 5 mice were used.

[0045] FIG. 9 is a graph showing reduced serum alanine aminotransferase (ALT) activities in NKG2D-knockout KLRK1<sup>-/-</sup>ApoE<sup>-/-</sup> mice compared to ApoE<sup>-/-</sup> mice. For  
30 each group, at least 5 mice were used.

**[0046] FIG. 10** is a pair of graphs showing that preventing the NKG2D/ligand interaction reduced the inflammation of livers of Western diet fed ApoE<sup>-/-</sup> mice. **(A)** Reduced IL-6 production by ex vivo cultured liver explants of NKG2D-knockout KLRK1<sup>-/-</sup>ApoE<sup>-/-</sup> mice. PBS-perfused livers were excised from Western diet fed ApoE<sup>-/-</sup> or NKG2D-knockout KLRK1<sup>-/-</sup>ApoE<sup>-/-</sup> mice. Equal weights of excised livers were cut into about 1mm<sup>3</sup> cubes and cultured in media for 1 or 3 days. The culture media were recovered and analyzed for cytokines by ELISA. The experiment was repeated twice. **(B)** Reduced immune cell infiltration in livers of Western diet fed NKG2D-knockout KLRK1<sup>-/-</sup>ApoE<sup>-/-</sup> mice. The numbers are of each type of immune cells per liver, calculated based on total mononucleocytes isolated from livers and percentages of each type. For each group, at least 3 mice were used. One representative of three independent experiments was shown.

**[0047] FIG. 11** is a series of graphs and fluorescence activated cell sorting analysis plots showing that NKG2D ligands were upregulated in the cells of livers of Western diet fed ApoE<sup>-/-</sup> mice and that preventing the NKG2D/ligand interaction reduced the activation of NKG2D-expressing immune cells in the livers. **(A)** Real-time RT-PCR analysis of Rae-1 $\delta$  transcripts in livers and other organs of 12-week-old male ApoE<sup>-/-</sup> mice fed on a Western diet for 8 weeks and wild type mice of same ages. **(B)** Real-time RT-PCR analysis of Rae-1 $\delta$  transcripts in purified macrophages of livers of Western diet fed ApoE<sup>-/-</sup> mice and wild type mice. **(C and D)** Flow cytometric analysis of Rae-1 expression on liver macrophages **(C)** and hepatocytes **(D)** of Western diet fed ApoE<sup>-/-</sup> mice. **(E)** Reduced production of IFN- $\gamma$  and IL-4 by the liver NKT cells of NKG2D-knockout KLRK1<sup>-/-</sup>ApoE<sup>-/-</sup> mice. **(F)** Lower IFN- $\gamma$  production by liver NK cells of NKG2D-knockout KLRK1<sup>-/-</sup>ApoE<sup>-/-</sup> than of ApoE<sup>-/-</sup> mice. **(G)** No difference in IL-6 production by liver macrophages of NKG2D-knockout KLRK1<sup>-/-</sup>ApoE<sup>-/-</sup> and ApoE<sup>-/-</sup> mice.

**[0048] FIG. 12** is a graph demonstrating that targeting NKG2D suppresses type 2 diabetes. The 8-week old ApoE<sup>-/-</sup> and NKG2D-deficient ApoE<sup>-/-</sup>KLRK1<sup>-/-</sup> mice were fed the Western diet for 3 months. Blood sera were then collected and assessed for glucose levels. The glucose levels of the ApoE<sup>-/-</sup> and ApoE<sup>-/-</sup>KLRK1<sup>-/-</sup> mice were the averages of six mice in each group. The difference between the two groups is statistically significant ( $p < 0.05$ ).

**[0049] FIG. 13** shows the effect of anti-NKG2D antibody on the development of diabetes in the gerbil *Psammomys obesus* (also known as sand rats), an animal model of type 2 diabetes. Male and female *P. obesus* (Harlan, Jerusalem, Israel) were fed low energy (2.4 kcal/g) chow until the age of 9 weeks where they were transferred to an ad libitum high energy (3.1kcal/g) diet during which body weight (BW) and morning blood glucose (mBG) was followed for up to 10 days (induction period). The animals that showed increased mBG levels, defined as mBG >10 mmol/L on two consecutive readings, were transferred back to low energy diet and were used in the actual study (prevention mode) 10 days later when their mBG levels were back to non-diabetic levels. The animals that did not show any increase in mBG during the induction period were sacrificed and not used further. (Data not shown.) *P. obesus* were treated with vehicle (N=19) or NKG2D-PE antibody (clone CX5) (N=9), once weekly by intra-peritoneal injection. The study was conducted over 6 weeks during which mBG and BW were followed regularly. All of the animals in the vehicle group became severely diabetic with a mean mBG of  $14.5 \pm 2.6$  mM (mean  $\pm$  sem) while the animals treated with the NKG2D antibody remained normoglycaemic (mBG<8 mM) and had a significantly lower mBG of  $8.0 \pm 1.9$  mM,  $p<0.0001$  (mean  $\pm$  sem). Treatment with NKG2D antibody totally inhibited the development of type 2 diabetes in *P.obesus* and five animals in the vehicle group had to be sacrificed during the study due to severe diabetic ketoacidosis. There was no difference in BW gain in the two treatment groups.

**[0050] FIG. 14** shows the flow cytometric analysis of NKG2D antibody binding to blood cells from *Psammomys obesus* (sand rats), an animal model of type 2 diabetes. A dose-dependent binding was observed for the anti-mouse NKG2D-PE antibody (clone CX5) to NK cells in sand rat blood. This binding was specific as there was no binding of the isotype control antibodies (rat IgG1-PE isotype control (R3-34) and mouse IgG1-PE isotype control (MOPC-21)) or the anti-human NKG2D antibodies (clone 1D11 and clone ON72).

## DEFINITIONS

**[0051]** Unless otherwise defined, all technical terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs.

**[0052]** As used herein, "protein" and "polypeptide" are used synonymously to mean any peptide-linked chain of amino acids, regardless of length or post-translational modification, e.g., glycosylation or phosphorylation.

**[0053]** As used herein, the terms "MICA/B proteins" or "MICA/B polypeptide" is meant an expression product of an MHC class I chain-related A or B gene such as the native human MICA protein (accession no. L14848), or a protein that shares at least 65% (but preferably 75, 80, 85, 90, 95, 96, 97, 98, or 99%) amino acid sequence identity with the foregoing and displays a functional activity of a native MICA protein, or the native human MICB protein (accession no. NM\_005931), or a protein that shares at least 65% (but preferably 75, 80, 85, 90, 95, 96, 97, 98, or 99%) amino acid sequence identity with the foregoing and displays a functional activity of a native MICB protein. A "functional activity" of a protein is any activity associated with the physiological function of the protein. For example, functional activities of a native MICA/B protein may include binding to NKG2D and inducing immune activation, such as secretion of cytokines.

**[0054]** As used herein, the terms "NKG2D protein" or "NKG2D polypeptide" is meant an expression product of a KLRK1 gene such as the native human NKG2D protein (accession no. 574240) or a protein that shares at least 65% (but preferably 75, 80, 85, 90, 95, 96, 97, 98, or 99%) amino acid sequence identity with the foregoing and displays a functional activity of a native NKG2D protein. For example, functional activities of a native NKG2D protein may include binding to its ligands and transducing signals into immune cells to modulate their gene expression and activation.

**[0055]** As used herein, the term "gene" is meant a nucleic acid molecule that codes for a particular protein, or in certain cases, a functional or structural RNA molecule.

**[0056]** As used herein, the terms "MICA/B gene," "MICA gene," "MICB gene," "MICA/B polynucleotide," "MICA polynucleotide," "MICB polynucleotide," "MICA/B nucleic acid," "MICA nucleic acid," or "MICB nucleic acid" is meant a native human MICA or MICB-encoding nucleic acid sequence, e.g., the native human MICA gene  
5 (accession no. L14848); e.g., the native human MICB gene (accession no. NM\_005931), a nucleic acid having sequences from which a MICA or MICB cDNA can be transcribed; and/or allelic variants and homologs of the foregoing. The terms encompass double-stranded DNA, single-stranded DNA, and RNA.

**[0057]** As used herein, "KLRK1," "Klrk1," "KLRK1 gene," "Klrk1 gene," "NKG2D gene," "NKG2D polynucleotide," or "NKG2D nucleic acid" is meant a native human  
10 NKG2D-encoding nucleic acid sequence, e.g., the native human KLRK1 gene (accession no. 574240); a nucleic acid having sequences from which a KLRK1 cDNA can be transcribed; and/or allelic variants and homologs of the foregoing. The terms encompass double-stranded DNA, single-stranded DNA, and RNA.

**[0058]** As used herein, a "nucleic acid" or a "nucleic acid molecule" means a  
15 chain of two or more nucleotides such as RNA (ribonucleic acid) and DNA (deoxyribonucleic acid). Nucleic acid molecules as described herein may be in the form of RNA or in the form of DNA (e.g., cDNA, genomic DNA, and synthetic DNA). The DNA may be double-stranded or single-stranded, and if single-stranded may be  
20 the coding (sense) strand or non-coding (anti-sense) strand.

**[0059]** As used herein, the terms "patient," "subject" and "individual" are used interchangeably herein, and mean a mammalian (e.g., human) subject to be treated and/or to obtain a biological sample from.

**[0060]** As used herein, "bind," "binds," or "interacts with" means that one  
25 molecule recognizes and adheres to a particular second molecule in a sample or organism, but does not substantially recognize or adhere to other structurally unrelated molecules in the sample.

**[0061]** As used herein, the term "labeled," with regard to a probe or antibody, is intended to encompass direct labeling of the probe or antibody by coupling (i.e.,  
30 physically linking) a detectable substance to the probe or antibody.

**[0062]** As used herein, when referring to a nucleic acid molecule or polypeptide, the term "native" refers to a naturally-occurring (e.g., a WT) nucleic acid or polypeptide.

**[0063]** As used herein, the terms "diagnostic," "diagnose" and "diagnosed" mean  
5 identifying the presence or nature of a pathologic condition.

**[0064]** As used herein, the term "sample" is used herein in its broadest sense. A sample including polynucleotides, peptides, antibodies and the like may include a bodily fluid, a soluble fraction of a cell preparation or media in which cells were grown, genomic DNA, RNA or cDNA, a cell, a tissue, skin, hair and the like.  
10 Examples of samples include saliva, serum, biopsy specimens, blood, urine, and plasma.

**[0065]** As used herein, "sequence identity" means the percentage of identical subunits at corresponding positions in two sequences when the two sequences are aligned to maximize subunit matching, i.e., taking into account gaps and insertions.  
15 Sequence identity is present when a subunit position in both of the two sequences is occupied by the same nucleotide or amino acid, e.g., if a given position is occupied by an adenine in each of two DNA molecules, then the molecules are identical at that position. For example, if 7 positions in a sequence 10 nucleotides in length are identical to the corresponding positions in a second 10-nucleotide sequence, then  
20 the two sequences have 70% sequence identity. Sequence identity is typically measured using sequence analysis software (e.g., Sequence Analysis Software Package of the Genetics Computer Group, University of Wisconsin Biotechnology Center, 1710 University Avenue, Madison, Wis. 53705).

**[0066]** When referring to mutations in a nucleic acid molecule, "silent" changes  
25 are those that substitute one or more base pairs in the nucleotide sequence, but do not change the amino acid sequence of the polypeptide encoded by the sequence. "Conservative" changes are those in which at least one codon in the protein-coding region of the nucleic acid has been changed such that at least one amino acid of the polypeptide encoded by the nucleic acid sequence is substituted with another amino  
30 acid having similar characteristics.

**[0067]** As used herein, the terms "oligonucleotide", "siRNA" "siRNA oligonucleotide" and "siRNA's" are used interchangeably throughout the specification and include linear or circular oligomers of natural and/or modified monomers or linkages, including deoxyribonucleosides, ribonucleosides, substituted and alpha-anomeric forms thereof, peptide nucleic acids (PNA), locked nucleic acids (LNA), phosphorothioate, methylphosphonate, and the like. Oligonucleotides are capable of specifically binding to a target polynucleotide by way of a regular pattern of monomer-to-monomer interactions, such as Watson-Crick type of base pairing, Hoögsteen or reverse Hoögsteen types of base pairing, or the like.

**[0068]** As used herein, the term "antibody" is used in the broadest sense and specifically includes full-length monoclonal antibodies, polyclonal antibodies, and, unless otherwise stated or contradicted by context, antigen-binding fragments, antibody variants, and multispecific molecules thereof, so long as they exhibit the desired biological activity. Generally, a full-length antibody is a glycoprotein comprising at least two heavy (H) chains and two light (L) chains inter-connected by disulfide bonds, or an antigen binding portion thereof. Each heavy chain is comprised of a heavy chain variable region (abbreviated herein as VH) and a heavy chain constant region. The heavy chain constant region is comprised of three domains, CH1, CH2 and CH3. Each light chain is comprised of a light chain variable region (abbreviated herein as VL) and a light chain constant region. The light chain constant region is comprised of one domain, CL. The VH and VL regions can be further subdivided into regions of hypervariability, termed complementarily determining regions (CDR), interspersed with regions that are more conserved, termed framework regions (FR). Each VH and VL is composed of three CDRs and four FRs, arranged from amino-terminus to carboxy-terminus in the following order: FR1, CDR1, FR2, CDR2, FR3, CDR3, FR4. The variable regions of the heavy and light chains contain a binding domain that interacts with an antigen. General principles of antibody molecule structure and various techniques relevant to the production of antibodies are provided in, *e.g.*, Harlow and Lane, ANTIBODIES: A LABORATORY MANUAL, Cold Spring Harbor Laboratory Press, Cold Spring Harbor, N.Y., (1988). For example, anti-NKG2D antibodies as described herein are capable of binding portions of NKG2D that interfere with NKG2D activation and/or

signaling. The anti-NKG2D antibodies as described herein are also capable of binding portions of NKG2D that interfere with NKG2D ligand binding interaction.

**[0069]** As used herein, an "antigen-binding fragment" of an antibody is a molecule that comprises a portion of a full-length antibody which is capable of detectably binding to the antigen, typically comprising one or more portions of at least the VH region. Antigen-binding fragments include multivalent molecules comprising one, two, three, or more antigen-binding portions of an antibody, and single-chain constructs wherein the VL and VH regions, or selected portions thereof, are joined by synthetic linkers or by recombinant methods to form a functional, antigen-binding molecule. While some antigen-binding fragments of an antibody can be obtained by actual fragmentation of a larger antibody molecule (e.g., enzymatic cleavage), most are typically produced by recombinant techniques.

**[0070]** As used herein, the term "human antibody" is intended to include antibodies having variable regions in which both the framework and CDR regions are derived from (*i.e.*, are identical or essentially identical to) human germline immunoglobulin sequences. Furthermore, if the antibody contains a constant region, the constant region also is "derived from" human germline immunoglobulin sequences. The human antibodies of the invention may include amino acid residues not encoded by human germline immunoglobulin sequences (*e.g.*, mutations introduced by random or site-specific mutagenesis *in vitro* or by somatic mutation *in viva*). However, the term "human antibody", as used herein, is not intended to include antibodies in which CDR sequences derived from the germline of another mammalian species, such as a mouse, have been grafted onto human framework sequences.

**[0071]** As used herein, a "humanized" antibody is a human/non-human chimeric antibody that contains a minimal sequence derived from non-human immunoglobulin. For the most part, humanized antibodies are human immunoglobulins (recipient antibody) in which residues from a hyper-variable region of the recipient are replaced by residues from a hypervariable region of a non-human species (donor antibody) such as mouse, rat, rabbit, or non-human primate having the desired specificity, affinity, and capacity. In some instances, FR residues of the human immunoglobulin are replaced by corresponding non-human residues.

Furthermore, humanized antibodies may comprise residues that are not found in the recipient antibody or in the donor antibody. These modifications are made to further refine antibody performance. In general, a humanized antibody will comprise substantially all of at least one, and typically two, variable domains, in which all or substantially all of the hypervariable loops correspond to those of a non-human immunoglobulin and all or substantially all of the FR residues are those of a human immunoglobulin sequence. The humanized antibody can optionally also comprise at least a portion of an immunoglobulin constant region (Fc), typically that of a human immunoglobulin. For further details, see, e.g., Jones et al., Nature 321:522-525 (1986); Riechmann et al., Nature 332:323-329 (1988); and Presta, Curr. Op. Struct. Biol. 2:593-596 (1992), WO 92/02190, US Patent Application 20060073137, and US Patents 6750325, 6632927, 6639055, 6548640, 6407213, 6180370, 6054297, 5929212, 5895205, 5886152, 5877293, 5869619, 5821337, 5821123, 5770196, 5777085, 5766886, 5714350, 5693762, 5693761, 5530101, 5585089, and 5225539.

15 **[0072]** As used herein, "framework region" or "FR" residues are those VH or VL residues other than the CDRs as herein defined.

**[0073]** As used herein, an "epitope" or "binding site" is an area or region on an antigen to which an antigen-binding peptide (such as an antibody) specifically binds. A protein epitope may comprise amino acid residues directly involved in the binding (also called the immunodominant component of the epitope) and other amino acid residues, which are not directly involved in the binding, such as amino acid residues which are effectively blocked by the specifically antigen binding peptide (in other words, the amino acid residue is within the "solvent-excluded surface" and/or "footprint" of the specifically antigen binding peptide). The term epitope herein includes both types of amino acid binding sites in any particular region of a hNKG2D that specifically binds to an anti-hNKG2D antibody, or another hNKG2D-specific agent according to the invention, unless otherwise stated (e.g., in some contexts the invention relates to antibodies that bind directly to particular amino acid residues). NKG2Ds may comprise a number of different epitopes, which may include, without limitation, (1) linear peptide antigenic determinants, (2) conformational antigenic determinants which consist of one or more non-contiguous amino acids located near each other in a mature NKG2D conformation; and (3) post-translational antigenic

determinants which consist, either in whole or part, of molecular structures covalently attached to a NKG2D, such as carbohydrate groups. Unless otherwise specified or contradicted by context, conformational antigenic determinants comprise NKG2D amino acid residues within about 4 Å distance from an atom of an antigen-binding peptide.

**[0074]** As used herein, the phrase "binds to essentially the same epitope or determinant as" an antibody of interest (*e.g.*, MS or 21F2) means that an antibody "competes" with the antibody of interest for NKG2D molecules to which the antibody of interest specifically binds.

10 **[0075]** As used herein, the ability of an anti-NKG2D antibody to "block" the binding of a NKG2D molecule to a natural NKG2D-ligand (*e.g.*, MICA), means that the antibody, in an assay using soluble or cell-surface associated NKG2D and ligand molecules, can detectably reduce the binding of a NKG2D-molecule to the ligand in a dose-dependent fashion, where the NKG2D molecule detectably binds to the ligand in the absence of the antibody.

**[0076]** As used herein, the phrase "NKG2D ligand binding interaction" refers to the specific recognition and binding interaction between NKG2D with its ligand (*e.g.*, MICA/B, ULBP/RAET1, Mult1, Rae-1 $\delta$ , Rae-1 $\epsilon$  and H60b). Examples of agents that could modulate the NKG2D ligand binding interaction include soluble NKG2D, an antibody or antigen-binding fragment thereof that specifically binds NKG2D, an NKG2D ligand and an inhibitor of NKG2D ligand activity or expression.

**[0077]** High cholesterol and triglyceride levels are considered to be lipid metabolic disorders that increase risk of cardiovascular diseases and type 2 diabetes.

25 **[0078]** As used herein, "diabetes" refers to a metabolic disorder that results in elevation of the blood glucose level because of relative or absolute deficiency in the pancreatic hormone insulin. There are two forms of diabetes: type 1 diabetes and type 2 diabetes. Type 1 diabetes is characterized by a progressive loss of pancreatic beta cells due to an unfavourable balance between the destructive autoimmune processes targeting the beta cells on one side and the regenerative capacity of these cells on the other side. This imbalance eventually leads to total

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loss of beta cells and endogenous insulin secretion. Type 2 diabetes is characterized by insulin resistance and impaired beta cell function, which includes impaired first phase insulin release, reduced beta cell pulse mass and insulin deficiency. In a preferred embodiment, the present invention relates to the treatment  
5 of type 2 diabetes.

**[0079]** As used herein, "type 2 diabetes" means a chronic condition in which the body is resistant to the effects of insulin or doesn't produce enough insulin to maintain a normal glucose level. In addition, it also means the metabolic dysfunctions that exist in people in early phases of the disease, such as  
10 dyslipidemia.

**[0080]** As used herein, the phrase "cardiovascular disease" is meant abnormal conditions affecting functions associated with the heart and blood vessels.

**[0081]** As used herein, the term "safe and effective amount" refers to the quantity of a component which is sufficient to yield a desired therapeutic response without  
15 undue adverse side effects (such as toxicity, irritation, or allergic response) commensurate with a reasonable benefit/risk ratio when used as described herein.

**[0082]** As used herein, the term "therapeutically effective amount" is meant an amount of a composition as described herein effective to yield the desired therapeutic response, for example, an amount effective to delay the development of  
20 atherosclerotic plaques, or an amount effective to lower blood glucose levels and promote weight loss in a diabetic patient.

**[0083]** The specific safe and effective amount or therapeutically effective amount will vary with such factors as the particular condition being treated, the physical condition of the patient, the type of mammal or animal being treated, the duration of  
25 the treatment, the nature of concurrent therapy (if any), and the specific formulations employed and the structure of the compounds or its derivatives.

**[0084]** As used herein, the term "treatment" is defined as the application or administration of a therapeutic agent to a patient, or application or administration of the therapeutic agent to an isolated tissue or cell line from a patient, who has a  
30 disease, a symptom of disease or a predisposition toward a disease, with the

purpose to cure, heal, alleviate, relieve, alter, remedy, ameliorate, improve or affect the disease, the symptoms of disease, or the predisposition toward disease. For example, "treatment" of a patient in whom no symptoms or clinically relevant manifestations of a disease or disorder have been identified is preventive or prophylactic therapy, whereas clinical, curative, or palliative "treatment" of a patient in whom symptoms or clinically relevant manifestations of a disease or disorder have been identified generally does not constitute preventive or prophylactic therapy. Treatment of type 2 diabetes in a subject, for example, includes lowering blood glucose levels and lowering the subject's body weight. Inhibiting type 2 diabetes disease progression includes preventing or suppressing lipid metabolic conditions, lowering insulin resistance, preventing or suppressing lipid metabolic disorders, improving glucose tolerance, etc. Treating type 2 diabetes and inhibiting type 2 diabetes disease progression can include alleviating or preventing symptoms, disorders or diseases associated with diabetes, e.g., metabolic syndrome, diabetic retinopathy, kidney failure, poor blood circulation and limb disorders associated therewith. Each form of treatment may be considered a distinct aspect of the invention.

**[0085]** Methods involving conventional molecular biology techniques are described herein. Such techniques are generally known in the art and are described in detail in methodology treatises such as *Molecular Cloning: A Laboratory Manual*, 3rd ed., vol. 1-3, ed. Sambrook et al., Cold Spring Harbor Laboratory Press, Cold Spring Harbor, N.Y., 2001; and *Current Protocols in Molecular Biology*, ed. Ausubel et al., Greene Publishing and Wiley-Interscience, New York, 1992 (with periodic updates). Conventional methods of gene transfer and gene therapy can also be adapted for use in the present invention. See, e.g., *Gene Therapy: Principles and Applications*, ed. T. Blackenstein, Springer Verlag, 1999; *Gene Therapy Protocols (Methods in Molecular Medicine)*, ed. P.D. Robbins, Humana Press, 1997; and *Retro-vectors for Human Gene Therapy*, ed. C.P. Hodgson, Springer Verlag, 1996. Immunology techniques are generally known in the art and are described in detail in methodology treatises such as *Advances in Immunology*, volume 93, ed. Frederick W. Alt, Academic Press, Burlington, MA, 2007; *Making and Using Antibodies: A Practical Handbook*, eds. Gary C. Howard and Matthew R. Kaser, CRC Press, Boca Raton, FL, 2006; *Medical Immunology*, 6<sup>th</sup> ed., edited by Gabriel Virella, Informa

Healthcare Press, London, England, 2007; and Harlow and Lane ANTIBODIES: A Laboratory Manual, Cold Spring Harbor Laboratory Press, Cold Spring Harbor, NY, 1988.

5 [0086] Although methods, compositions and kits similar or equivalent to those described herein can be used in the practice or testing of the present invention, suitable methods, compositions and kits are described below.

10 [0087] All publications, patent applications, and patents mentioned herein are incorporated by reference in their entirety. In the case of conflict, the present specification, including definitions, will control. The particular embodiments discussed below are illustrative only and not intended to be limiting.

#### DETAILED DESCRIPTION OF THE INVENTION

15 [0088] The present invention is based on the discovery that a family of immune stimulatory molecules is upregulated in patients and animals with diabetes or lipid-metabolic dysfunctions and is important for cardiovascular disease development. The data described herein provide the first evidence that MICA/B proteins are elevated in the sera of type 2 diabetic human patients and that injection of anti-NKG2D antibody into diabetic mice blocks the NKG2D ligand interaction and significantly suppresses atherosclerotic plaque formation. The data described herein  
20 also shows that NKG2D/ligand mediated immune activation is involved in type 2 diabetic progression. Injection of an anti-NKG2D antibody into an animal model of type 2 diabetes was able to treat diabetes and significantly reduce blood glucose levels. Blocking the NKG2D/ligand interaction also alleviated abnormal metabolic conditions including reducing cholesterol and triglyceride levels.

25 [0089] MICA/B and other NKG2D ligands are therefore novel molecular markers for predicting type 2 diabetes as well as cardiovascular disease development in diabetic patients, and they, as well as the NKG2D/ligand interaction, are novel targets for preventing or treating type 2 diabetes as well as other abnormal metabolic conditions or diseases (e.g., dyslipidemia, diabetic retinopathy, poor blood  
30 circulation, limb disorders) and cardiovascular disease (e.g., atherosclerosis).

**[0090]** Accordingly, the present invention provides novel methods, compositions and kits for detecting and treating type 2 diabetes as well as other abnormal metabolic conditions, such as cardiovascular diseases or disorders.

**[0091]** NKG2D is an immune stimulatory molecule expressed by many immune cells, such as NK, NKT, ab T and gd T cells. Stimulation of NKG2D by its cognate ligands results in activation of the NKG2D-expressing immune cells. There are multiple molecules that could serve as ligands for NKG2D, which include members of Rae-1, H60, and Mult1 in mice and the MICA/B and the ULBP/RAET1 families of proteins in humans. Most of the NKG2D ligands are not expressed or are expressed at low levels in normal cells but are upregulated in various disease conditions, which could in turn activate the NKG2D-expressing immune cells. While such immune activation plays an important role in host defenses such as microbial immunity and tumor surveillance, it could also contribute to immune-mediated diseases.

**[0092]** In one embodiment, the present invention provides methods and kits for detecting MICA/B proteins in a biological sample from a subject to detect the presence of or predict the occurrence of type 2 diabetes, cardiovascular disease, inflammatory disease or a metabolic dysfunction-associated disease in the subject. Metabolic dysfunction-associated diseases include hyperglycemia, diabetic retinopathy, poor blood circulation, limb disorders, and dyslipidemia (e.g., high cholesterol and high triglycerides).

**[0093]** The data described herein in Example 1 indicate that NKG2D ligands are upregulated in type 2 diabetic patients that would promote organ inflammation and associated complications. The data described herein provides that elevated levels of MICA/B proteins were detected in sera and atherosclerotic plaques of type 2 diabetic human patients. It was also found that H60 and Rae-1 (retinoic acid early inducible gene-1) proteins were upregulated in blood vessels especially in atherosclerotic lesion regions, and livers of diabetic or non-diabetic ApoE<sup>-/-</sup> mice, an animal model for dysfunctional lipid metabolism and atherosclerosis, and that Mult1 was upregulated in the serum of these animals (see Example 2). Thus, the upregulation of NKG2D ligands (e.g., MICA/B proteins or ULBP/RAET1 proteins) may be useful to detect the presence of or predict the occurrence of type 2 diabetes, cardiovascular disease, inflammatory disease or a metabolic dysfunction-associated disease.

**[0094]** A typical method of detecting a predisposition to developing type 2 diabetes, cardiovascular disease, inflammatory disease or a metabolic dysfunction-associated disease or the presence of type 2 diabetes, cardiovascular disease, inflammatory disease or a metabolic dysfunction-associated disease includes  
5 obtaining a biological sample from the subject; contacting the biological sample with at least one reagent that detects expression of an NKG2D ligand (e.g., MICA/B expression); measuring the level of expression of the NKG2D ligand in the biological sample; and correlating overexpression of the NKG2D ligand with a predisposition to  
10 type 2 diabetes, cardiovascular disease, inflammatory disease or metabolic dysfunction-associated disease development in the subject. As illustrated by the data discussed in Example 1, soluble MICA/B expression was measured. However, in some embodiments, membrane forms of MICA/B expression can be measured. Instead of or in addition to MICA/B, the expression of any NKG2D ligand can be analyzed. The ULBP/RAET1 family of proteins, for example, are NKG2D ligands and  
15 have been found to be shed and present in serum, just as MICA/B can be, thus making these proteins suitable markers for the methods, compositions, and kits described herein. NKG2D ligands are described, for example, in Waldhauer, I. and A. Steinle, *Oncogene*, 27:5932-5943 (2008).

**[0095]** In some embodiments, the reagent that detects expression of an NKG2D  
20 ligand (e.g., MICA/B expression) may include any suitable reagent such as MICA/B antibodies and soluble NKG2D.

**[0096]** Generally, the biological sample is serum. Any suitable biological sample, however, can be used. Examples of additional biological samples include biopsy specimens, plasma, urine, skin, blood, and saliva.

**[0097]** Any suitable method or assay can be used to measure the level of NKG2D  
25 ligand (e.g., MICA/B) expression in the biological sample of a subject. Numerous antibody-based detection formats are well known in the art, and include ELISA (enzyme linked immunosorbent assay), radioimmunoassays, immunoblots, Western blots, flow cytometry, immunofluorescence assays, immunoprecipitation, protein A  
30 assays, immunoelectrophoresis assays, and other related techniques. In some embodiments, antibody binding is detected by detecting a label on the primary antibody. In another embodiment, the primary antibody is detected by detecting

binding of a secondary antibody or reagent to the primary antibody. In a further embodiment, the secondary antibody is labeled. Many means are known in the art for detecting binding in an immunoassay and are within the scope of the compositions, kits and methods described herein. Antibodies specific for MICA/B or other NKG2D ligands may be provided in a diagnostic kit that incorporates at least one of these procedures to detect NKG2D ligand (e.g., MICA/B) expression. The kit may contain other components, packaging, instructions, or other material to aid the detection of the protein and use of the kit.

**[0098]** Methods of detecting a predisposition to developing type 2 diabetes, cardiovascular disease, inflammatory disease or a metabolic dysfunction-associated disease or the presence of type 2 diabetes, cardiovascular disease, inflammatory disease or a metabolic dysfunction-associated disease in a subject include correlating overexpression of MICA/B or other NKG2D ligand(s) with a predisposition to type 2 diabetes, cardiovascular disease development, inflammatory disease or a metabolic dysfunction-associated disease or having type 2 diabetes, cardiovascular disease, inflammatory disease or a metabolic dysfunction-associated disease in the subject. Whether or not one or more NKG2D ligands (e.g., MICA/B) are overexpressed in the biological sample can be determined by comparing the level of NKG2D ligand (e.g., MICA/B) expression in the biological sample to a baseline level (also known as a control level) of expression of the NKG2D ligand (e.g., MICA/B). A "baseline level" is a control level, and in some embodiments a normal level or a level not observed in subjects having type 2 diabetes, inflammatory disease or other metabolic dysfunction-associated disease and a predisposition to cardiovascular disease. Therefore, it can be determined, based on the control or baseline level of NKG2D ligand (e.g., MICA/B) expression, whether a sample to be evaluated for type 2 diabetes, cardiovascular disease, inflammatory disease or metabolic dysfunction-associated disease development has a measurable increase (i.e., overexpression, upregulation), decrease, or substantially no change in expression of the NKG2D ligand, as compared to the baseline level. In certain embodiments, the baseline level can be established from a previous sample from the subject being tested, so that the disease state of the subject can be monitored over time and/or so that the efficacy of a given therapeutic protocol can be evaluated over time.

**[0099]** In some embodiments of a method of detecting a predisposition to developing type 2 diabetes, cardiovascular disease, inflammatory disease or a metabolic dysfunction-associated disease or the presence of type 2 diabetes, cardiovascular disease, inflammatory disease or a metabolic dysfunction-associated inflammation disease in a subject, expression of one or more markers in addition to an NKG2D ligand (e.g., MICA/B) is analyzed. The one or more markers can also be NKG2D ligands; expression of any NKG2D ligand can be analyzed. Examples of additional markers that can be measured include C-reactive protein, IL-6, TNF- $\alpha$ , sICAM-1, sCD40, the ULBP/RAET1 family of proteins (e.g., ULBP1, ULBP2, ULBP3, ULBP4, RAET1G, RAET1L), and others. In embodiments in which expression of one or more markers in addition to an NKG2D ligand (e.g., MICA/B) is analyzed, the combination of the NKG2D ligand (e.g., MICA/B) and other biomarkers may provide a more reliable prediction of vascular disease and/or metabolic dysfunction-associated disease development. In such an embodiment, the biological sample is contacted with at least one reagent that detects the expression of an NKG2D ligand and two or more reagents that detect the presence of expression of the one or more markers in addition to the NKG2D ligand (e.g., MICA/B), respectively. The levels of expression of the NKG2D ligand (e.g., MICA/B) and the two or more additional markers in the biological sample is measured; and overexpression of the NKG2D ligand (e.g., MICA/B) is correlated with a predisposition to type 2 diabetes, cardiovascular disease, inflammatory disease and/or metabolic dysfunction-associated disease (e.g., dyslipidemia, diabetic retinopathy, poor blood circulation, limb disorders, etc.) development in the subject. Depending on the particular two or more additional markers, their underexpression or overexpression may be correlated with a predisposition to type 2 diabetes, cardiovascular disease, inflammatory disease and/or metabolic dysfunction-associated disease development in the subject.

**[00100]** In another embodiment, the present invention provides compositions and methods for modulating NKG2D ligand (e.g., MICA/B or ULBP/RAET1 proteins) expression (e.g., inhibiting MICA/B or ULBP/RAET1 expression) and activity (e.g., binding to NKG2D) to treat a subject having type 2 diabetes, cardiovascular disease, inflammatory disease or a metabolic dysfunction-associated disease. The compositions may also be useful for treating those who are predisposed to and/or

has developed cardiovascular disease (e.g., atherosclerosis) and/or who has a metabolic dysfunction-associated disease such as high cholesterol or triglyceride levels, diabetes, dyslipidemia, diabetic retinopathy, poor blood circulation, limb disorders, etc., are described herein. Such compositions generally include a therapeutically effective amount of an agent for modulating expression or activity/signaling of one or more NKG2D ligands (e.g., MICA/B or ULBP/RAET1) and a pharmaceutically acceptable carrier. An inhibitor of an NKG2D ligand (e.g., MICA/B or ULBP/RAET1) is active to reduce the level of NKG2D ligand in a cell and/or to reduce the activity of NKG2D ligand in a cell. An inhibitor of the NKG2D ligand (e.g., MICA/B or ULBP/RAET1), active to reduce the level of an NKG2D ligand in the cell, may be an inhibitor of transcription or translation of the gene encoding the NKG2D ligand. In addition, an inhibitor of an NKG2D ligand active to reduce the level of the NKG2D ligand in the cell may stimulate degradation of the NKG2D ligand and/or NKG2D ligand-encoding RNA. An inhibitor of transcription and/or translation may be a nucleic acid-based inhibitor such as antisense oligonucleotides complementary to a target NKG2D ligand mRNA, as well as ribozymes and DNA enzymes which are catalytically active to cleave the target mRNA.

**[00101]** In some embodiments, a composition described herein includes an siRNA specific for a gene encoding an NKG2D ligand. Sequence-specific siRNA bind to a target nucleic acid molecule, inhibiting the expression thereof. Compositions for delivery of siRNA and methods of treatment thereof are provided. Methods of constructing and using ribozymes, siRNA and antisense molecules are known in the art (e.g., Isaka Y., *Curr Opin Mol Ther*, 9:132-136 (2007); Sioud M. and Iversen P.O., *Curr Drug Targets*, 6:647-653 (2005); *Ribozymes and siRNA Protocols (Methods in Molecular Biology)* by Mouldy Sioud, 2<sup>nd</sup> ed., 2004, Humana Press, New York, New York). An "antisense" nucleic acid can include a nucleotide sequence which is complementary to a "sense" nucleic acid encoding a protein, e.g., complementary to the coding strand of a double-stranded cDNA molecule or complementary to an mRNA sequence. The antisense nucleic acid can be complementary to an entire MICA/B coding strand, or to only a portion thereof. In another embodiment, the antisense nucleic acid molecule is antisense to a "noncoding region" of the coding strand of a nucleotide sequence encoding an NKG2D ligand (e.g., the 5' and 3'

untranslated regions). Anti-sense agents can include, for example, from about 8 to about 80 nucleobases (i.e. from about 8 to about 80 nucleotides), e.g., about 8 to about 50 nucleobases, or about 12 to about 30 nucleobases. Antisense compounds include ribozymes, external guide sequence (EGS) oligonucleotides (oligozymes),  
5 and other short catalytic RNAs or catalytic oligonucleotides which hybridize to the target nucleic acid and modulate its expression. Anti-sense compounds can include a stretch of at least eight consecutive nucleobases that are complementary to a sequence in the target gene. An oligonucleotide need not be 100% complementary to its target nucleic acid sequence to be specifically hybridizable. An oligonucleotide  
10 is specifically hybridizable when binding of the oligonucleotide to the target interferes with the normal function of the target molecule to cause a loss of utility, and there is a sufficient degree of complementarity to avoid non-specific binding of the oligonucleotide to non-target sequences under conditions in which specific binding is desired, i.e., under physiological conditions in the case of in vivo assays or  
15 therapeutic treatment or, in the case of in vitro assays, under conditions in which the assays are conducted.

**[00102]** In some embodiments, a composition for modulating expression of an NKG2D ligand (e.g., inhibiting MICA/B or ULBP/RAET1 expression) and activity (e.g., binding to NKG2D) to treat a subject having a metabolic dysfunction-associated inflammation disease such as type 2 diabetes who is predisposed to  
20 and/or has developed cardiovascular disease (e.g., atherosclerosis) and/or who has abnormal metabolic conditions such as high cholesterol or triglyceride levels, dyslipidemia, diabetic retinopathy, etc., includes a therapeutically effective amount of an agent for blocking the interaction of NKG2D with one or more of its ligands (e.g.,  
25 the NKG2D/MICA/B interaction), a pharmaceutically acceptable carrier, and a known drug for treating cardiovascular disease, high blood pressure, or metabolic disorders that result from a pathway other than the NKG2D/ligand interaction pathway. An example of a known drug for treating cardiovascular disease is any one of the 3-hydroxy-3-methylglutaryl coenzyme A reductase inhibitors (statins). Examples of  
30 statins include Cervistatin, Fluvastatin, Atorvastatin, Simvastatin, Pravastatin or Lovastatin, or a pharmaceutically acceptable salt thereof. Compositions and methods involving statins are known in the art (see, e.g., U.S. Patent No. 6,465,454).

**[00103]** In another embodiment, the present invention provides a composition for treating type 2 diabetes, cardiovascular disease, inflammatory disease and/or abnormal metabolic conditions (e.g., high cholesterol levels, high triglyceride levels, dyslipidemia, poor blood circulation, limb disorders, diabetic retinopathy, etc.) that includes an agent for blocking the interaction of NKG2D with one or more of its ligands (e.g., the NKG2D/MICA/B interaction) and a pharmaceutically acceptable carrier. In another embodiment, the composition includes an agent that inhibits NKG2D activation or signaling and a pharmaceutically acceptable carrier.

**[00104]** The data described herein in Example 3 indicate that blocking the NKG2D ligand binding interaction using an anti-NKG2D antibody was able to suppress plaque formation in diabetic ApoE<sup>-/-</sup> mice without altering the number the NKG2D-expressing cells.

**[00105]** Any suitable agent for blocking the interaction of NKG2D with one or more of its ligands (e.g., the NKG2D/MICA/B interaction) or inhibiting NKG2D activation or signaling can be used. For example, the agent may be selected from the group consisting of soluble NKG2D, an antibody or antigen-binding fragment thereof that specifically binds NKG2D, an NKG2D ligand and an inhibitor of NKG2D ligand activity or expression.

**[00106]** A typical agent that inhibits NKG2D activation or signaling or blocks the interaction of NKG2D with one or more of its ligands is an antibody that specifically binds NKG2D. In some embodiments, the antibody or antigen-binding fragment thereof binds human NKG2D (hNKG2D).

**[00107]** Any suitable antibody that specifically binds to NKG2D can be used. Anti-NKG2D antibodies as described herein include polyclonal and monoclonal human antibodies, or any antigen-binding fragment portions thereof, having at least one antigen binding region of an immunoglobulin variable region, which antibody specifically binds NKG2D. An antibody is specific for NKG2D if it is produced against an epitope of the polypeptide and binds to at least part of the natural or recombinant protein. Another example of an agent that inhibits NKG2D activation or signaling is an antibody that specifically binds an NKG2D ligand (e.g., MICA/B,

ULBPs). Any suitable antibody that specifically binds to an NKG2D ligand can be used.

**[00108]** Methods for determining monoclonal antibody specificity and affinity by competitive inhibition can be found in Harlow, *et al.*, *Antibodies: A Laboratory Manual*, Cold Spring Harbor Laboratory Press, Cold Spring Harbor, N.Y., 1988, Colligan *et al.*, eds., *Current Protocols in Immunology*, Greene Publishing Assoc. and Wiley Interscience, N.Y., (1992, 1993), and Muller, *Meth. Enzymol.* 92:589-601 (1983), which references are entirely incorporated herein by reference.

**[00109]** In some embodiments, the antibodies that specifically bind NKG2D are the human monoclonal antibodies 16F16, 16F31, MS, and 21F2 with the sequences described below. In some embodiments, the antibodies are human monoclonal antibodies MS. Full-length, variable, and CDR sequences of these antibodies are set forth in Table 1.

15

**Table 1**  
**Full-length, variable, and CDR amino acid sequences**  
**for 16F16, 16F31, MS, and 21F2**

<b>Antibody portion</b>	<b>SEQ ID NO:</b>	<b>Antibody portion</b>	<b>SEQ ID NO:</b>
16F16 IgG4 H chain	1	MS IgG4 H chain	21
16F16 L chain	2	MS L chain	22
16F31 IgG4 H chain	3	21F2 IgG4 H chain	23
16F16 L chain	4	21F2 L chain	24
16F16 VH region	5	MS VH region	25
16F16 VL region	6	MS VL region	26
16F31 VH region	7	21F2 VH region	27
16F31 VL region	8	21F2 VL region	28
16F16 VH CDR1	9	MS VH CDR1	29
16F16 VH CDR2	10	MS VH CDR2	30
16F16 VH CDR3	11	MS VH CDR3	31
16F16 VL CDR1	12	MS VL CDR1	32

16F16 VL CDR2	13	MS VL CDR2	33
16F16 VL CDR3	14	MS VL CDR3	34
16F31 VH CDR1	15	21F2 VH CDR1	35
16F31 VH CDR2	16	21F2 VH CDR2	36
16F31 VH CDR3	17	21F2 VH CDR3	37
16F31 VL CDR1	18	21F2 VL CDR1	38
16F31 VL CDR2	19	21F2 VL CDR2	39
16F31 VL CDR3	20	21F2 VL CDR3	40

**[00110]** Anti-NKG2D and anti-NKG2D ligand antibodies as described herein can be routinely made according to methods such as, but not limited to, inoculation of an appropriate animal with the polypeptide or an antigenic fragment, in vitro stimulation  
5 of lymphocyte populations, synthetic methods, hybridomas, and/or recombinant cells expressing nucleic acid encoding such anti-NKG2D antibodies. Immunization of an animal using purified recombinant NKG2D or peptide fragments thereof, is an example of a method of preparing anti-NKG2D antibodies. Similarly, immunization of an animal using purified recombinant NKG2D ligand (e.g., one of the  
10 ULBP/RAET1 proteins, MICA/B, Mult1, etc.) or peptide fragments thereof, is an example of a method of preparing anti-NKG2D ligand antibodies.

**[00111]** Monoclonal antibodies that specifically bind NKG2D or an NKG2D ligand may be obtained by methods known to those skilled in the art. See, for example Kohler and Milstein, *Nature* 256:495-497, 1975; U.S. Pat. No. 4,376,110; Ausubel et al., eds., *Current Protocols in Molecular Biology*, Greene Publishing Assoc. and  
15 Wiley Interscience, N.Y., (1987, 1992); Harlow and Lane *ANTIBODIES: A Laboratory Manual* Cold Spring Harbor Laboratory Press, Cold Spring Harbor, NY, 1988; Colligan et al., eds., *Current Protocols in Immunology*, Greene Publishing Assoc. and Wiley Interscience, N.Y., (1992, 1993), the contents of which are incorporated  
20 entirely herein by reference. Such antibodies may be of any immunoglobulin class including IgG, IgM, IgE, IgA, and any subclass thereof. A hybridoma producing a monoclonal antibody of the present invention may be cultivated in vitro, in situ or in vivo.

**[00112]** In another embodiment, the agent that inhibits NKG2D activation or signaling is a soluble NKG2D. Soluble NKG2D can be prepared by any suitable method known in the art (see, e.g., Diefenbach et al., Nat Immunol. vol. 1(2):119-26, 2000). In one embodiment, soluble NKG2D is administered to the subject by any suitable delivery route and means. In another embodiment, a nucleic acid encoding soluble NKG2D can be administered to a subject for treating type 2 diabetes, cardiovascular disease, inflammatory disease and/or a metabolic dysfunction-associated disease (e.g., high cholesterol levels, high triglyceride levels, dyslipidemia, poor blood circulation, limb disorders, diabetic retinopathy, etc.). The coding sequence which encodes a soluble NKG2D protein may be identical to the nucleotide sequence of accession no. 574240, or it may also be a different coding sequence which, as a result of the redundancy or degeneracy of the genetic code, encodes the same polypeptide as the polynucleotide of accession no. 574240. Other nucleic acid molecules as described herein include variants of the native NKG2D gene such as those that encode fragments, analogs and derivatives of a native NKG2D protein. Such variants may be, e.g., a naturally occurring allelic variant of the native NKG2D gene, a homolog of the native NKG2D gene, or a non-naturally occurring variant of the native NKG2D gene. These variants have a nucleotide sequence that differs from the native NKG2D gene in one or more bases. For example, the nucleotide sequence of such variants can feature a deletion, addition, or substitution of one or more nucleotides of the native NKG2D gene.

**[00113]** In yet another embodiment, an agent that inhibits NKG2D activation or signaling can be a soluble NKG2D ligand. Shed (soluble) forms of MICA/B have been shown to inhibit NKG2D function throughout the body. In such an embodiment, soluble NKG2D ligand or a nucleic acid encoding a soluble NKG2D ligand can be administered to a subject for treating type 2 diabetes, cardiovascular disease, inflammatory disease and/or a metabolic dysfunction-associated disease (e.g., high cholesterol levels, high triglyceride levels, dyslipidemia, poor blood circulation, limb disorders, diabetic retinopathy, etc.).

**[00114]** In other embodiments, variant NKG2D proteins or NKG2D ligands (e.g., MICA/B, ULBP/RAET1 proteins etc.) displaying substantial changes in structure can be generated by making nucleotide substitutions that cause less than conservative

changes in the encoded polypeptide. Examples of such nucleotide substitutions are those that cause changes in (a) the structure of the polypeptide backbone; (b) the charge or hydrophobicity of the polypeptide; or (c) the bulk of an amino acid side chain. Nucleotide substitutions generally expected to produce the greatest changes in protein properties are those that cause non-conservative changes in codons. Examples of codon changes that are likely to cause major changes in protein structure are those that cause substitution of (a) a hydrophilic residue, e.g., serine or threonine, for (or by) a hydrophobic residue, e.g., leucine, isoleucine, phenylalanine, valine or alanine; (b) a cysteine or proline for (or by) any other residue; (c) a residue having an electropositive side chain, e.g., lysine, arginine, or histadine, for (or by) an electronegative residue, e.g., glutamine or aspartine; or (d) a residue having a bulky side chain, e.g., phenylalanine, for (or by) one not having a side chain, e.g., glycine.

**[00115]** Naturally occurring allelic variants of a native Klrk1 gene or native Klrk1 mRNAs as described herein are nucleic acids isolated from human tissue that have at least 75% (e.g., 76%, 77%, 78%, 79%, 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, and 99%) sequence identity with the native Klrk1 gene or native Klrk1 mRNAs, and encode polypeptides having structural similarity to a native Klrk1 protein. Homologs of the native Klrk1 gene or native Klrk1 mRNAs as described herein are nucleic acids isolated from other species that have at least 75% (e.g., 76%, 77%, 78%, 79%, 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, and 99%) sequence identity with the native human Klrk1 gene or native human Klrk1 mRNAs, and encode polypeptides having structural similarity to native human NKG2D protein. Public and/or proprietary nucleic acid databases can be searched to identify other nucleic acid molecules having a high percent (e.g., 70, 80, 90% or more) sequence identity to the native Klrk1 gene or native Klrk1 mRNAs.

**[00116]** Non-naturally occurring Klrk1 gene or mRNA variants are nucleic acids that do not occur in nature (e.g., are made by the hand of man), have at least 75% (e.g., 76%, 77%, 78%, 79%, 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, and 99%) sequence identity with the native human Klrk1 gene or native human Klrk1 mRNAs, and encode polypeptides having structural similarity to native human NKG2D protein.

Examples of non-naturally occurring Klrk1 gene variants are those that encode a fragment of a NKG2D protein, those that hybridize to the native Klrk1 gene or a complement of the native Klrk1 gene under stringent conditions, those that share at least 65% sequence identity with the native Klrk1 gene or a complement thereof, and  
5 those that encode a NKG2D fusion protein.

**[00117]** Nucleic acids encoding fragments of a native NKG2D protein as described herein are those that encode, e.g., 2, 5, 10, 25, 50, 100, 150, 200 or more amino acid residues of the native NKG2D protein. Shorter oligonucleotides (e.g., those of 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 30, 50, base pairs in length) that  
10 encode or hybridize with nucleic acids that encode fragments of a native NKG2D protein can be used as probes, primers, or antisense molecules. Nucleic acids encoding fragments of a native NKG2D protein can be made by enzymatic digestion (e.g., using a restriction enzyme) or chemical degradation of the full length native Klrk1 gene, a Klrk1 mRNA or cDNA, or variants of the foregoing. Using the  
15 nucleotide sequence of the native human Klrk1 gene and the amino acid sequence of the native NKG2D protein previously reported, those skilled in the art can create nucleic acid molecules that have minor variations in their nucleotide sequence, by, for example, standard nucleic acid mutagenesis techniques or by chemical synthesis. Variant Klrk1 nucleic acid molecules can be expressed to produce variant  
20 NKG2D proteins.

**[00118]** In some embodiments, a composition for inhibiting type 2 diabetes, cardiovascular disease, inflammatory disease and/or treating abnormal metabolic conditions (e.g., high cholesterol levels, high triglyceride levels, dyslipidemia, diabetic retinopathy, limb disorders, poor blood circulation, etc.) includes an agent  
25 (e.g., anti-NKG2D antibody or anti-NKG2D ligand antibody) for blocking the interaction of NKG2D with one or more of its ligands (e.g., the NKG2D/MICA/B interaction), a pharmaceutically acceptable carrier, and a known drug for treating cardiovascular disease. An example of a known drug for treating cardiovascular disease is any one of the 3-hydroxy-3-methylglutaryl coenzyme A reductase  
30 inhibitors (statins). Examples of statins include Cervistatin, Fluvastatin, Atorvastatin, Simvastatin, Pravastatin or Lovastatin, or a pharmaceutically acceptable salt thereof.

Compositions and methods involving statins are known in the art (see, e.g., U.S. Patent No. 6,465,454).

**[00119]** The data described herein in Example 3 illustrates that blocking the NKG2D ligand binding interaction using an anti-NKG2D antibody significantly suppressed the atherosclerotic plaque formation in diabetic ApoE<sup>-/-</sup> mice, suggesting that the NKG2D/ligand interaction is a critical pathway in promoting cardiovascular disease development and can serve as a drug target for the prevention or treatment of cardiovascular disease. The data described herein in Examples 3 and 4 further illustrates the critical role of NKG2D/ligand interaction in atherosclerosis and inflammation using NKG2D knockout mice and anti-NKG2D antibody studies. Blocking the NKG2D/ligand interaction also alleviated abnormal metabolic conditions including reducing cholesterol and triglyceride levels as illustrated in Example 5. Further comparison of cytokine expression profiles in the anti-NKG2D antibody treated and control groups demonstrated that the anti-NKG2D antibody treatment significantly suppressed the production of multiple pro-inflammatory cytokines, suggesting that it functions by preventing vascular inflammation (see Example 4). The data described herein also provides that the NKG2D/ligand mediated immune activation is involved in type 2 diabetic progression. In the experiments described herein in Example 7, compared to the Western diet fed ApoE<sup>-/-</sup> mice, the NKG2D-deficient ApoE<sup>-/-</sup>Klrk1<sup>-/-</sup> mice fed with the same diet had significantly lower glucose levels in the blood, demonstrating the usefulness of targeting NKG2D or its ligands to treat type 2 diabetes. Moreover, anti-NKG2D antibody treatment was able to prevent the development and progression of hyperglycaemia and diabetes in a rodent model of type 2 diabetes, as described in Example 8.

**[00120]** In another embodiment, the present invention provides for methods of treating type 2 diabetes, cardiovascular disease, inflammatory disease and/or abnormal metabolic conditions (e.g., high cholesterol levels, high triglyceride levels, dyslipidemia, diabetic retinopathy, limb disorders, poor blood circulation, etc.) in a subject. In certain embodiments, the present invention provides for treating type 2 diabetes. In another embodiment, the present invention provides for methods for treating a condition that may be regulated or normalised via inhibition of NKG2D in a subject. Such conditions include, for example, type 2 diabetes, cardiovascular

disease, inflammatory disease and/or abnormal metabolic conditions (e.g., high cholesterol levels, high triglyceride levels, dyslipidemia, diabetic retinopathy, limb disorders, poor blood circulation, etc.). In certain embodiments, the condition is type 2 diabetes. In certain other embodiments, the condition is cardiovascular disease.

5 **[00121]** A typical method includes administering a therapeutically effective amount of an agent that inhibits NKG2D activation or signaling for inhibiting type 2 diabetes, cardiovascular disease, inflammatory disease and/or abnormal metabolic conditions and a pharmaceutically acceptable carrier to the subject. In certain embodiments, the method includes administering a therapeutically effective amount of an agent that  
10 blocks the NKG2D ligand binding interaction. The agent can be any of those described above, e.g., soluble NKG2D, antibody or antigen-binding fragment thereof that specifically binds NKG2D, soluble NKG2D ligand, antibody specific for an NKG2D ligand, an inhibitor of NKG2D ligand (e.g., MICA/B) activity or expression. In certain embodiments, the agent is an antibody or antigen-binding fragment thereof  
15 that specifically binds NKG2D. In certain embodiments, the antibody or antigen-binding fragment thereof is human or humanized. In certain embodiments, the antibody or antigen-binding fragment thereof binds human NKG2D (hNKG2D). In certain embodiments, the antibody or antigen-binding fragment thereof reduces NKG2D-mediated activation or signalling of an NKG2D-expressing cell. In certain  
20 embodiments, the antibody or antigen-binding fragment thereof competes with at least one NKG2D ligand in binding to NKG2D. In certain embodiments, the NKG2D ligand is MICA/B.

**[00122]** In certain embodiments, administration of the agent results in at least one of the following in the subject: reduces blood glucose levels, improves glucose  
25 tolerance, lowers insulin resistance, reduces body weight, lowers blood pressure, lowers inflammation or reduces metabolic dysfunctions.

**[00123]** The therapeutic methods described herein (which include prophylactic treatment) in general include administration of a therapeutically effective amount of the compositions described herein to a subject (e.g., animal, human) in need thereof,  
30 including a mammal, particularly a human. Such treatment will be suitably administered to subjects, particularly humans, suffering from, having, susceptible to, or at risk for a disease, disorder, or symptom thereof. Determination of those

subjects "at risk" can be made by any objective or subjective determination by a diagnostic test or opinion of a subject or health care provider (e.g., genetic test, enzyme or protein marker, marker (as defined herein), family history, and the like). The compositions herein may be also used in the treatment of any other disorders in  
5 which an excess of NKG2D signaling, expression, or activity may be implicated.

**[00124]** In one embodiment, a method of treating type 2 diabetes, cardiovascular disease, inflammatory disease and/or abnormal metabolic conditions (e.g., high cholesterol levels, high triglyceride levels, dyslipidemia, diabetic retinopathy, limb disorders, poor blood circulation, etc.) in a subject includes monitoring treatment  
10 progress. One can monitor treatment progress by determining a level of diagnostic marker (e.g., any target delineated herein modulated by a composition or agent described herein, a protein or indicator thereof, etc.) or diagnostic measurement (e.g., screen, assay) in a subject suffering from or susceptible to a disorder or symptoms thereof associated with type 2 diabetes, cardiovascular disease,  
15 inflammatory disease and/or abnormal metabolic conditions (e.g., high cholesterol levels, high triglyceride levels, dyslipidemia, diabetic retinopathy, limb disorders, poor blood circulation, etc.) in which the subject has been administered a therapeutic amount of a composition as described herein sufficient to treat the disease or symptoms thereof. The level of marker determined in the method can be compared  
20 to known levels of marker in either healthy normal controls or in other afflicted patients to establish the subject's disease status. Generally, a second level of marker in the subject is determined at a time point later than the determination of the first level, and the two levels are compared to monitor the course of disease or the efficacy of the therapy. In certain embodiments, a pre-treatment level of marker in  
25 the subject is determined prior to beginning treatment as described herein; this pre-treatment level of marker can then be compared to the level of marker in the subject after the treatment commences, to determine the efficacy of the treatment.

**[00125]** The administration of compositions including an inhibitor of NKG2D ligand activity or expression (e.g., a MICA/B inhibitor), soluble NKG2D, soluble NKG2D  
30 ligand(s), anti-NKG2D antibody, anti-NKG2D ligand antibody, etc. for the treatment of diabetes, cardiovascular disease (e.g., atherosclerosis) and/or abnormal metabolic conditions (e.g., high cholesterol levels, high triglyceride levels,

dyslipidemia, diabetic retinopathy, limb disorders, poor blood circulation, etc.) may be by any suitable means that results in a concentration of the therapeutic that, combined with other components, is effective in ameliorating, reducing, or eliminating type 2 diabetes, cardiovascular disease (e.g., suppress atherosclerotic plaque formation), inflammatory disease and/or abnormal metabolic conditions (e.g., type high cholesterol levels, high triglyceride levels, dyslipidemia, diabetic retinopathy, limb disorders, poor blood circulation, etc.). The inhibitor of NKG2D ligand activity or expression (e.g., a MICA/B inhibitor), soluble NKG2D, soluble NKG2D ligand(s), anti-NKG2D antibody, anti-NKG2D ligand antibody, etc., may be contained in any appropriate amount in any suitable carrier substance, and is generally present in an amount of 1-95% by weight of the total weight of the composition. The composition may be provided in a dosage form that is suitable for local or systemic administration (e.g., parenteral, subcutaneously, intravenously, intramuscularly, or intraperitoneally). In certain embodiments, the composition is administered intravenously, intraperitoneally or subcutaneously. The pharmaceutical compositions may be formulated according to conventional pharmaceutical practice (see, e.g., Remington: The Science and Practice of Pharmacy (20th ed.), ed. A. R. Gennaro, Lippincott Williams & Wilkins, 2000 and Encyclopedia of Pharmaceutical Technology, eds. J. Swarbrick and J. C. Boylan, 1988-1999, Marcel Dekker, New York).

**[00126]** Compositions as described herein may be administered parenterally by injection, infusion or implantation (subcutaneous, intravenous, intramuscular, intraperitoneal, or the like) in dosage forms, formulations, or via suitable delivery devices or implants containing conventional, non-toxic pharmaceutically acceptable carriers and adjuvants. The formulation and preparation of such compositions are well known to those skilled in the art of pharmaceutical formulation. Formulations can be found in Remington: The Science and Practice of Pharmacy, supra.

**[00127]** Compositions for parenteral use may be provided in unit dosage forms (e.g., in single-dose ampules), or in vials containing several doses and in which a suitable preservative may be added (see below). The composition may be in the form of a solution, a suspension, an emulsion, an infusion device, or a delivery device for implantation, or it may be presented as a dry powder to be reconstituted

with water or another suitable vehicle before use. Apart from the active agent, the composition may include suitable parenterally acceptable carriers and/or excipients. The active therapeutic agent(s) may be incorporated into microspheres, microcapsules, nanoparticles, liposomes, or the like for controlled release.

5 Furthermore, the composition may include suspending, solubilizing, stabilizing, pH-adjusting agents, tonicity adjusting agents, and/or dispersing agents.

**[00128]** As indicated above, the pharmaceutical compositions according to the invention may be in the form suitable for sterile injection. To prepare such a composition, the suitable active therapeutic(s) are dissolved or suspended in a

10 parenterally acceptable liquid vehicle. Among acceptable vehicles and solvents that may be employed are water, water adjusted to a suitable pH by addition of an appropriate amount of hydrochloric acid, sodium hydroxide or a suitable buffer, 1,3-butanediol, Ringer's solution, and isotonic sodium chloride solution and dextrose solution. The aqueous formulation may also contain one or more preservatives (e.g.,

15 methyl, ethyl or n-propyl p-hydroxybenzoate). In cases where one of the compounds is only sparingly or slightly soluble in water, a dissolution enhancing or solubilizing agent can be added, or the solvent may include 10-60% w/w of propylene glycol or the like.

**[00129]** Materials for use in the preparation of microspheres and/or microcapsules

20 are, e.g., biodegradable/bioerodible polymers such as polygalactin, poly-(isobutyl cyanoacrylate), poly(2-hydroxyethyl-L-glutamine) and, poly(lactic acid). Biocompatible carriers that may be used when formulating a controlled release parenteral formulation are carbohydrates (e.g., dextrans), proteins (e.g., albumin), lipoproteins, or antibodies. Materials for use in implants can be non-biodegradable

25 (e.g., polydimethyl siloxane) or biodegradable (e.g., poly(caprolactone), poly(lactic acid), poly(glycolic acid) or poly(ortho esters) or combinations thereof).

**[00130]** At least two anti-cardiovascular disease therapeutics (e.g., NKG2D or a MICA/B inhibitor and a statin) may be mixed together in one formulation.

**[00131]** Compositions as described herein may also be combined with a second or

30 more pharmacologically active agent, e.g., selected from antidiabetic agents, antiobesity agents, appetite regulating agents, antihypertensive agents, agents for

the treatment and/or prevention of complications resulting from or associated with diabetes and agents for the treatment and/or prevention of complications and disorders resulting from or associated with obesity. Examples of these pharmacologically active substances are: GLP-1 and GLP-1 derivatives and analogues, GLP-2 and GLP-2 derivatives and analogues, Exendin-4 and Exendin-4 derivatives and analogues, amylin and amylin derivatives and analogues, sulphonylureas, biguanides, meglitinides, glucosidase inhibitors, glucagon antagonists, DPP-IV (dipeptidyl peptidase-IV) inhibitors, SGLT2 inhibitors, SGLT1 inhibitors, inhibitors of hepatic enzymes involved in stimulation of gluconeogenesis and/or glycogenolysis, glucose uptake modulators, compounds modifying the lipid metabolism such as antihyperlipidemic agents as HMG CoA inhibitors (statins), compounds lowering food intake, RXR agonists and agents acting on the ATP-dependent potassium channel of the  $\beta$ -cells; Cholestyramine, colestipol, clofibrate, gemfibrozil, lovastatin, pravastatin, simvastatin, probucol, dextrothyroxine, nateglinide, repaglinide;  $\beta$ -blockers such as alprenolol, atenolol, timolol, pindolol, propranolol and metoprolol, ACE (angiotensin converting enzyme) inhibitors such as benazepril, captopril, enalapril, fosinopril, lisinopril, alatriopril, quinapril and ramipril, calcium channel blockers such as nifedipine, felodipine, nocardipine, isradipine, nimodipine, diltiazem and verapamil, and  $\alpha$ -blockers such as doxazosin, urapidil, prazosin and terazosin; CART (cocaine amphetamine regulated transcript) agonists, NPY (neuropeptide Y) antagonists, PYY (polypeptide YY) agonists, PP (pancreatic polypeptide) agonists, Y2 receptor agonists, Y4 receptor agonists, mixed Y2/Y4 receptor agonists, adiponectin agonists, PPAR agonists, MC4 (melanocortin 4) agonists, orexin antagonists, TNF (tumor necrosis factor) agonists, CRF (corticotropin releasing factor) agonists, CRF BP (corticotropin releasing factor binding protein) antagonists, urocortin agonists,  $\beta$ 3 agonists, MSH (melanocyte-stimulating hormone) agonists, MCH (melanocyte-concentrating hormone) antagonists, CCK (cholecystokinin) agonists, serotonin re-uptake inhibitors, serotonin and noradrenaline re-uptake inhibitors, mixed serotonin and noradrenergic compounds, 5HT (serotonin) agonists, bombesin agonists, galanin antagonists, growth hormone, growth hormone releasing compounds, TRH (thyrotropin releasing hormone) agonists, UCP 2 or 3 (uncoupling protein 2 or 3) modulators, leptin agonists, DA agonists (bromocriptin, doprexin), lipase/amylase inhibitors, RXR

(retinoid X receptor) modulators, TR  $\beta$  agonists; histamine H3 antagonists, gastrin and gastrin analogues and derivatives, glucagon and glucagon derivatives and analogues, FGF-21 (fibroblast growth factor 21) and FGF-21 derivatives and analogues, proton pump inhibitors such as lansoprazole, omeprazole, 5 dexlansoprazole, esomeprazole, pantoprazole, and rabeprazole and glucokinase activators.

**[00132]** It should be understood that any suitable combination of the compositions according to the invention with one or more of the above-mentioned compounds and optionally one or more further pharmacologically active substances are considered to 10 be within the scope of the present invention.

**[00133]** Although many of the compositions, methods and kits described above pertain to treating type 2 diabetes and cardiovascular disease, the compositions and methods described herein can also be used to prevent any metabolic dysfunction-associated disease in a subject, including type 2 diabetes and cardiovascular 15 diseases. In certain embodiments, the compositions and methods of the present invention can prevent or abolish the symptoms of a disease, a delay in onset of the symptoms of a disease, or lessening in the severity of a disease.

**[00134]** In other embodiments, the compositions and methods described herein can be used to detect, prevent and/or treat any metabolic dysfunction-associated 20 disease in a subject, regardless of whether or not the subject has type 2 diabetes. For example, a method of detecting elevated levels of cholesterol and triglycerides in a subject is described herein and includes obtaining a biological sample from the subject, contacting the biological sample with at least one reagent that detects expression of an NKG2D ligand (e.g., MICA/B expression); measuring the level of 25 expression of the NKG2D ligand in the biological sample; and correlating overexpression of the NKG2D ligand (e.g., MICA/B) with a predisposition to having elevated levels of cholesterol and triglycerides or the presence of elevated levels of cholesterol and triglycerides in the subject. A method of treating a subject (who may or may not have type 2 diabetes) having elevated levels of cholesterol and 30 triglycerides includes administering a therapeutically effective amount of an agent that inhibits NKG2D activation or signaling for lowering cholesterol and triglyceride levels and a pharmaceutically acceptable carrier to the subject. As another example,

described herein is a method of treating a subject having diabetic retinopathy. Such a method includes administering a therapeutically effective amount of an agent that inhibits NKG2D activation or signaling for inhibiting diabetic retinopathy and a pharmaceutically acceptable carrier to the subject. The agent that inhibits NKG2D  
5 activation or signaling for inhibiting diabetic retinopathy or lowering cholesterol and triglyceride levels can be any of those described above, e.g., soluble NKG2D, antibody specific for NKG2D, soluble NKG2D ligand, antibody specific for an NKG2D ligand, an inhibitor of NKG2D ligand (e.g., MICA/B) activity or expression, etc. The agent and pharmaceutically acceptable carrier can be packaged in a kit as described  
10 above.

**[00135]** In additional embodiments, compositions and methods for treating type 2 diabetes, cardiovascular disease, inflammatory disease and/or metabolic dysfunction-associated diseases (e.g., high cholesterol levels, high triglyceride levels, dyslipidemia, poor blood circulation, limb disorders, diabetic retinopathy, etc.)  
15 can include an agent that promotes shedding of an NKG2D ligand from the surface of cells. NKG2D ligands are often cleaved from the cell surface by proteases (called "shedding") and shedding is generally thought to inhibit NKG2D signaling by binding of the shed ligand to NKG2D and downregulating NKG2D activity (e.g., signaling). Any agent that promotes or inhibits shedding can modulate NKG2D signalling and  
20 activity and can be used in such an embodiment. For example, an antibody or antigen binding fragment against a protein involved in shedding can be administered to a subject in an amount effective for promoting shedding of at least one NKG2D ligand.

**[00136]** Additionally, the compositions, kits and methods described herein can be  
25 used to prevent a metabolic dysfunction-associated disease in a subject. For example, a physician may administer the compositions and methods described herein to a subject who has a predisposition to cardiovascular disease and/or a metabolic dysfunction-associated disease, whether due to a family history (genetics) or environmental factors (e.g., diet, lack of exercise, etc.).

**[00137]** The compositions described above are preferably administered to a  
30 subject (e.g., human) in an effective amount, that is, an amount capable of producing a desirable result in the treated subject (e.g., inhibiting or preventing type 2 diabetes,

cardiovascular disease such as atherosclerosis, lowering blood glucose levels and promoting weight loss in a type 2 diabetes patient, reducing cholesterol or triglyceride levels in the subject, lowering insulin resistance in the subject, preventing or alleviating dyslipidemia, diabetic retinopathy, limb disorders, poor blood circulation, etc., in the subject). Toxicity and therapeutic efficacy of the compositions described herein can be determined by standard pharmaceutical procedures. As is well known in the medical and veterinary arts, dosage for any one animal depends on many factors, including the subject's size, body surface area, age, the particular composition to be administered, time and route of administration, general health, and other drugs being administered concurrently.

**[00138]** The amount of the therapeutic agent to be administered varies depending upon the manner of administration, the age and body weight of the patient, and with the clinical symptoms of the cancer. A composition as described herein is typically administered at a dosage that inhibits NKG2D activity and/or signaling, as assayed by identifying a reduction in atherosclerotic plaque formation, blood glucose levels, body weight, cholesterol levels, triglyceride levels, insulin resistance, etc., or using any that assay that measures the expression or the biological activity of an NKG2D ligand (e.g., MICA/B or ULBP/RAET1) or NKG2D activity or signaling.

**[00139]** Described herein are kits for detecting NKG2D ligands (e.g., MICA/B or ULBP/RAET1 proteins) in a biological sample from a subject (e.g., human) to detect the presence of or predict the occurrence of type 2 diabetes, cardiovascular disease, inflammatory disease and/or abnormal metabolic conditions (e.g., high cholesterol levels, high triglyceride levels, dyslipidemia, diabetic retinopathy, limb disorders, poor blood circulation, etc.) in the subject. A typical kit includes at least one reagent for detecting the expression of an NKG2D ligand (e.g., MICA/B or ULBP/RAET1) in a biological sample from the subject and instructions for use. In one embodiment, a kit includes a monoclonal or polyclonal antibody to a ULBP/RAET1 protein, or to MICA/B, a detectable label, and instructions for use. Generally, the biological sample is serum. However, any suitable biological sample can be used. Examples of additional biological samples include blood, plasma, urine, saliva, skin, and biopsy samples.

**[00140]** Kits for administering treatment to a subject (e.g., human) having diabetes or any conditions that may be regulated or normalised via inhibition of NKG2D, such as type 2 diabetes, cardiovascular disease, inflammatory disease and/or abnormal metabolic conditions (e.g., high cholesterol levels, high triglyceride levels, 5 dyslipidemia, diabetic retinopathy, limb disorders, poor blood circulation, etc.) are also described herein. In one embodiment, the kit includes a therapeutic or prophylactic composition containing a therapeutically effective amount of an agent for blocking the interaction of NKG2D and one or more of its ligands (e.g., the NKG2D/MICA/B interaction, the interaction of NKG2D and one of the ULBP/RAET1 10 proteins, etc.) or for inhibiting NKG2D activation or signaling and a pharmaceutically acceptable carrier in unit dosage form. The agent may be a soluble NKG2D, an antibody or antigen-binding fragment thereof that specifically binds NKG2D, an NKG2D ligand and an inhibitor of NKG2D ligand activity or expression. In certain 15 embodiments, the agent is an antibody or antigen-binding fragment thereof that specifically binds NKG2D. In certain embodiments, the antibody or antigen-binding fragment thereof is human or humanized. In certain embodiments, the antibody or antigen-binding fragment thereof binds human NKG2D (hNKG2D).

**[00141]** If desired, the kit also contains an effective amount of a known drug for treating cardiovascular disease (e.g., a statin) and/or a drug for treating an abnormal 20 metabolic condition (e.g., high cholesterol levels, high triglyceride levels, dyslipidemia, diabetic retinopathy, limb disorders, poor blood circulation, etc.).

**[00142]** In certain embodiments, the kit further comprises at least one additional agent selected from the group consisting of antidiabetic agents, antiobesity agents, appetite regulating agents, antihypertensive agents, agents for the treatment and/or 25 prevention of complications resulting from or associated with diabetes and agents for the treatment and/or prevention of complications and disorders resulting from or associated with obesity.

**[00143]** Generally, a kit as described herein includes packaging and instructions for use. In some embodiments, the kit includes a sterile container which contains a 30 therapeutic or prophylactic composition; such containers can be boxes, ampules, bottles, vials, tubes, bags, pouches, blister-packs, or other suitable container forms

known in the art. Such containers can be made of plastic, glass, laminated paper, metal foil, or other materials suitable for holding medicaments.

[00144] The present invention is further illustrated by the following specific examples. The examples are provided for illustration only and should not be  
5 construed as limiting the scope of the invention in any way.

## EXAMPLES

**EXAMPLE 1: Detection of MICA, a ligand for NKG2D, in sera and  
atherosclerotic plaques of type 2 diabetes patients and its association with  
10 expression of other proinflammatory cytokines**

[00145] To determine whether metabolic dysfunction might cause upregulation of certain stress response immune stimulating molecules, MICA/B expression was assessed in a group of type 2 diabetic patients who have confirmed diabetes and, in some, have dyslipidemia as well. Type 1 diabetic patients were not included  
15 because they are mostly of autoimmune diseases and might have MICA upregulation independent of the metabolic conditions, as inferred from type 1 diabetic NOD mouse studies (Ogasawara *et al.*, *Immunity*, 20:757-767 (2004)). Since it is unpractical to analyze MICA/B expression on blood vessels of the patients, levels of soluble MICA (sMICA) proteins in the blood were assayed. The  
20 sMICA is enzymatically cleaved products of membrane MICA (mMICA) expressed on the cell surface and was previously reported to be detected in the blood of various cancer patients and immune disease patients but not in healthy people. Therefore, the detection of sMICA in the blood of the diabetic patients would indicate MICA upregulation in the blood vessels or other tissues.

25 [00146] Twenty-two patients were tested and elevated levels of sMICA were detected in significant percentages of them (Fig. 1A). Of the 22 patients, six (27%) had serum MICA at levels of higher than 400 pg/ml with the highest at 12250 pg/ml (Fig. 1A, Patient #1-6). In addition, four patients (18%) had detectable levels of serum sMICA (50-350 pg/ml) (Fig. 1A, patients #7-10). To determine how the  
30 sMICA levels in the diabetic patients were comparable to those in cancer patients, 50 serum samples from various cancer patients were also tested. The type 2

diabetic patients have more significantly elevated levels of sMICA proteins than the cancer patients since the sMICA levels of the 50 cancer patients were all below 20 pg/ml (Fig. 1E). Although the sMICA levels in cancer patients vary a lot depending on cancer types and stages, those of the type 2 diabetic patients were still at the higher end when compared to the sMICA levels of cancer patients reported in the literature (Salih *et al.*, J Immunol., 169:4098-4102 (2002); Groh *et al.*, Nature, 419:734-738 (2002)).

**[00147]** Considering that these patients have been diagnosed with diabetes for 1 to 20 years with various healthy conditions, it is not surprising that they have variable levels of sMICA. In spite of the variation, certain trends were found that were associated with the high serum sMICA level, especially when comparing the MICA-high with MICA-negative patients. Particularly, the average blood glucose level was higher in the MICA-high patients than in the MICA-negative patients ( $190\pm 65$  vs.  $157\pm 47$ ;  $p = 0.1$ ). The high levels of sMICA proteins in the blood indicated that membrane MICA was expressed on certain cell types that, if on arteries, may impact vascular inflammation through interaction with its receptor NKG2D expressed on the multiple immune cells. It should be noted that although both membrane and soluble forms of MICA proteins bind to NKG2D, they have different effects on immune activation. NKG2D/mMICA engagement activates the immune cells while NKG2D/sMICA interaction does not. In fact, sMICA might interfere with NKG2D/mMICA interaction-mediated immune activation through the competition with mMICA for the NKG2D binding. Therefore, expression of several inflammation-associated cytokines and factors in the sera of the diabetic patients was analyzed and an attempt to correlate them with soluble MICA expression was made.

**[00148]** Levels of cytokines IL-6, TNF- $\alpha$ , IL-1 $\beta$ , interferon- $\gamma$  (IFN- $\gamma$ ) and C-reactive protein (CRP) in the sera of the same diabetic patients was assessed to determine whether upregulation of sMICA is associated with any of these parameters (Fig. 1B-D). The IL-1 $\beta$  and IFN- $\gamma$  were below detectable range of the assays. There was no correlation between levels of sMICA/B and TNF- $\alpha$  or CRP (Fig. 1A, C&D), suggesting that MICA expression was regulated differentially from the TNF- $\alpha$  or CRP, two well-defined inflammation markers. Interestingly, there was an inverse correlation between sMICA/B and IL-6 expression in the sera (Fig. 1A & B). The

serum level of IL-6 in MICA-positive group (patients #1-10) was significantly lower than that of MICA-negative group (patients #11-22) ( $1.21 \pm 0.51$  ng/ml vs.  $1.85 \pm 1.13$  ng/ml,  $P=0.05$ ), suggesting an interdependent relationship between these two factors.

5 [00149] Together, these data demonstrated that MICA/B molecules are upregulated in the type 2 diabetic patients and might be involved in vascular inflammation and atherosclerosis. Although a high level of sMICA clearly indicates the MICA upregulation in the diabetic patients, the net effect of MICA upregulation on inflammation and atherosclerosis depends on relative contribution of the soluble and  
10 membrane MICA proteins. Generation of sMICA is usually a compensation mechanism for mMICA/NKG2D interaction to regulate the immune activation. Therefore, mouse models were used to directly assess the upregulation of NKG2D ligands in arteries and its importance in the inflammation and atherosclerosis.

[00150] To further establish clinical relevance of the NKG2D ligand expression,  
15 immunohistochemical staining of atherosclerotic aortic sections of human patients was performed to determine whether the ligands of NKG2D were upregulated in the tissues. In contrast to plaque-free aortae (Fig. 2I), many cells in the atherosclerotic aortae stained positive with a MICA/B antibody (Fig. 2A, C, E and G). The overlapping staining patterns of MICA/B with Mac-3 or CD31 in adjacent sections  
20 suggested that both macrophages and endothelial cells of the atherosclerotic aortae expressed MICA/ B (Fig. 2B, D, F, H), suggesting that human have similar expression patterns of NKG2D ligands in affected tissues.

***EXAMPLE 2: Upregulation of NKG2D ligands in cells of atherosclerotic plaques and other tissues of ApoE<sup>-/-</sup> mice***

25 [00151] To test directly whether the ligands for NKG2D were upregulated in blood vessels of diabetic and dyslipidemic mice, expression of NKG2D ligands was determined in ApoE<sup>-/-</sup> mice, an animal model of dyslipidemia and atherosclerosis. It has been well established that the chronic dysfunctional metabolism in the ApoE<sup>-/-</sup> mice leads to the development of atherosclerotic plaques, in which immune cells  
30 account for a significant portion. These mice have impaired lipid metabolism and

develop atherosclerosis as they age. The upregulation of NKG2D ligands in aortae of ApoE-null mice that developed atherosclerotic plaques was analyzed.

**[00152]** First, mRNA expression of the NKG2D ligands was examined in aortae of 8-10 month-old ApoE<sup>-/-</sup> mice (no diabetic induction) which had atherosclerotic plaques in the aorta, especially in the arch areas. Referring to Fig. 3A, to determine specifically whether the plaque lesions have different levels of NKG2D ligand expression, RNAs were isolated separately from the atherosclerotic aortic arch ("plaqued") and the thoracic part of an aorta that did not have apparent plaques ("plaque-free") of 8-10 month-old, non-diabetic ApoE<sup>-/-</sup> mice ("Atherosclerotic ApoE<sup>-/-</sup>"). RNAs of corresponding parts of an aorta from 2 month-old, plaque-free ApoE<sup>-/-</sup> mice were used as controls ("plaque-free ApoE<sup>-/-</sup>"). To more specifically determine upregulation of the different individual NKG2D ligands, isoform-specific primers for the different isoforms of Rae-1 genes, as well as H60 and Mult-1 genes, were used. Rae-1, H60 and MULT-1 are all NKG2D ligands that belong to different families (Diefenbach *et al.*, Nature Immunology, 1:119-126 (2000); Takada *et al.*, J Immunol., 180:1678-1685 (2008)). There are five closely related Rae-1 genes in mice (>98% identical) and three different isoforms of H60 genes (H60a, b and c) have been identified (Diefenbach *et al.*, Nature Immunology, 1:119-126 (2000); Takada *et al.*, J Immunol., 180:1678-1685 (2008)). The transcripts for Rae-1 $\delta$ , Rae-1 $\epsilon$  and H60 were analyzed by semi-quantitative radioactive RT-PCR. Briefly, The RNA samples were reverse transcribed with Superscript II RNase-H reverse transcriptase using oligo-dT primers. The RT products were serially diluted (5-fold each) and subjected to PCR using gene-specific primers in the presence of P<sup>32</sup> dCTP. The primers used were based on reported gene sequences (Diefenbach *et al.*, Nature Immunology, 1:119-126 (2000); Takada *et al.*, J Immunol., 180:1678-1685 (2008)). The PCR products were run on a polyacrylamide gel, which was then dried and exposed to a Phospho-Image screen.  $\beta$ -Actin was used as loading control.

**[00153]** Compared to those in the controls, transcripts for Rae-1 $\delta$ , Rae-1 $\epsilon$  and H60b were drastically upregulated in the plaque regions of the atherosclerotic ApoE-null mice (Fig. 3A). Compared to the atherosclerosis-free younger ApoE-null controls, up to 100-fold increases of Rae-1 $\delta$ , Rae-1 $\epsilon$  and H60b transcripts were detected in the plaque areas (Fig. 3A). Even when compared to the non-plaque part

of the aorta of the same mouse, 10- 20 fold increases of the Rae-1 $\delta$ , Rae-1 $\epsilon$  and H60 $\beta$  genes were found in the plaque area (Fig. 3A). The non-plaque region of the aorta of the old ApoE $^{-/-}$  mice had modest upregulation of Rae-1 $\delta$ & $\epsilon$  when compared to the corresponding region of the young atherosclerosis-free ApoE $^{-/-}$  mice. Much higher levels of transcripts for NKG2D ligands Rae-1 $\delta$ , Rae-1 $\epsilon$  and H60b (10-30 fold increase) were also detected in aortic arches of Western diet (WD)-fed ApoE $^{-/-}$  mice than in age-matched wild type (WT) controls (Fig. 3B). These data suggested that certain cellular components of the atherosclerotic plaques have very dramatic upregulation of the NKG2D ligand expression.

10 **[00154]** To further confirm the upregulation of the NKG2D ligands in the plaques, immunohistochemical staining was performed on the cryosections of atherosclerotic plaques of the ApoE-null mice with polyclonal anti-Rae-1 and H60 antibodies. Since diabetes and high fat Western diets accelerate plaque formation and might be involved in upregulation of the NKG2D ligands, plaques in ApoE-null mice that were rendered diabetic by streptozotocin (STZ) injection or fed with a Western diet were also examined. Referring to Fig. 3C, for the STZ treatment, six-week-old ApoE-null mice (Jackson Lab, Bar Harbor, Maine) were induced to develop diabetes by intraperitoneal injection of streptozotocin (STZ) (55 mg/kg, freshly dissolved in pH 4.5 citrate buffer) for six consecutive days and confirmed by blood glucose concentration (>300 mg/dL). Two months after the diabetic induction, aortae were isolated and cryopreserved. The cryosections were stained with polyclonal goat anti-Rae-1 or H60 antibody (R&D Systems and Santa Cruz Biotechnology respectively), followed by horseradish peroxidase (HRP)-conjugated donkey anti-goat IgG antibody and ABC-HRP staining system to reveal positive staining (brown color) (Santa Cruz Biotechnology). The sections were further stained with monoclonal rat anti-mouse CD68 antibody (Serotec), followed by Alkaline Phosphatase (AP)-conjugated donkey anti-rat antibody and ABC-AP staining kit (blue color) (Vector Laboratory). For the Western diet fed ApoE $^{-/-}$  model of atherosclerosis, six-week-old ApoE-null mice switched from normal chow to the Western diet. Two months after being on the Western diet, aortae were isolated and cryopreserved and analyzed by anti-Rae-1 and H60 antibody staining (Fig. 3D).

**[00155]** Positive staining for both Rae-1 and H60 were apparent in the sections of the plaque areas but much less in tunica media or adventitia of the atherosclerotic aortic arch regions of both diabetic and non-diabetic ApoE null mice (Fig. 3C and 3D). As controls, nearly not Rae-1 or H60 staining was detected in plaque-free aortic regions of the same mice (Fig. 3D, bottom panels). Staining for CD68, a marker for tissue resident macrophages, had a significant overlap with the RAE-1 and H60 staining, indicating that the plaque-infiltrating macrophages were at least one cellular population of the plaques that expressed the NKG2D ligands, which was further confirmed by flow cytometric analysis of Rae-1 expression on macrophages directly isolated from atherosclerotic aortae (Fig. 3E). In addition, endothelial cells isolated from aortae of the atherosclerotic ApoE<sup>-/-</sup> mice also had higher Rae-1 expression (Fig. 3E).

**[00156]** Considering their defective metabolism, macrophages of ApoE<sup>-/-</sup> mice likely upregulated the NKG2D ligand expression in response to increased abnormal metabolites in blood and tissues. Therefore, whether or not macrophages could be induced in the *in vitro* culture by oxidized LDL (oxLDL) or advanced glycation end products (AGE), two abnormal metabolites associated with dyslipidemia and diabetes, was determined. As shown, macrophages of wild type mice significantly upregulated their expression of multiple NKG2D ligands at both transcript and protein levels when cultured in the presence of oxLDL and AGE (Fig. 3F-H). Referring to Fig. 3F, after a 2-day culture, mRNAs were isolated from the differently treated macrophages, reverse transcribed to generate cDNAs, which were five-fold serially diluted and subject to PCRs for detection of NKG2D ligands Rae-1 $\delta$ , Rae-1 $\epsilon$  and H60b. Referring to Fig. 3G, macrophages treated in the same way as in Fig. 3F were lysed, separated on PAGE gels and analyzed by Western blot with an anti-Rae1 antibody that reacts with all isoforms of Rae-1 molecules. Referring to Fig. 3H, wild type macrophages cultured with oxLDL or AGE also had higher cell surface levels of the Rae-1 staining based on flow cytometry analysis. The Rae-1 staining could be competed off by non-colored "cold" anti-RAE-1 antibodies, confirming a specific upregulation of the NKG2D ligand (Fig. 3H).

**[00157]** Taken together, these experiments demonstrated that multiple ligands for NKG2D were upregulated in arteries of mice with lipid and/or glucose metabolism

disorders. The profound upregulation of the NKG2D ligands in the plaque lesions suggested a direct role of the NKG2D ligands in propagating vascular inflammation and atherosclerosis. Interestingly, only cells in the plaques, such as macrophages, had the most profound upregulation of transcripts and proteins of the NKG2D ligands. Considering that many cells in the plaques are activated in response to the lipid components, these data suggested that the NKG2D ligand upregulation is likely induced through both stress-responsible and immune activation pathways in the different types of cells.

**Example 3: Suppression of plaque formation in ApoE-null mice by blockage of the NKG2D/ligand interaction with monoclonal anti-NKG2D antibodies or NKG2D knockout**

**[00158]** The NKG2D ligand upregulation in arteries, especially on the plaques, might activate NKG2D-expressing immune cells to promote the vascular inflammation and atherosclerosis. To test this, monoclonal anti-NKG2D antibody (clone MI-6) was injected into diabetic ApoE-null mice to block the potential NKG2D/ligands interaction and whether such a blockage could suppress the plaque formation was determined. Injection of the anti-NKG2D antibody has been shown to block the NKG2D/ligand interaction in mice without deleting NKG2D-expressing immune cells (Jamieson and Raulet, unpublished). Six-week old male homozygous ApoE-null mice of C57BL/6 background were induced diabetic by STZ injection to accelerate the plaque formation. One week and three days before the STZ administration, 200 micrograms/injection of the monoclonal anti-NKG2D antibody (clone MI-6, rat IgG2a) were intraperitoneally injected into the ApoE-null mice. In the control group, the mice were treated in the same way except that they were given isotype-matched control antibody instead of anti-NKG2D antibody. The mice were kept on normal chow for eight weeks after induction of the diabetes, during which period anti-NKG2D or control antibodies were given to the mice once a week throughout the experimental duration. One week after the last antibody injection, the mice were sacrificed and analyzed for atherosclerotic lesions in aorta.

**[00159]** Compared to those injected with isotype-matched control antibodies, the diabetic ApoE-null mice injected with the anti-NKG2D antibody had a dramatic reduction in the plaque formation (Fig. 4). Of all the seven anti-NKG2D antibody

treated and eight control antibody treated mice (in three separate experiments), sizes of the plaques in the NKG2D-antibody treated mice were always significantly smaller than those of the control antibody treated mice (Fig. 4A). To further determine the extent of the suppression of the plaque formation, en face staining of aortae was performed with Oil Red O dye for deposition of lipid contents in five of the seven anti-NKG2D antibody-treated mice and six of the eight control antibody-treated mice (of two separate experiments). There was enormous amounts of oil red O staining in the arch areas of aortae of the control antibody-treated mice (Fig. 4B, the three on the right). In contrast, the staining was much less intense in the anti-NKG2D antibody-treated mice (Fig. 4B, the two on the left), further demonstrating that the anti-NKG2D antibody blockage suppressed lipid deposition and plaque formation. On average, there was about a five-fold reduction in the Oil Red O staining positive area in the anti-NKG2D antibody treated mice compared to the controls (Fig. 5A).

**[00160]** Confirming that the NKG2D-antibody treatment specifically blocked NKG2D without induction of deletion of NKG2D-expressing cells, it was found that there were equal numbers of NK1.1+ NK cells and NKT cells in the anti-NKG2D and control antibody treated mice and the NK cells of the anti-NKG2D antibody treated mice express NKG2D normally. In addition, the anti-NKG2D antibody treatment did not result in global anergy of the NKG2D-expressing immune cells. In the *in vitro* assays, NK cells of the anti-NKG2D treated mice were responsive to the anti-NK1.1 antibody stimulation to express interferon- $\gamma$  just as efficiently as those of control antibody treated mice. Together, these experiments demonstrated that the NKG2D/ligand interaction-mediated immune activation played an important role in the atherosclerosis and blockage of such an interaction suppressed the atherosclerosis.

**[00161]** To prove the critical role of NKG2D/ligand interaction in the atherosclerosis, ApoE<sup>-/-</sup> mice were crossed with NKG2D knockout mice to generate ApoE/NKG2D double knockout (ApoE<sup>-/-</sup>-KLRK1<sup>-/-</sup>) mice. Two models to test the effect of the ApoE/NKG2D double knockout on the development of atherosclerosis were tested. The first model is the STZ-induced diabetes, as used in the anti-NKG2D antibody blockage assay (Fig. 4). The second model is Western diet-

accelerated atherosclerosis in which mice were fed with a high fat diet, starting at age six weeks. Eight to ten weeks after the onset of diabetes or start of the Western diet, the ApoE<sup>-/-</sup>-KLRK1<sup>-/-</sup> mice were analyzed for the plaque formation on aorta by the en face Oil Red O staining. Compared to the ApoE<sup>-/-</sup>-KLRK1<sup>+/+</sup> mice treated in the same ways, both the diabetic and Western-diet fed ApoE<sup>-/-</sup>-KLRK1<sup>-/-</sup> mice had dramatically reduced plaque sizes based on Oil Red O staining positive areas (Fig. 5B and C). These findings provided genetic proof of the important role of NKG2D/ligand interaction in atherosclerosis. In addition, they also provide evidence on wide involvement of this interaction in both diabetes and dyslipidemia-associated atherosclerosis, suggesting potential usage of targeting this molecular interaction for treatment and prevention of atherosclerosis of various origins.

***Example 4: Blockage of NKG2D/ligand interaction decreased expression of pro-inflammatory cytokines in atherosclerotic ApoE-null mice***

[00162] Since the NKG2D/ligand interaction mediates immune activation in multiple NKG2D-expressing immune cell types, the suppression of the atherosclerosis by the anti-NKG2D antibody blockage suggested that it functioned through inhibiting inflammation. To test this, sera from the anti-NKG2D and control antibody treated diabetic ApoE<sup>-/-</sup> mice were collected at the time of plaque analysis and levels of multiple pro-inflammatory cytokines in the sera were analyzed, along with sera of other control mice, using a mouse pro-inflammatory-7 plex kit (Meso Scale Discovery). Of 7 cytokines assessed, five (IL-6, TNF- $\alpha$ , IFN- $\gamma$ , IL-10 and IL-12p70) were reduced in the anti-NKG2D antibody treated mice, compared to the control antibody treated mice (Fig. 6). Most noticeably, IL-6 was dramatically reduced to the levels of aged-matched healthy wild-type B6 mice or young ApoE<sup>-/-</sup> mice that have not had dyslipidemia or diabetes (more than 10 fold reduction, P<0.001). TNF- $\alpha$  was reduced to non-detectable levels in the anti-NKG2D treated mice. These data indicated that the antibody blockage of NKG2D/ligand interaction suppressed the inflammation in the diabetic ApoE<sup>-/-</sup> mice to prevent the atherosclerosis.

[00163] The reduction of IL-6 in the anti-NKG2D antibody treated mice correlates with the reverse relationship of soluble MICA and IL-6 in the serum of diabetic patients (Fig. 1). Considering both the anti-NKG2D antibody and sMICA function by

interfering with NKG2D mediated immune activation, high levels of sMICA in the human patients might be a naturally occurring mechanism for suppression of inflammation.

[00164] The decreased production of pro-inflammatory cytokines was also observed in the KLRK1<sup>-/-</sup>ApoE<sup>-/-</sup> mice. Compared to diabetic or western diet fed NKG2D-sufficient ApoE<sup>-/-</sup> mice, the similarly treated KLRK1<sup>-/-</sup>ApoE<sup>-/-</sup> mice had reduced serum levels of most pro-inflammatory cytokines (Fig. 7). Multiple inflammatory cytokines (IL-6, IFN- $\gamma$ , IL-12 and TNF- $\alpha$ ) were also reduced in the serum of NKG2D-antibody-treated KLRK1<sup>-/-</sup>ApoE<sup>-/-</sup> mice. Notably, IL-6 and IFN- $\gamma$  were dramatically reduced in all the models. Together, these results demonstrate that preventing the NKG2D/ligand interaction suppressed inflammation and reduced atherosclerosis.

***Example 5: Preventing the NKG2D/ligand interaction alleviated abnormal metabolic conditions in ApoE<sup>-/-</sup> mice***

[00165] Besides reducing the atherosclerosis and inflammation, preventing the NKG2D/ligand interaction also considerably alleviated metabolic disorders. In striking contrast to the turbid appearance of sera from western-diet fed ApoE<sup>-/-</sup> mice, those of similarly fed KLRK1<sup>-/-</sup>ApoE<sup>-/-</sup> mice were clear (Fig. 8A), suggesting reduced accumulation of lipid components in their blood. Confirming this, serum levels of cholesterol and triglycerides were significantly lower in KLRK1<sup>-/-</sup>ApoE<sup>-/-</sup> mice than in the ApoE<sup>-/-</sup> mice (Fig. 8B). Considering that the abnormal lipid metabolic condition contributes to atherosclerosis directly and promotes inflammation, these results suggested that the NKG2D/ligand interaction propagates the positive feedback cycle of inflammation and metabolic dysfunction to sustain atherosclerotic progression.

[00166] In summary, these results demonstrate that abnormal metabolic condition-associated upregulation of NKG2D ligands is critically involved in atherosclerosis and inhibiting the NKG2D/ligand interaction suppressed the disease progression by reducing the inflammation and alleviating abnormal metabolic disorders, suggesting it as an attractive therapeutic target in treatment against atherosclerosis.

**Example 6: Preventing the NKG2D/ligand interaction suppressed liver inflammation in ApoE<sup>-/-</sup> mice**

[00167] Reduced serum levels of cholesterol and triglycerides in the Western diet fed NKG2D-knockout ApoE<sup>-/-</sup> mice suggested that the NKG2D/ligand mediated immune activation aggravates the metabolic dysfunctions. Since the liver is the major organ of lipid metabolism, the NKG2D/ligand interaction mediated inflammation likely aggravated the abnormal metabolic conditions by impairing the function. Indeed, compared to ApoE<sup>-/-</sup> mice, NKG2D-knockout ApoE<sup>-/-</sup> mice had significantly lower activity of serum alanine aminotransferase (ALT) (Fig. 9), indicating an alleviated liver dysfunction. The ALT activities in the serum were determined using a kit from Bioo Scientific (Austin, TX) according to the manufacturer's instruction. For each group, at least 5 mice were used. \*\*P<0.01.

[00168] It was tested whether preventing the NKG2D/ligand interaction reduced the amount of liver inflammation. Compared to those of ApoE<sup>-/-</sup> mice, liver explants of NKG2D-knockout ApoE<sup>-/-</sup> mice, cultured *ex vivo*, produced significantly less IL-6, indicating a reduced inflammation (Fig. 10A). In addition, compared to those of ApoE<sup>-/-</sup> mice, numbers of various immune cells, including macrophages, NKT and NK cells, were all reduced in livers of NKG2D-knockout ApoE<sup>-/-</sup> mice, (Fig. 10B), indicating that preventing the NKG2D/ligand interaction indeed reduced liver inflammation.

[00169] What immune cells were affected by the NKG2D/ligand interaction to contribute to the liver inflammation was investigated. Like the atherosclerotic aortae, livers of ApoE<sup>-/-</sup> mice had high upregulation of NKG2D ligands (Fig. 11A). Both macrophages and hepatocytes of livers had upregulated Rae-1 expression in ApoE<sup>-/-</sup> mice, compared to the wild-type controls (Fig. 11B-D). Corresponding to the upregulated ligands in the livers of Western diet fed ApoE<sup>-/-</sup> mice, NKG2D-expressing immune cells, such as NK and particularly NK T cells, of the livers of these mice exhibited considerable cytokine production, including IFN- $\gamma$  and IL-4, which was markedly attenuated when the mice also lacked NKG2D (Fig. 11E and F). In contrast, the liver macrophages, which do not express NKG2D, produced high levels of IL-6 in ApoE<sup>-/-</sup> mice whether or not the mice expressed NKG2D (Fig. 11G). As already noted, however, the number of macrophages was reduced substantially in

Klrk1<sup>-/-</sup>ApoE<sup>-/-</sup> mice, indicating that macrophages were indirectly influenced by NKG2D mediated inflammation. These findings demonstrate that abnormal metabolic conditions induce the upregulation of NKG2D ligands, particularly in tissues where abnormal metabolites accumulate, such as atherosclerotic plaques and the liver, and therefore the NKG2D/ligand interaction is a useful intervention target against atherosclerosis.

**Example 7: Preventing the NKG2D/ligand interaction reduced glucose levels in Western diet fed ApoE<sup>-/-</sup> mice**

[00170] In one experiment, 8-week old ApoE<sup>-/-</sup> and NKG2D-deficient ApoE<sup>-/-</sup> Klrk1<sup>-/-</sup> mice were fed on the Western diet for 3 months. Blood sera were then collected and assessed for the glucose levels at the end of the feeding regimen. The ApoE<sup>-/-</sup>-Klrk<sup>-/-</sup> mice on average had significantly lower glucose levels than ApoE<sup>-/-</sup> mice after feeding on the Western diet for three months (Fig. 12), suggesting that preventing the NKG2D/ligand interaction could suppress the hyperglycemia progression.

**Example 8: Anti-NKG2D antibody prevents the development and progression of hyperglycaemia and diabetes in a rodent model of type 2 diabetes**

[00171] To further determine the effect of blocking NKG2D on the development and progression of type 2 diabetes, an anti-NKG2D antibody was administered to *Psammomys obesus* (also known as sand rats), a gerbil animal model of type 2 diabetes.

[00172] Male and female *P. obesus* (Harlan, Jerusalem, Israel), were fed low energy (2.4 kcal/g) chow until the age of 9 weeks when they were transferred to an ad libitum high energy (3.1 kcal/g) diet during which body-weight (BW) and morning blood glucose (mBG) was followed for up to 10 days (induction period). The animals that showed increased mBG levels, defined as mBG >10 mmol/L on two consecutive readings, were transferred back to low energy diet and were used in the actual study (prevention) 10 days later when their mBG levels were back to non-diabetic levels. The animals that did not show any increase in mBG during the induction period were sacrificed and not used further.

**[00173]** *P. obesus* were treated with vehicle (N=19) or NKG2D-PE antibody clone CX5) (N=9), once weekly by intra-peritoneal injection. The NKG2D rodent antibody formulation includes CX5 OP001 - ca. at 10 EU/ml or 0.96 mg/ml. One vial of 45 ml, dissolved in PBS buffer was kept at 4°C and the dose volume used was 0.52 ml/kg  
5 or 0.5 mg/kg.

**[00174]** The study was conducted over 6 weeks during which mBG and BW were followed regularly. For the determination of mBG (mmol/l), blood samples were taken from the tail tip capillary into 10µl glass capillary tubes and immediately suspended in buffer (500µl of Biosen analysis buffer) in eppendorf vials and  
10 analyzed for glucose on the test day.

**[00175]** During the study, five animals in the vehicle group and one in the NKG2D antibody group had to be sacrificed due to severely elevated mBG and ketoacidosis. The study was approved by the Animal Experiments Inspectorate, Ministry of Justice, Denmark.

**[00176]** As shown in Fig. 13, six weeks after the first dose of vehicle or NKG2D antibody, all the animals in the vehicle had become severely diabetic with a mean mBG of  $14.5 \pm 2.6$  mM (mean  $\pm$  sem) while the animals treated with the NKG2D antibody had remained normoglycaemic (mBG<8 mM) and had a significantly lower mBG of  $8.0 \pm 1.9$  mM,  $p<0.0001$  (mean  $\pm$  sem). There was no difference in BW gain  
15 in the two treatment groups. These findings demonstrate that NKG2D plays a very important role in the development of overt type 2 diabetes (probably through reduced inflammation, insulin resistance and beta cell failure) in a rodent animal model that has many of the same features as humans with type 2 diabetes. By blocking the effects of NKG2D with an antibody, the high-energy diet induced development of  
20 type 2 diabetes in *P.obesus* was completely abolished.  
25

**[00177]** To confirm the specificity of the anti-NKG2D antibody, flow cytometric analysis of the NKG2D antibody binding to blood cells from *P. obesus* was performed.

**[00178]** Briefly, EDTA-stabilized blood from sand rats was stained in 100 µl  
30 aliquots with antibodies against NKG2D or isotype controls: anti-mouse NKG2D-PE

(clone CX5), rat IgG1-PE isotype control, anti-human NKG2D-PE (clone 1D11), mouse IgG1-PE isotype control and anti-human NKG2D-PE (clone ON72). Blood was then lysed, fixed and washed using BD FACS lysing/fixing solution and PBS and binding of PE-conjugated antibodies was measured on a LSRII flow cytometer.

5 FSC/SSC was used to identify non-granulocytes.

**[00179]** As shown by the flow cytometric analysis in Fig. 14, a dose-dependent binding was observed for the anti-mouse NKG2D-PE antibody (clone CX5) to NK cells in sand rat blood. This binding was specific as there was no binding of the isotype control antibodies (rat IgG1-PE isotype control (R3-34) and mouse IgG1-PE isotype control (MOPC-21)) or the anti-human NKG2D antibodies (clone 1D11 and  
10 clone ON72).

**[00180]** The results demonstrate the usefulness of targeting NKG2D for the treatment of type 2 diabetes and hyperglycemia.

### Materials and Methods

15 **[00181]** *Mouse models and human patients:* ApoE<sup>-/-</sup> mice on the C56BL/6 background were purchased from Jackson Lab. Klrk1<sup>-/-</sup> mice were previously described. Klrk1<sup>-/-</sup>ApoE<sup>-/-</sup> mice were generated by crossing ApoE<sup>-/-</sup> and Klrk1<sup>-/-</sup> mice and intercrossing the pups. To accelerate atherosclerosis, six-week old males were fed on a Western diet ad libido or injected with streptozotocin (STZ) to induce  
20 diabetes (Park *et al.*, Nat Med, 4:1025-1031 (1998)) and analyzed 8-10 weeks after initiation of the treatments. For the NKG2D antibody blockage experiment, ApoE<sup>-/-</sup> mice were injected with the monoclonal NKG2D antibody (clone MI-6, rat IgG2a) (Jamieson *et al.*, Immunity, 17:19-29 (2002)) one week and three days before the STZ administration and weekly afterwards for eight weeks (200 µg/1st injection and  
25 100 µg/injection of the others).

**[00182]** *Antibodies and reagents:* The NKG2D antibody (clone MI-6) was prepared in house. Pan-Rae-1 antibody was purchased from R&D Systems while the others were from BD Biosciences or eBioscience or indicated in the following relevant sections.

**[00183]** *En face Oil Red O staining:* Aortae of differently treated mice were opened up, fixed in 10% formalin and stained with Oil Red O dye. Sizes of Oil Red O staining positive plaque areas were calculated based on digital pictures of the stained aortae using Adobe Photoshop.

5 **[00184]** *Immunohistochemical staining:* Cryosections of mouse aortic plaques were stained with polyclonal goat anti-mouse Rae-1 or H60 antibody (R&D Systems and Santa Cruz Biotechnology respectively), followed by horseradish peroxidase (HRP)-conjugated donkey anti-goat IgG antibody and ABC-HRP staining system (brown color) (Santa Cruz Biotechnology). The sections were further stained with  
10 monoclonal rat anti-mouse CD68 antibody (Serotec), followed by Alkaline Phosphatase (AP)-conjugated donkey anti-rat antibody and ABC-AP staining kit (blue color) (Vector Laboratory). Adjacent cryosections of human aortic plaques were stained with a monoclonal mouse anti-human MICA/B antibody (clone 6D4, eBioscience), anti-Mac-3 or anti-CD31 antibody.

15 **[00185]** *Cellular isolation:* Mononucleocytes, endothelial cells and hepatocytes were isolated from aortae or livers according to the reported procedures. The isolated cells were counted and used for various analyses.

**[00186]** *Flow cytometry:* Cells were stained with proper combination of fluorescently labeled antibodies and analyzed by flow cytometry using the flow  
20 cytometer FC500 (Beckman Counter).

**[00187]** *Semi-quantitative and real-time RT-PCR analysis:* RNA was analyzed for transcripts of Rae-1 $\delta$ , Rae-1 $\epsilon$  and H60b by semi-quantitative radioactive or real-time RT-PCR.

**[00188]** *In vitro treatment of macrophages:* Peritoneal macrophages were cultured  
25 *in vitro* for two days in media containing oxLDL (10  $\mu$ g/ml), natural LDL (nLDL) (10  $\mu$ g/ml), AGE (200  $\mu$ g/ml) or LPS (200 ng/ml), and analyzed for the expression of NKG2D ligands.

**[00189]** *Western blot analysis for total Rae-1 proteins:* The macrophages were lysed, separated on PAGE gels, transferred to PEGF membrane, blotted with anti-  
30 Rae1 antibody (C20, Santa Cruz Biotechnology) and developed with a SEL system.

[00190] *Multiplex analysis of serum cytokines:* Mouse sera were analyzed directly on a mouse proInflammatory-7plex kit (IL-6, TNF- $\alpha$ , IFN- $\gamma$ , IL-12p70, IL-10, IL-1 $\beta$  and KC/CXCL1) (Meso Scale Discovery, Gaithersburg, MD).

5 [00191] *Assessment of cholesterol and triglyceride levels in serum:* Levels of cholesterol and triglycerides were analyzed on VetTest® Chemistry Analyzer (IDEXX Laboratories, Inc. Maine).

[00192] *ALT activity analysis:* The ALT activities in the serum were determined using a kit from Bioo Scientific (Austin, TX) according to the manufacturer's instruction.

10 [00193] *Ex vivo culture of liver explants:* PBS-perfused livers were excised from Western diet fed ApoE<sup>-/-</sup> or Klrk1<sup>-/-</sup>ApoE<sup>-/-</sup> mice. Equal weights of excised livers were cut into about 1mm<sup>3</sup> cubes and cultured in media for 1 or 3 days. The culture media were recovered and analyzed for cytokines by ELISA.

15 [00194] *Intracellular cytokine staining:* Mononucleocytes isolated from livers were cultured in media overnight in presence of brofeldin A and analyzed by the intracellular cytokine staining for the production of IL-6, IFN- $\gamma$  and IL-4 in gated subsets of immune cells according to the manufacturers' instructions (eBioscience and Biolegend).

20 [00195] *ELISA detection of soluble MICA:* Sera of type 2 diabetic and cancer patients were assayed for MICA proteins using an ELISA kit (R&D Systems, Minneapolis, MN).

[00196] *Statistical analyses:* All data are expressed as means  $\pm$  s.e.m. Statistical significance was determined with a two-tail student T test. P < 0.05 is considered statistically significant.

25 [00197] All references, including publications, patent applications and patents, cited herein are hereby incorporated by reference to the same extent as if each reference was individually and specifically indicated to be incorporated by reference and was set forth in its entirety herein.

**[00198]** Any combination of the above-described elements in all possible variations thereof is encompassed by the invention unless otherwise indicated herein or otherwise clearly con-tradicted by context.

**[00199]** The terms “a” and “an” and “the” and similar referents as used in the  
5 context of de-scribing the invention are to be construed to cover both the singular and the plural, unless otherwise indicated herein or clearly contradicted by context.

**[00200]** The use of any and all examples, or exemplary language (e.g., “such as”) provided herein, is intended merely to better illuminate the invention and does not pose a limitation on the scope of the invention unless otherwise indicated. No  
10 language in the specification should be construed as indicating any element is essential to the practice of the invention unless as much is explicitly stated.

**[00201]** The description herein of any aspect or embodiment of the invention using terms such as “comprising”, “having”, “including” or “containing” with reference to an element or elements is intended to provide support for a similar aspect or  
15 embodiment of the invention that “consists of”, “consists essentially of”, or “substantially comprises” that particular element or elements, unless otherwise stated or clearly contradicted by context (e.g., a composition described herein as comprising a particular element should be understood as also describing a composition consisting of that element, unless otherwise stated or clearly  
20 contradicted by context).

**[00202]** This invention includes all modifications and equivalents of the subject matter recited in the aspects or claims presented herein to the maximum extent permitted by applicable law.

**EXEMPLARY EMBODIMENTS**

The following are exemplary embodiments of the invention.

1. A method of treating type 2 diabetes comprising administering to a subject in need thereof a therapeutically effective amount of an agent that inhibits NKG2D activation or signaling.
2. A method of treating type 2 diabetes comprising administering to a subject in need thereof a therapeutically effective amount of an agent that blocks the NKG2D ligand binding interaction.
3. A method of treating a condition that may be regulated or normalized via inhibition of NKG2D comprising administering to a subject in need thereof a therapeutically effective amount of an agent that inhibits NKG2D activation or signaling, wherein the condition is selected from the group consisting of type 2 diabetes, cardiovascular disease, inflammatory disease and metabolic dysfunction-associated diseases.
4. A method of treating a condition that may be regulated or normalized via inhibition of NKG2D comprising administering to a subject in need thereof a therapeutically effective amount of an agent that blocks the NKG2D ligand binding interaction, wherein the condition is selected from the group consisting of type 2 diabetes, cardiovascular disease, inflammatory disease and metabolic dysfunction-associated diseases.
5. The method according to embodiment 3 or 4, wherein the condition is type 2 diabetes.
6. The method according to embodiment 3 or 4, wherein the condition is cardiovascular disease.
7. The method according to any of one of the preceding embodiments, wherein the subject is human.

8. The method according to any of one of the preceding embodiments, wherein the agent is selected from the group consisting of soluble NKG2D, an antibody or antigen-binding fragment thereof that specifically binds NKG2D, an NKG2D ligand and an inhibitor of NKG2D ligand activity or expression.
9. The method according to embodiment 8, wherein the agent is an antibody or antigen-binding fragment thereof that specifically binds NKG2D.
10. The method according to embodiment 9, wherein the antibody or antigen-binding fragment thereof is human or humanized.
11. The method according to embodiment 9, wherein the antibody or antigen-binding fragment thereof binds human NKG2D (hNKG2D).
12. The method according to embodiment 9, wherein the antibody or antigen-binding fragment thereof reduces NKG2D-mediated activation or signalling of an NKG2D-expressing cell.
13. The method according to any one of embodiments 9-12, wherein the antibody or antigen-binding fragment thereof competes with at least one NKG2D ligand in binding to NKG2D.
14. The method according to embodiment 13, wherein the NKG2D ligand is MICA/B.
15. The method according to any of one of the preceding embodiments, wherein administration of the agent results in at least one of the following in the subject: reduces blood glucose levels, improves glucose tolerance, lowers insulin resistance, reduces body weight, lowers blood pressure, lowers inflammation or reduces metabolic dysfunctions.
16. The method according to any of one of the preceding embodiments, wherein the agent is administered intravenously, intraperitoneally or subcutaneously.
17. The method according to any one of the preceding embodiments, further comprising administering at least one additional agent selected from the group consisting of antidiabetic agents, antiobesity agents, appetite regulating

agents, antihypertensive agents, agents for the treatment and/or prevention of complications resulting from or associated with diabetes and agents for the treatment and/or prevention of complications and disorders resulting from or associated with obesity.

18. The method according to embodiment 17, wherein the additional agent is selected from the group consisting of: (a) a blood glucose lowering agent selected from the group consisting of GLP-1 and GLP-1 derivatives and analogues, Exendin-4 and Exendin-4 derivatives and analogues, amylin and amylin derivatives and analogues, sulphonylureas, biguanides, meglitinides (such as nateglinide and repaglinide), glucosidase inhibitors, DPP-IV (dipeptidyl peptidase-IV) inhibitors, SGLT2 inhibitors, SGLT1 inhibitors or agonists, gastrin and gastrin analogues and derivatives, FGF-21 (fibroblast growth factor 21) and FGF-21 derivatives and analogues, proton pump inhibitors such as lansoprazole, omeprazole, dexlansoprazole, esomeprazole, pantoprazole, and rabeprazole, RXR agonists, Cholestyramine, colestipol, probucol, dextrothyroxine, PPAR agonists, and adiponectin and adiponectin derivatives and analogues; (b) a blood lipid lowering or lipid metabolism modifying agent selected from the group consisting of antihyperlipidemic agents, HMG CoA inhibitors (statins) such as lovastatin, pravastatin and simvastatin, and fibrates such as gemfibrozil and clofibrate; (c) an agent that lowers food intake or increases energy expenditure selected from the group consisting of NPY (neuropeptide Y) antagonists, PYY (polypeptide YY) agonists, PP (pancreatic polypeptide) agonists, Y2 receptor agonists, Y4 receptor agonists, mixed Y2/Y4 receptor agonists, MC4 (melanocortin 4) agonists, orexin antagonists, glucagon and glucagon derivatives and analogues, CRF (corticotropin releasing factor) agonists, CRF BP (corticotropin releasing factor binding protein) antagonists, urocortin agonists,  $\beta$ 3 agonists, MSH (melanocyte-stimulating hormone) agonists, MCH (melanocyte-concentrating hormone) antagonists, CCK (cholecystokinin) agonists, serotonin re-uptake inhibitors, serotonin and noradrenaline re-uptake inhibitors, mixed serotonin and noradrenergic compounds, 5HT (serotonin) agonists, bombesin agonists, galanin antagonists, growth hormone, growth hormone releasing compounds, TRH (thyrotropin releasing

hormone) agonists, UCP 2 or 3 (uncoupling protein 2 or 3) modulators, leptin agonists, DA agonists (bromocriptin, doprexin), lipase/amylase inhibitors, RXR (retinoid X receptor) modulators, histamine H3 antagonists, and CART (cocaine amphetamine regulated transcript) agonists; and (d) a blood pressure lowering agent selected from the group consisting of  $\beta$ -blockers such as alprenolol, atenolol, timolol, pindolol, propranolol and metoprolol, ACE (angiotensin converting enzyme) inhibitors such as benazepril, captopril, enalapril, fosinopril, lisinopril, alatriopril, quinapril and ramipril, calcium channel blockers such as nifedipine, felodipine, nicardipine, isradipine, nimodipine, diltiazem and verapamil, and  $\alpha$ -blockers such as doxazosin, urapidil, prazosin and terazosin.

19. A composition comprising a therapeutically effective amount of an agent that inhibits NKG2D activation or signaling and a pharmaceutically acceptable carrier.
20. A composition comprising a therapeutically effective amount of an agent that blocks the NKG2D ligand binding interaction and a pharmaceutically acceptable carrier.
21. A composition according to embodiment 19 or 20, wherein the agent is useful for treating type 2 diabetes.
22. A composition according to embodiment 19 or 20, wherein the agent is useful for treating a condition that may be regulated or normalized via inhibition of NKG2D.
23. The composition according to embodiment claim 22, wherein the condition is selected from the group consisting of type 2 diabetes, cardiovascular disease, inflammatory disease and metabolic dysfunction-associated diseases.
24. The composition according to embodiment 23, wherein the condition is type 2 diabetes.
25. The composition according to embodiment 23, wherein the condition is cardiovascular disease.

26. The composition according to any of one of the preceding embodiments 19-25, wherein the agent is selected from the group consisting of soluble NKG2D, an antibody or antigen-binding fragment thereof that specifically binds NKG2D, an NKG2D ligand and an inhibitor of NKG2D ligand activity or expression.
27. The composition according to embodiment 26, wherein the agent is an antibody or antigen-binding fragment thereof that specifically binds NKG2D.
28. The composition according to embodiment 27, wherein the antibody or antigen-binding fragment thereof is human or humanized.
29. The composition according to embodiment 27, wherein the antibody or antigen-binding fragment thereof binds human NKG2D (hNKG2D).
30. The composition according to embodiment 26, wherein the agent is an inhibitor of NKG2D ligand activity or expression.
31. The composition according to embodiment 30, wherein the inhibitor of NKG2D ligand activity or expression is a MICA/B inhibitor.
32. The composition according to embodiment 31, wherein the MICA/B inhibitor is MICA/B-specific siRNA.
33. The composition according to any one of embodiments 19-32, further comprising at least one additional agent selected from the group consisting of antidiabetic agents, antiobesity agents, appetite regulating agents, antihypertensive agents, agents for the treatment and/or prevention of complications resulting from or associated with diabetes and agents for the treatment and/or prevention of complications and disorders resulting from or associated with obesity.
34. The composition according to embodiment 33, wherein the additional agent is selected from the group consisting of (a) a blood glucose lowering agent selected from the group consisting of GLP-1 and GLP-1 derivatives and analogues, Exendin-4 and Exendin-4 derivatives and analogues, amylin and amylin derivatives and analogues, sulphonylureas, biguanides, meglitinides

(such as nateglinide and repaglinide), glucosidase inhibitors, DPP-IV (dipeptidyl peptidase-IV) inhibitors, SGLT2 inhibitors, SGLT1 inhibitors or agonists, gastrin and gastrin analogues and derivatives, FGF-21 (fibroblast growth factor 21) and FGF-21 derivatives and analogues, proton pump inhibitors such as lansoprazole, omeprazole, dexlansoprazole, esomeprazole, pantoprazole, and rabeprazole, RXR agonists, Cholestyramine, colestipol, probucol, dextrothyroxine, PPAR agonists, and adiponectin and adiponectin derivatives and analogues; (b) a blood lipid lowering or lipid metabolism modifying agent selected from the group consisting of antihyperlipidemic agents, HMG CoA inhibitors (statins) such as lovastatin, pravastatin and simvastatin, and fibrates such as gemfibrozil and clofibrate; (c) an agent that lowers food intake or increases energy expenditure selected from the group consisting of NPY (neuropeptide Y) antagonists, PYY (polypeptide YY) agonists, PP (pancreatic polypeptide) agonists, Y2 receptor agonists, Y4 receptor agonists, mixed Y2/Y4 receptor agonists, MC4 (melanocortin 4) agonists, orexin antagonists, glucagon and glucagon derivatives and analogues, CRF (corticotropin releasing factor) agonists, CRF BP (corticotropin releasing factor binding protein) antagonists, urocortin agonists,  $\beta$ 3 agonists, MSH (melanocyte-stimulating hormone) agonists, MCH (melanocyte-concentrating hormone) antagonists, CCK (cholecystokinin) agonists, serotonin re-uptake inhibitors, serotonin and noradrenaline re-uptake inhibitors, mixed serotonin and noradrenergic compounds, 5HT (serotonin) agonists, bombesin agonists, galanin antagonists, growth hormone, growth hormone releasing compounds, TRH (thyrotropin releasing hormone) agonists, UCP 2 or 3 (uncoupling protein 2 or 3) modulators, leptin agonists, DA agonists (bromocriptin, dorexin), lipase/amylase inhibitors, RXR (retinoid X receptor) modulators, histamine H3 antagonists, and CART (cocaine amphetamine regulated transcript) agonists; and (d) a blood pressure lowering agent selected from the group consisting of  $\beta$ -blockers such as alprenolol, atenolol, timolol, pindolol, propranolol and metoprolol, ACE (angiotensin converting enzyme) inhibitors such as benazepril, captopril, enalapril, fosinopril, lisinopril, alatriopril, quinapril and ramipril, calcium channel blockers such as nifedipine, felodipine, nicardipine, isradipine,

nimodipine, diltiazem and verapamil, and  $\alpha$ -blockers such as doxazosin, urapidil, prazosin and terazosin.

35. A kit comprising:
  - (a) a therapeutically effective amount of an agent that inhibits NKG2D activation or signaling combined with a pharmaceutically acceptable carrier; and
  - (b) instructions for use.
36. A kit comprising:
  - (a) a therapeutically effective amount of an agent that blocks the NKG2D ligand binding interaction combined with a pharmaceutically acceptable carrier; and
  - (b) instructions for use.
37. The kit according to embodiment 35 or 36, wherein the agent is useful for treating type 2 diabetes.
38. The kit according to embodiment 35 or 36, wherein the agent is useful for treating a condition that may be regulated or normalized via inhibition of NKG2D.
39. The kit according to embodiment 38, wherein the condition is selected from the group consisting of type 2 diabetes, cardiovascular disease, inflammatory disease and metabolic dysfunction-associated diseases.
40. The kit according to embodiment 39, wherein the condition is type 2 diabetes.
41. The kit according to embodiment 39, wherein the condition is cardiovascular disease.
42. The kit according to any of one of the preceding embodiments 35-41, wherein the agent is selected from the group consisting of soluble NKG2D, an

antibody or antigen-binding fragment thereof that specifically binds NKG2D, an NKG2D ligand and an inhibitor of NKG2D ligand activity or expression.

43. The kit according to embodiment 42, wherein the agent is an antibody or antigen-binding fragment thereof that specifically binds NKG2D.
44. The kit according to embodiment 43, wherein the antibody or antigen-binding fragment thereof is human or humanized.
45. The kit according to embodiment 43, wherein the antibody or antigen-binding fragment thereof binds human NKG2D (hNKG2D).
46. The kit according to any one of the preceding embodiments claims 35-45, further comprising at least one additional agent selected from the group consisting of antidiabetic agents, antiobesity agents, appetite regulating agents, antihypertensive agents, agents for the treatment and/or prevention of complications resulting from or associated with diabetes and agents for the treatment and/or prevention of complications and disorders resulting from or associated with obesity.
47. The kit according to embodiment 46, wherein the additional agent is selected from the group consisting of (a) a blood glucose lowering agent selected from the group consisting of GLP-1 and GLP-1 derivatives and analogues, Exendin-4 and Exendin-4 derivatives and analogues, amylin and amylin derivatives and analogues, sulphonylureas, biguanides, meglitinides (such as nateglinide and repaglinide), glucosidase inhibitors, DPP-IV (dipeptidyl peptidase-IV) inhibitors, SGLT2 inhibitors, SGLT1 inhibitors or agonists, gastrin and gastrin analogues and derivatives, FGF-21 (fibroblast growth factor 21) and FGF-21 derivatives and analogues, proton pump inhibitors such as lansoprazole, omeprazole, dexlansoprazole, esomeprazole, pantoprazole, and rabeprazole, RXR agonists, Cholestyramine, colestipol, probucol, dextrothyroxine, PPAR agonists, and adiponectin and adiponectin derivatives and analogues; (b) a blood lipid lowering or lipid metabolism modifying agent selected from the group consisting of antihyperlipidemic agents, HMG CoA inhibitors (statins) such as lovastatin, pravastatin and simvastatin, and fibrates such as gemfibrozil and clofibrate; (c) an agent that lowers food intake or increases energy expenditure

selected from the group consisting of NPY (neuropeptide Y) antagonists, PYY (polypeptide YY) agonists, PP (pancreatic polypeptide) agonists, Y2 receptor agonists, Y4 receptor agonists, mixed Y2/Y4 receptor agonists, MC4 (melanocortin 4) agonists, orexin antagonists, glucagon and glucagon derivatives and analogues, CRF (corticotropin releasing factor) agonists, CRF BP (corticotropin releasing factor binding protein) antagonists, urocortin agonists,  $\beta$ 3 agonists, MSH (melanocyte-stimulating hormone) agonists, MCH (melanocyte-concentrating hormone) antagonists, CCK (cholecystokinin) agonists, serotonin re-uptake inhibitors, serotonin and noradrenaline re-uptake inhibitors, mixed serotonin and noradrenergic compounds, 5HT (serotonin) agonists, bombesin agonists, galanin antagonists, growth hormone, growth hormone releasing compounds, TRH (thyrotropin releasing hormone) agonists, UCP 2 or 3 (uncoupling protein 2 or 3) modulators, leptin agonists, DA agonists (bromocriptin, doprexin), lipase/amylase inhibitors, RXR (retinoid X receptor) modulators, histamine H3 antagonists, and CART (cocaine amphetamine regulated transcript) agonists; and (d) a blood pressure lowering agent selected from the group consisting of  $\beta$ -blockers such as alprenolol, atenolol, timolol, pindolol, propranolol and metoprolol, ACE (angiotensin converting enzyme) inhibitors such as benazepril, captopril, enalapril, fosinopril, lisinopril, alatriopril, quinapril and ramipril, calcium channel blockers such as nifedipine, felodipine, nicardipine, isradipine, nimodipine, diltiazem and verapamil, and  $\alpha$ -blockers such as doxazosin, urapidil, prazosin and terazosin.

48. A method of detecting a predisposition to developing type 2 diabetes or the presence of type 2 diabetes in a subject comprising:
- (a) obtaining a sample from the subject;
  - (b) contacting the sample with at least one reagent that detects the presence of MICA/B expression;
  - (c) measuring the level of MICA/B expression in the sample; and

- (d) correlating overexpression of MICA/B with a predisposition to type 2 diabetes development or the presence of type 2 diabetes in the subject.
49. A method of detecting a predisposition to developing cardiovascular disease or the presence of cardiovascular disease in a subject comprising:
- (a) obtaining a sample from the subject;
  - (b) contacting the sample with at least one reagent that detects the presence of MICA/B expression;
  - (c) measuring the level of MICA/B expression in the sample; and
  - (d) correlating overexpression of MICA/B with a predisposition to cardiovascular disease development or the presence of cardiovascular disease in the subject.
50. The method according to embodiment 48 or 49, wherein the reagent is a MICA/B antibody.
51. The method according to embodiment 48 or 49, wherein the sample is serum.
52. The method according to embodiment 48 or 49, wherein the subject is human.
53. The method according to any one of the preceding embodiments 48-52, further comprising measuring the level of expression of a cardiovascular disease marker that is not MICA/B in the sample and correlating overexpression or underexpression of the cardiovascular disease marker with a predisposition to cardiovascular disease development or presence of cardiovascular disease in the subject.

**WHAT IS CLAIMED:**

1. Use of a therapeutically effective amount of an agent that inhibits NKG2D activation or signaling in a subject for treating type 2 diabetes.
2. Use of a therapeutically effective amount of an agent that blocks the NKG2D ligand binding interaction in a subject for treating type 2 diabetes.
3. Use of a therapeutically effective amount of an agent that inhibits NKG2D activation or signaling in a subject for treating a condition that may be regulated or normalized via inhibition of NKG2D, wherein the condition is selected from the group consisting of type 2 diabetes, cardiovascular disease, inflammatory disease and metabolic dysfunction-associated disease.
4. Use of a therapeutically effective amount of an agent that blocks the NKG2D ligand binding interaction in a subject for treating a condition that may be regulated or normalized via inhibition of NKG2D, wherein the condition is selected from the group consisting of type 2 diabetes, cardiovascular disease, inflammatory disease and metabolic dysfunction-associated disease.
5. The use according to any of one of claims 1-4, wherein the subject is human.
6. The use according to any of one of claims 1-5, wherein the agent is selected from the group consisting of soluble NKG2D, an antibody or antigen-binding fragment thereof that specifically binds NKG2D, an NKG2D ligand and an inhibitor of NKG2D ligand activity or expression.
7. The use according to claim 6, wherein the agent is an antibody or antigen-binding fragment thereof that specifically binds NKG2D.
8. The use according to claim 7, wherein the antibody or antigen-binding fragment thereof is human or humanized.
9. The use according to claim 7, wherein the antibody or antigen-binding fragment thereof binds human NKG2D (hNKG2D).

10. The use according to claim 7, wherein the antibody or antigen-binding fragment thereof reduces NKG2D-mediated activation or signalling of an NKG2D-expressing cell.
11. The use according to claim 7, wherein the antibody or antigen-binding fragment thereof competes with at least one NKG2D ligand in binding to NKG2D.
12. The use according to claim 11, wherein the NKG2D ligand is MICA/B.
13. The use according to any of one of claims 1-12, wherein administration of the agent results in at least one of the following in the subject: reduces blood glucose levels, improves glucose tolerance, lowers insulin resistance, reduces body weight, lowers blood pressure, lowers inflammation or reduces metabolic dysfunctions.
14. The use according to any of one of claims 1-13, wherein the agent is administered intravenously, intraperitoneally or subcutaneously.
15. The use according to any one of claims 1-13, further comprising at least one additional agent selected from the group consisting of antidiabetic agents, antiobesity agents, appetite regulating agents, antihypertensive agents, agents for the treatment and/or prevention of complications resulting from or associated with diabetes and agents for the treatment and/or prevention of complications and disorders resulting from or associated with obesity.

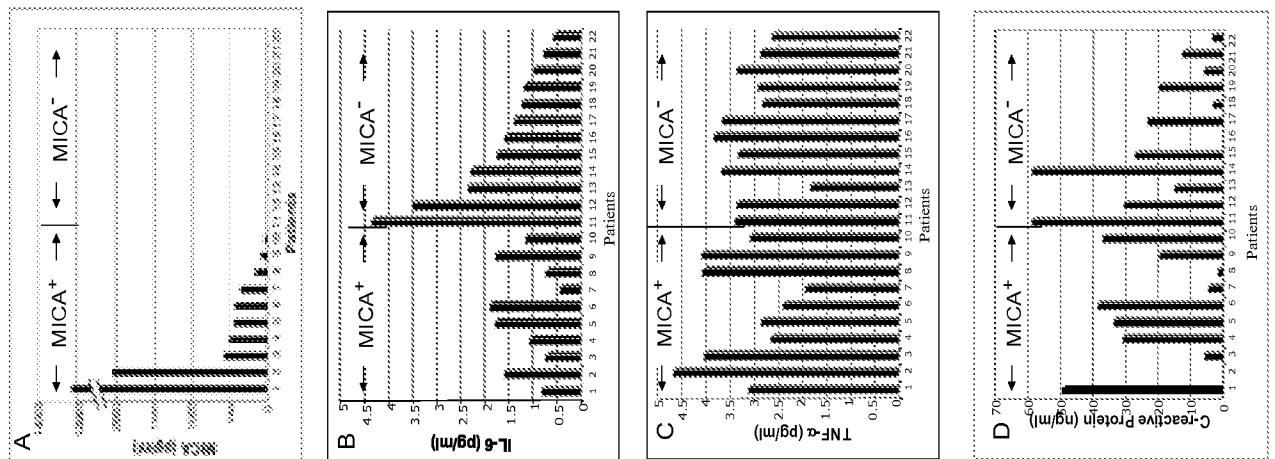


Fig. 1

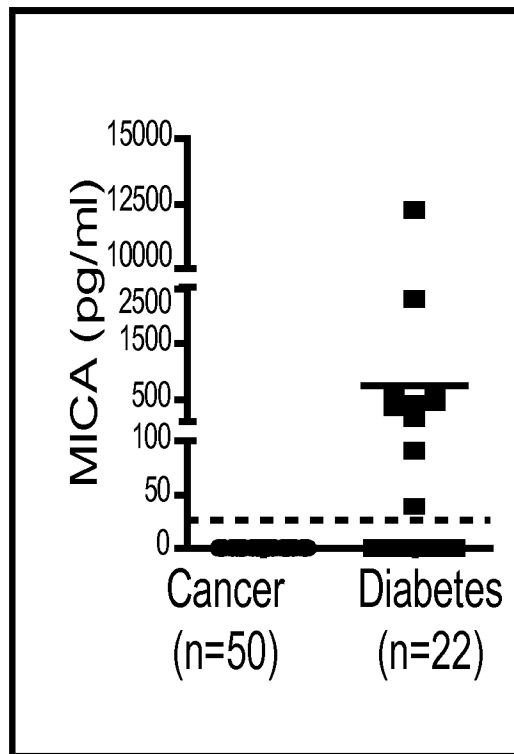


Fig. 1E

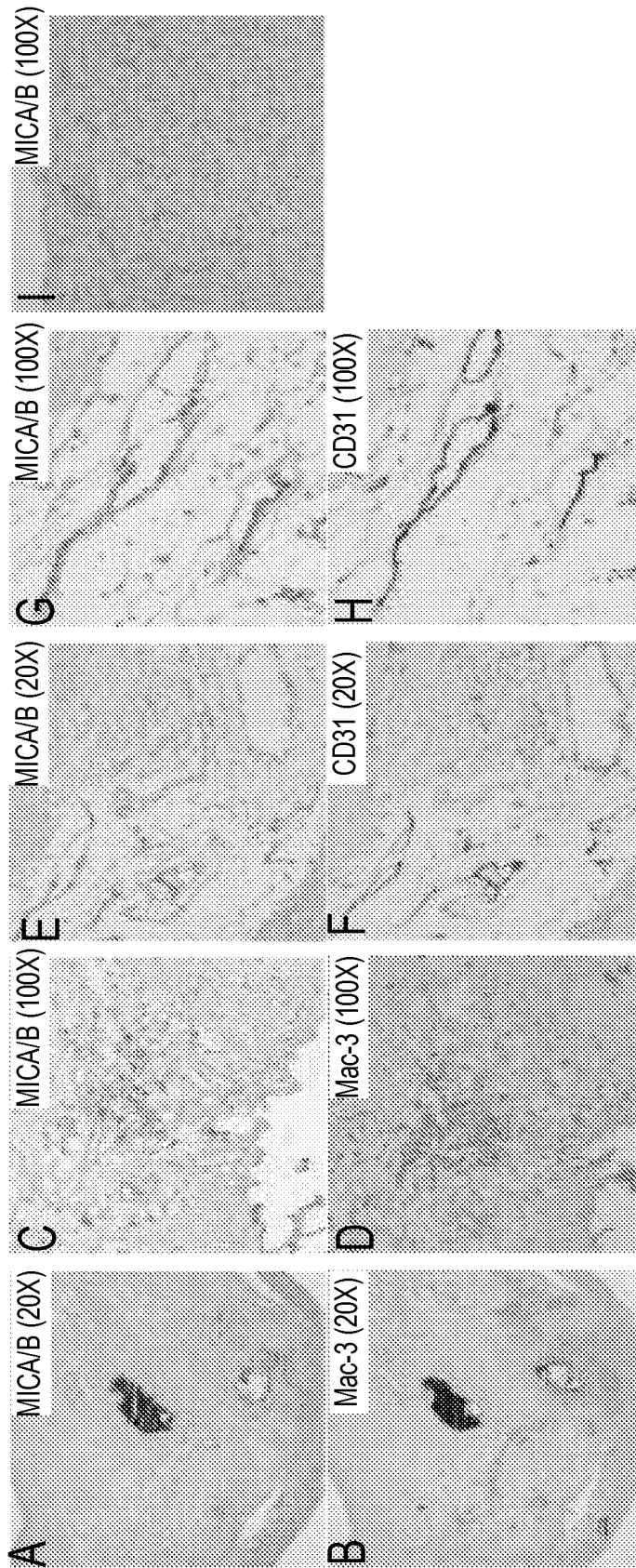


Fig. 2

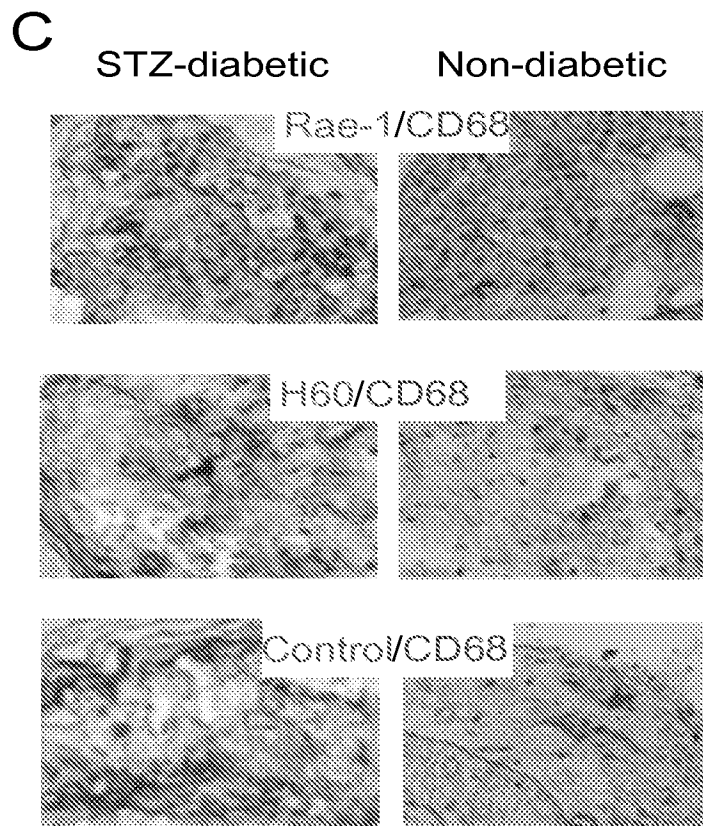
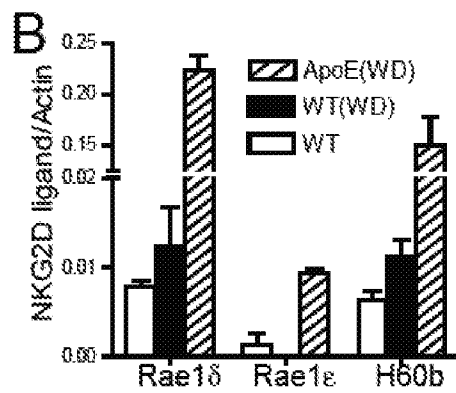
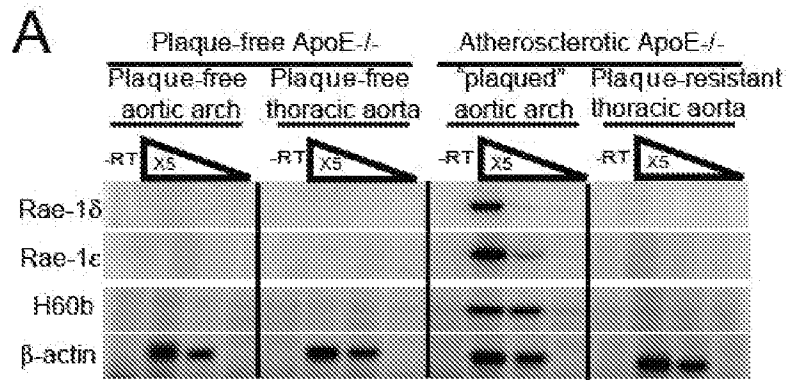


Fig. 3

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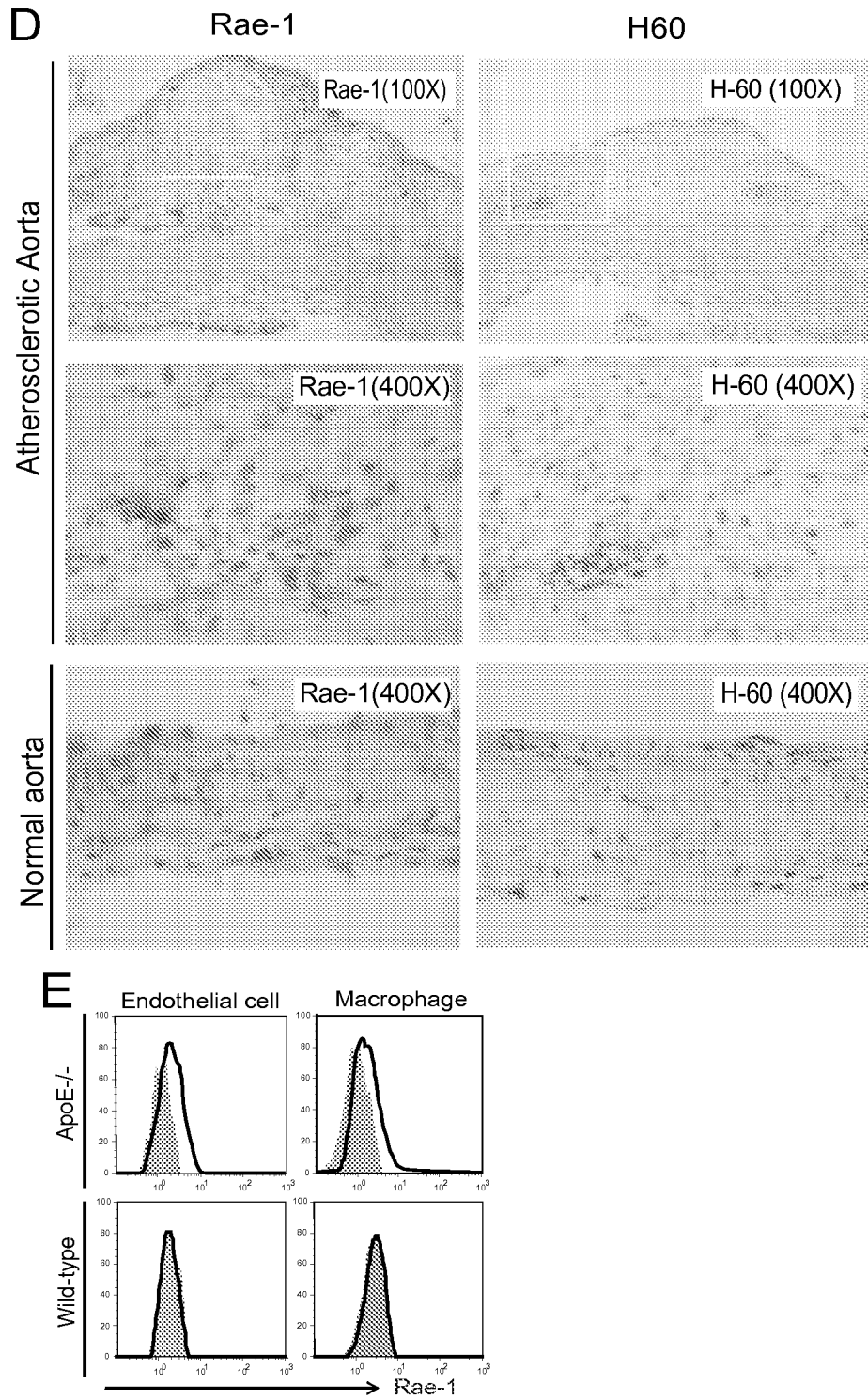


Fig. 3

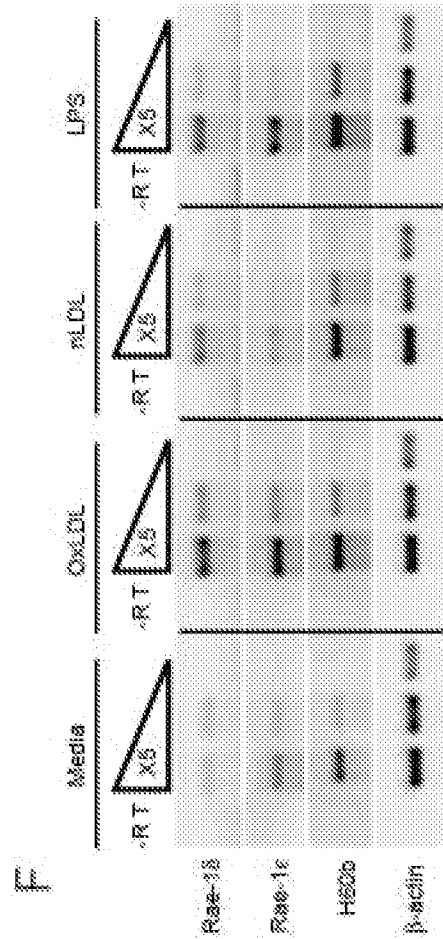
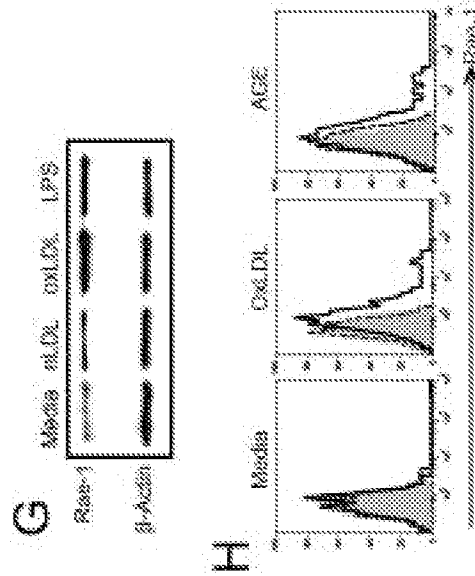


Fig. 3

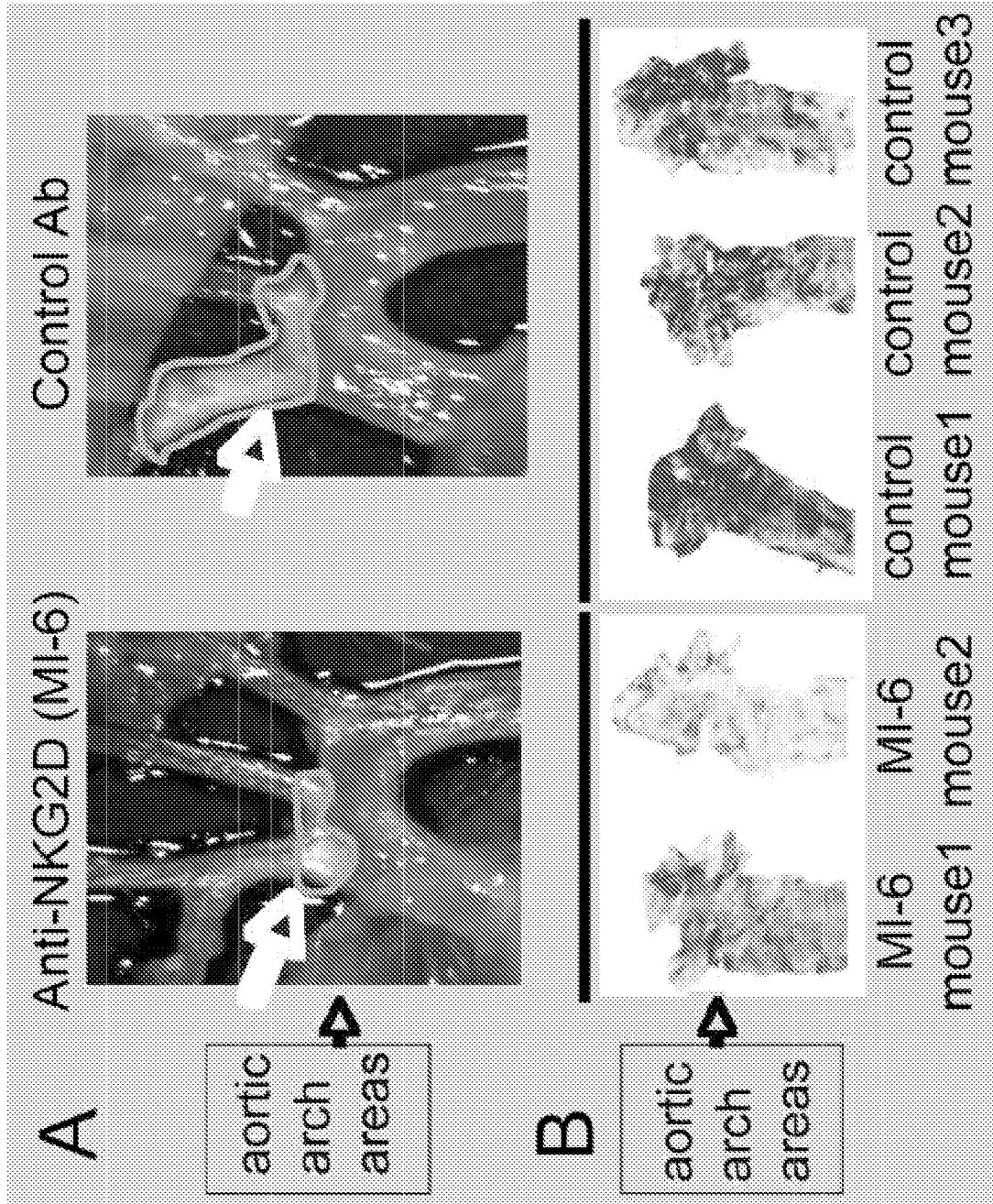


Fig. 4

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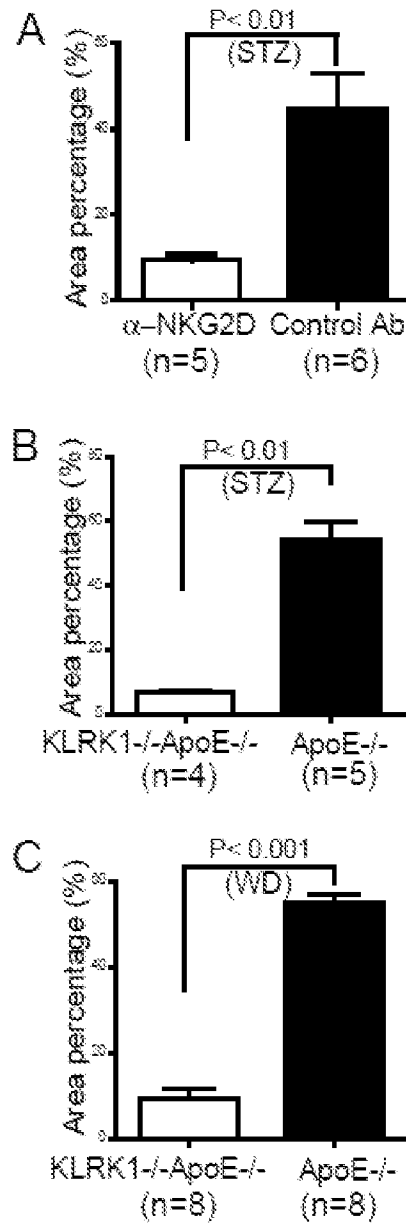


Fig. 5

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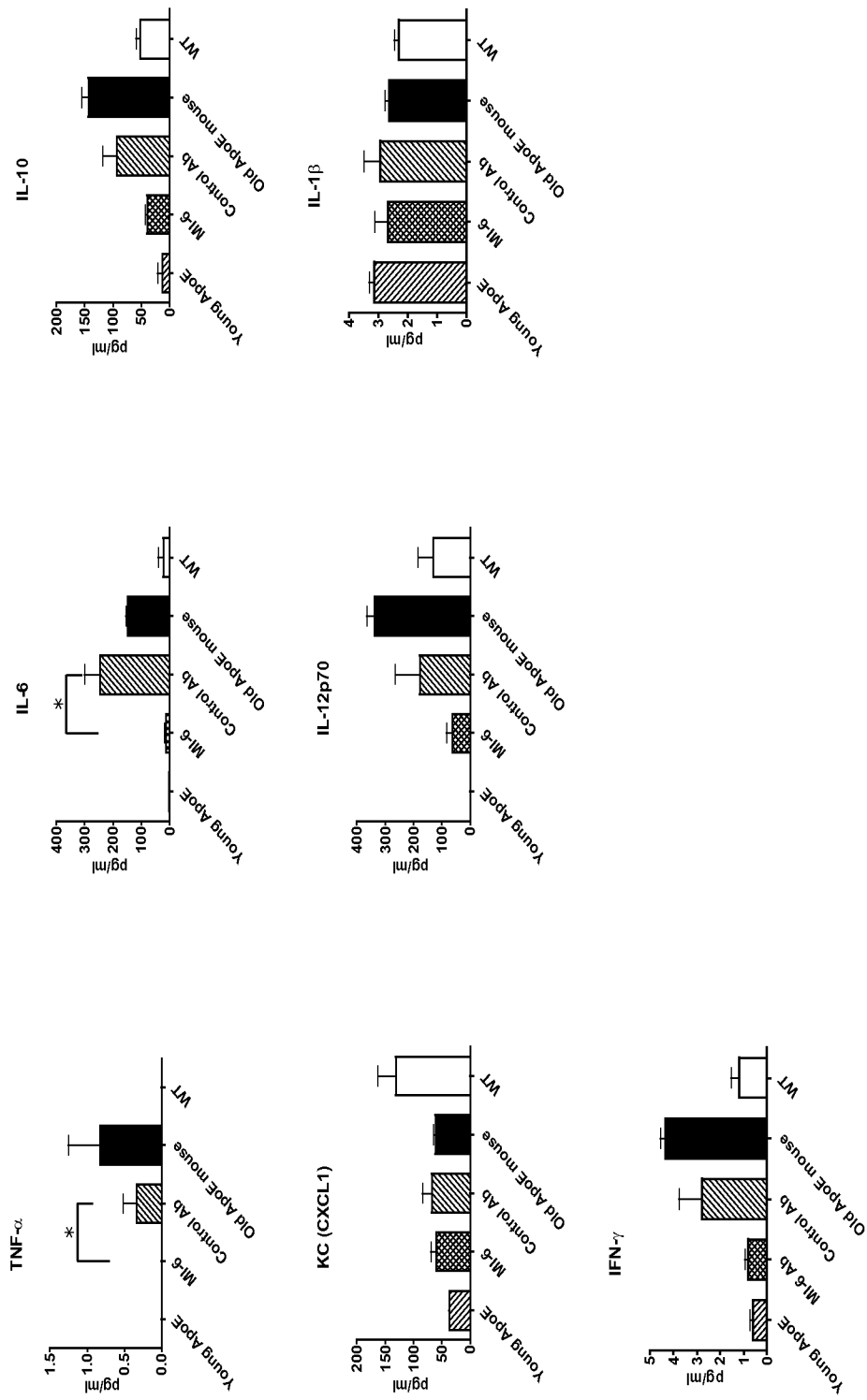


Fig. 6

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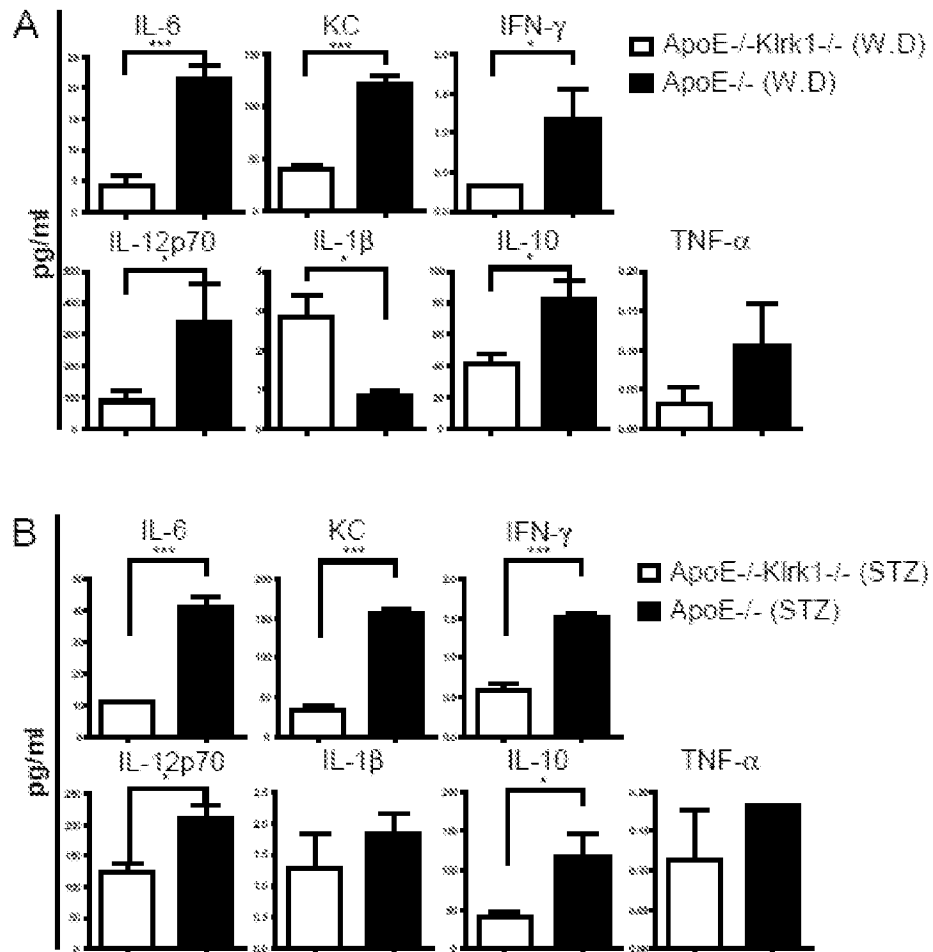


Fig. 7

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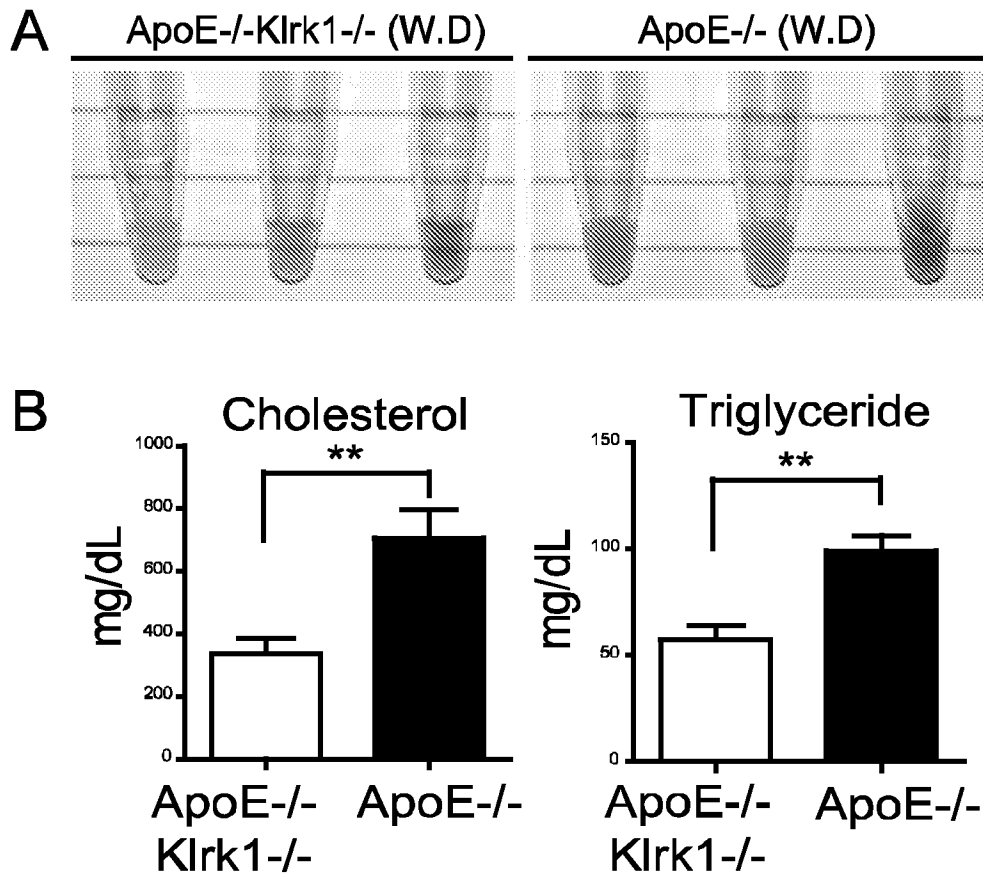


Fig. 8

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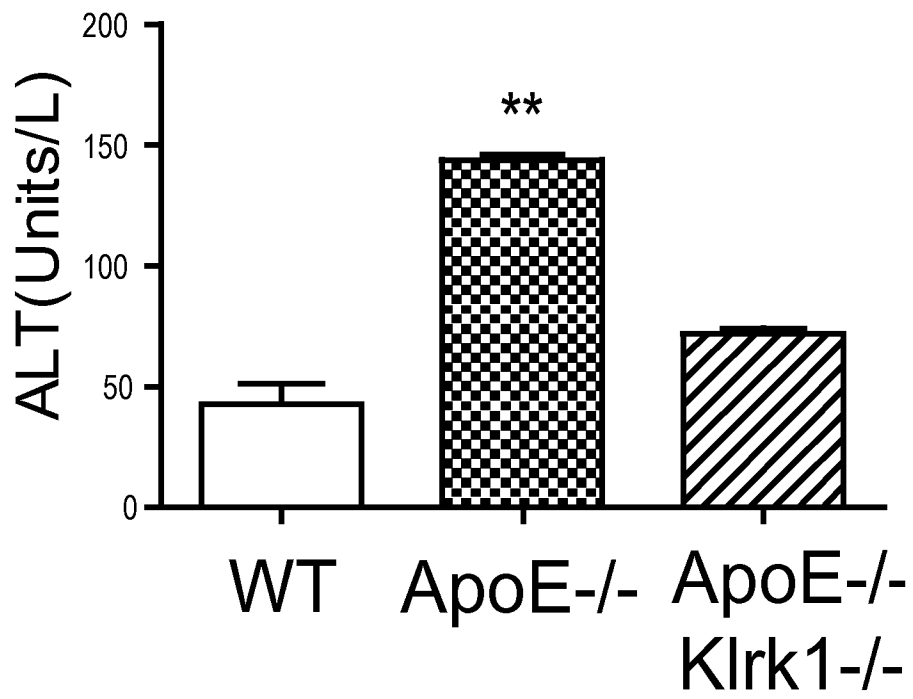


Fig. 9

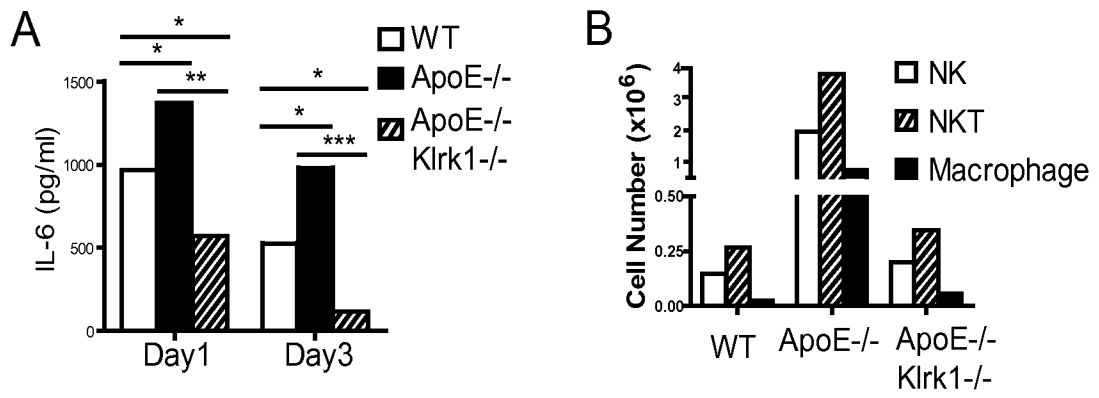


Fig. 10

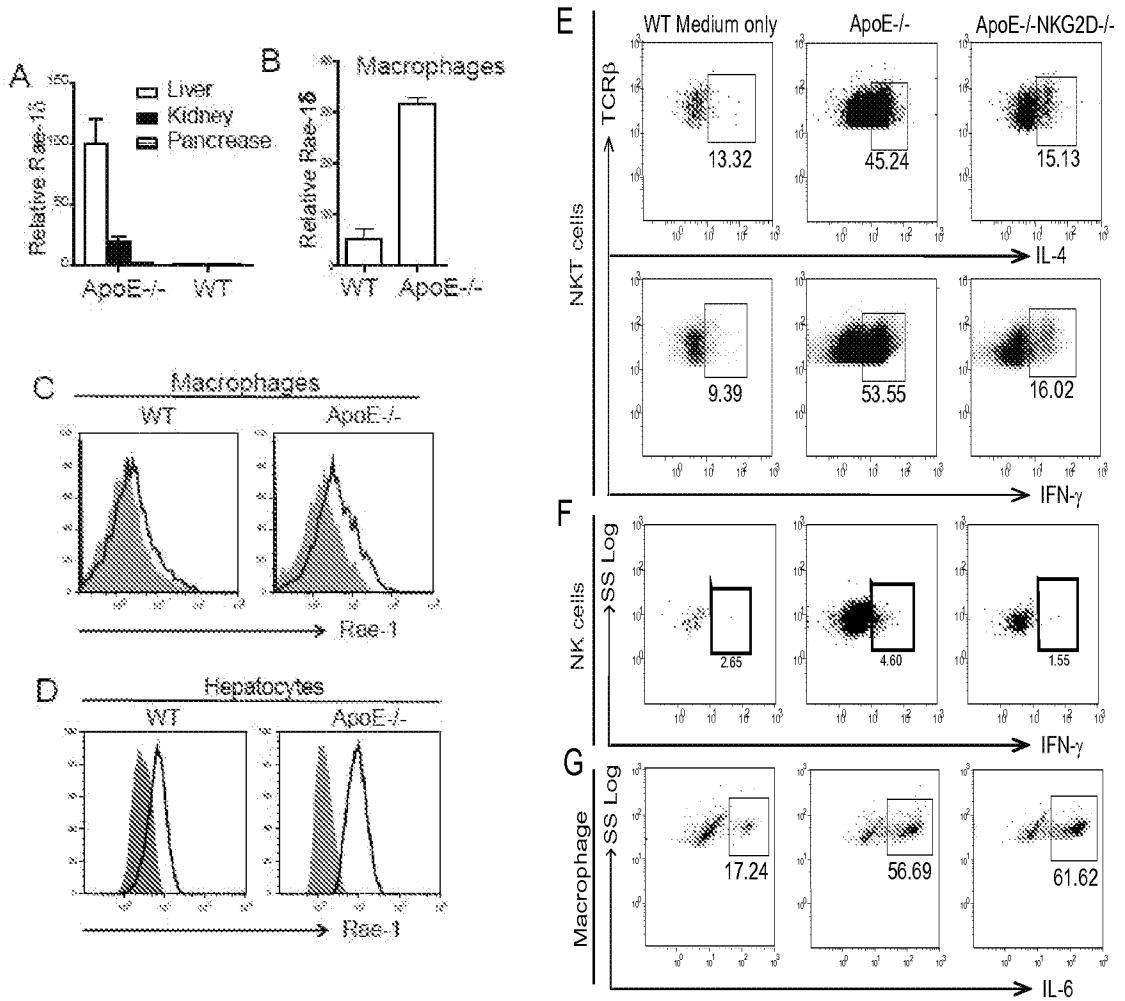


Fig. 11

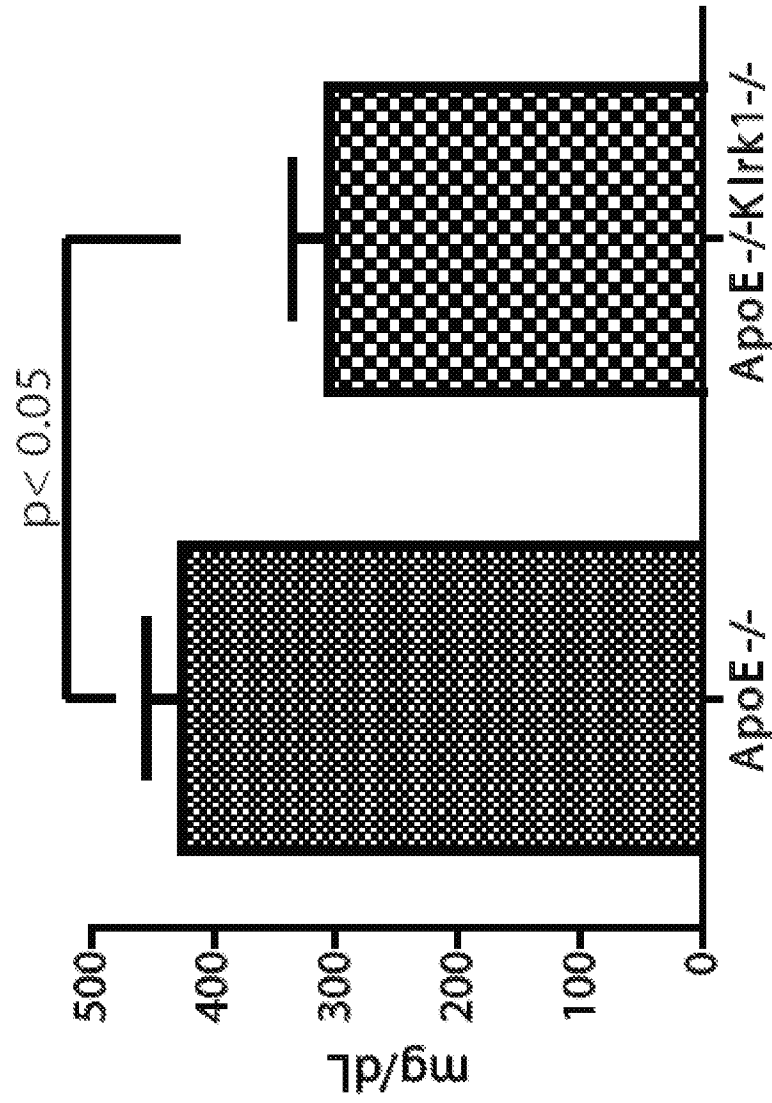


Fig. 12

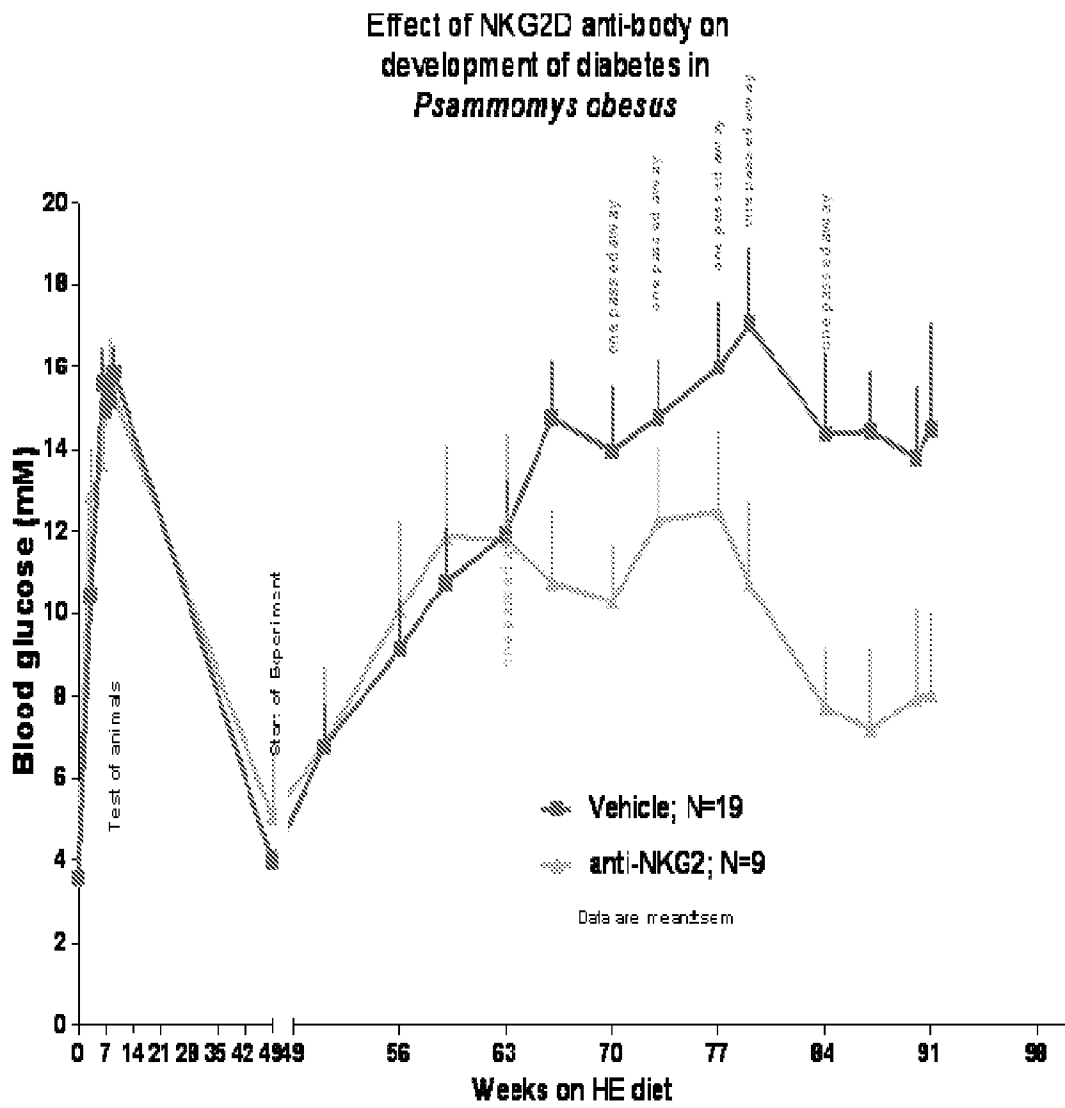


Fig. 13

CsHa-NKG2D-280409  
NKG2D-FACS on sandrat blood

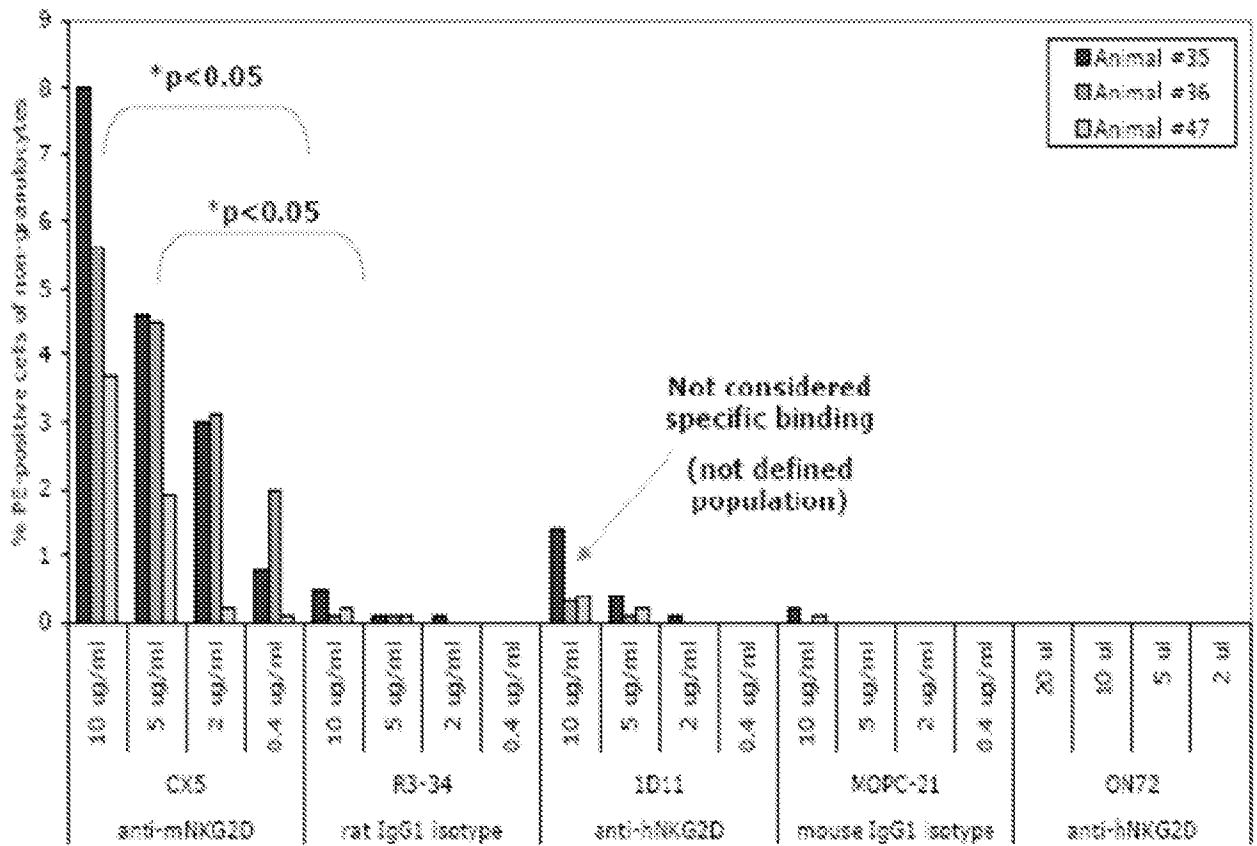


Fig. 14

**INTERNATIONAL SEARCH REPORT**

International application No  
PCT/US2010/045627

**A. CLASSIFICATION OF SUBJECT MATTER**  
**INV.** A61K38/17 A61K39/395 A61P3/10 A61P3/00 A61P9/00  
 A61P29/00  
**ADD.**  
 According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**  
 Minimum documentation searched (classification system followed by classification symbols)  
**A61K A61P**

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)  
**EPO-Internal, WPI Data**

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2005/158307 A1 (SPIES THOMAS [US] ET AL) 21 July 2005 (2005-07-21) see claims 1-7, [0026]-[0027], [0091]-[0092], [0114] [0118] -----	3-14
X	WO 2008/014035 A2 (UNIV CALIFORNIA [US]; BARON JODY L [US]; KANG SANG-MO [US]; LANIER LEW) 31 January 2008 (2008-01-31) see claims 1-6 and examples 3-11 -----	3-14
X	WO 2005/097160 A2 (UNIV CALIFORNIA [US]; LANIER LEWIS L [US]; OGASAWARA KOETSU [US]; BLUE) 20 October 2005 (2005-10-20) see cl.1-26 and pages 18-25 -----	3-14

Further documents are listed in the continuation of Box C.  See patent family annex.

\* Special categories of cited documents :

<p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p>	<p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"&amp;" document member of the same patent family</p>
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Date of the actual completion of the international search <b>2 November 2010</b>	Date of mailing of the international search report <b>09/11/2010</b>
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Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer <b>Merckling-Ruiz, V</b>
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# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No PCT/US2010/045627
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		AU 2005231478 A1	20-10-2005
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