Method for determining genotoxicity

The present invention relates to the fields of molecular biology and toxicology. More specifically, the present invention relates to methods for determining genotoxicity in compounds, and test cells, transgenic animals, kits and reagents therefore.

The mammalian cellular response to genotoxic damage is often analyzed using a battery of tests, which often include *in vitro* chromosomal aberration or micronuclei formation tests. Both of these tests visualize DNA damage in cells after exposure to potential genotoxicants by analyzing harvested chromosomes for aberrations (S.M. Galloway, *Environ Mol Mutagen* (2000) 35:191-201) or by examining micronuclei formed in cells whose DNA has been damaged (W. von der Hude et al., *Mutation Res* (2000) 468:137-63). However, there are significant problems with interpreting the results of the currently used *in vitro* genotoxic tests. False positive results in these tests are not uncommon, and the subsequent analysis, which involves *in vivo* animal testing, can be costly and time consuming. Assays which can better predict the genotoxic potential of a compound are needed (see, e.g., R.K. Newton et al., *Environ Health Persp* (2004) 112:420-22). In response to genotoxic stress, cycling cells that are undergoing cellular differentiation are arrested at discrete stages in the cell cycle (see, e.g., T. Weinert et al., *Nature Gen* (1999) 21:151-52; T. Weinert, *Cell* (1998) 94:555-58). This differentiation arrest is thought to result from activation of key regulatory kinases and other components in response to DNA damage at critical checkpoints in the cell cycle (T. Weinert (1998) *supra*; B.S. Zhou-Bin et al., *Nature Rev Cancer* (2004) 4:216-25).

P.L. Puri et al., *Nature Gen* (2002) 32:585-93 investigated the ability of four known genotoxic agents (methyl-methane sulfonate, cisplatin, etoposide, and ionizing radiation) to inhibit the differentiation of C2C12 myoblast cells into myotubes. Effects of the agents were also examined by assaying the expression of muscle-specific proteins (myogenin, myosin heavy chain, MyoD), and using a luciferase reporter gene coupled to the muscle creatinine kinase promoter.

The murine gene DDA3 was sequenced for study due to its regulation by p53 (P.-K. Lo et al., *Oncogene* (1999) 18:7765-74). P-K Lo et al. also found that DDA3 was upregulated in NIH3T3 cells exposed to DNA damaging agents such as adriamycin and mitomycin C. P-K Lo et al. found that DDA3 was strongly expressed in brain, spleen, and lung (with moderate expression in kidney): no expression or minimal expression was

found in heart, liver, skeletal muscle, or testis. The 5' genomic sequence (including the upstream regulatory region) was sequenced and described by S.-C. Hsieh et al., *Oncogene* (2002) 21:3050-57, who identified the p53-binding element and determined that expression was also induced by p73. P.-K. Lo & F.-F. Wang, *Biochim Biophys Acta* (2002) 1579:214-18 reported the identification and sequencing of the human DDA3 homolog, also finding that it was expressed in nearly every tissue except adult skeletal muscle. P.-K. Lo & F.-F. Wang, *Arch Biochem Biophys* (2004) 425:221-32 reported that murine DDA3 is transcribed or edited into a number of different forms.

Tugendreich et al., WO2004/037200, disclosed the measurement of genomic responses of rat liver cells to hydroxyurea, cytarabine, doxorubicin, ifosfamide, thioguanine, azathioprine, etoposide, and albendazole, each administered in vivo. The genomic responses were then used to derive a "drug signature" that correlates the transcriptional regulation of two genes (aminolevulinate synthase 2 delta, Genbank NM 013197; and peripherin 1, Genbank NM 012633) with the propensity of each compound to cause depletion of reticulocytes.

We have now determined that several genes are activated in eukaryotic cells that are capable of further differentiation when such cells are exposed to DNA-damaging (genotoxic) agents followed by induction of differentiation.

One aspect of the invention comprises a method for determining the genotoxicity of a test compound, by contacting a cell capable of differentiation with the test compound, inducing differentiation, and determining the expression level of one or more indicator genes. Therefore, the present invention provides a method for determining the genotoxicity of a test compound, said method comprising: (a) contacting a viable test cell with said test compound; (b) determining the change in expression level of an indicator gene selected from the group consisting of Prelp (Proline arginine-rich end leucine-rich repeat); Sesn2 (Sestrin 2); 4833427G06 Rik (RIKEN cDNA); Dda3 (Differential display and activated by p53); Usp30 (Ubiquitin specific protease 30); 0610013D04 Rik (RIKEN cDNA); Slc19a2 (Solute carrier family 19 (thiamine transporter), member 2); Trp53inp1 (Transformation related protein 53, inducible nuclear protein 1); D4Ertd421e (DNA segment, Chr 4, ERATO Doi 421, expressed); Shcbp1 (Shc SH2-domain binding protein 1); Mki67 (Antigen identified by MAb Ki67); Phex (Phosphate regulating neutral endopeptidase (X chromosome)); Tk1 (Thymidine kinase 1); Mmhead (Mus musculus 15 day embryo head cDNA clone); Osbpl6 (Oxysterol binding protein-like 6); Mphosph1 (M-phase phosphoprotein); Ephx1 (Epoxide hydrolase 1 (microsomal xenobiotic hydrolase)); Top2a (Topoisomerase (DNA) II alpha); Ccng1 (Cyclin G1); Plf (Proliferin); Np95 (Nuclear protein 95); Rad51ap1 (RAD51-associated protein 1); Nos3

(Nitric oxide synthase 3, endothelial cell); 2610005B21 Rik (RIKEN cDNA); Brca1 (Breast cancer 1); Stk18 (Serine/threonine kinase 18); Calmbp1 (Calmodulin binding protein 1); Lek1 (Leucine, glutamic acid, lysine family 1 protein); Smc2l1 (SMC2 structural maintenance of chromosomes 2-like 1); E2f7 (E2F transcription factor 7); Hmmr (Hyaluronan mediated motility receptor (RHAMM)); Nusap1 (Nucleolar and spindle associated protein 1); Fbxo5 (f-box only protein 31); Slc19a2 (Solute carrier family 19 (thiamine transporter), member 2); 9030617O03 Rik (RIKEN cDNA); Ly6e (Lymphocyte antigen 6 complex, locus E); 6530401L14 Rik (RIKEN cDNA); Mad3 (Max dimerization protein 3); Hmgb2 (High mobility group box 2); Kif11 (Kinesin 11); Mad2l1 (MAD2 (mitotic arrest deficient, homolog)-like 1 (yeast)); Asf1b (ASF1 anti-silencing function 1 homolog B (Saccharomyces)); Mcm3 (Minichromosome maintenance deficient 3 (Saccharomyces)); MGC: 32192 (Mus musculus cDNA clone MGC:32192 IMAGE:5006129); Foxm1 (Forkhead box M1); Anxa8 (Annexin A8); Slc35a5 (Solute carrier family 35, member A5); E030024M05 Rik (RIKEN cDNA); Cks2 (CDC28 protein kinase regulatory subunit 2); Cilp (Cartilage intermediate layer pro); Tacc3 (Transforming, acidic coiled-coil containing protein 3); Prc1 (Protein regulator of cytokinesis 1); 2610509G12 Rik (RIKEN cDNA); 2810417H13 Rik (RIKEN cDNA); Pbk (PDZ binding kinase); Capn6 (Calpain 6); Gmnn (Geminin); Mcmd4 (Minichromosome maintenance deficient 4 homolog); Ccna2 (Cyclin A2); Pola1 (DNA polymerase alpha 1, 180 kDa); Hmgb3 (High mobility group box 3); Tagln (Transgelin (smooth muscle 22 protein)); 1600013K19 Rik (RIKEN cDNA); Serpine1 (Ser (or Cys) proteinase inhibitor, clade E, member 1); Wig1 (Wild-type p53-induced gene 1); Hgf (Hepatocyte growth factor (scatter factor)); Gnpi (Glucosamine-6-phosphate deaminase); Birc5 (Baculoviral IAP repeat-containing 5); Prim1 (DNA primase, p49 subunit); Rbl1 (Retinoblastoma-like 1 (p107)); Pcna (Proliferating cell nuclear antigen); E130315B21 Rik (RIKEN cDNA); 2610019I03 RIK (RIKEN cDNA); wherein an increase in expression of at least 1.5-fold indicates that said test compound exhibits genotoxicity. Preferably, the indicator gene is selected from the group consisting of 4833427G06Rik and Dda3.

The test cell comprises preferably a myoblast cell. Preferably, the test cell are blast cells derived from mouse, rat, zebrafish, human, chimpanzee or chicken. The test cells may be modified to express a detectable label in addition to the indicator gene or to express a label instead of the indicator gene.

The change of the expression level may be preferably determined by measuring the amount of mRNA produced using RT-PCR. A further preferred method for determining the change of the expression level comprises measuring the increase in signal produced by increased expression of a label.

Another aspect of the invention comprises a kit for determining the genotoxicity of a test compound, comprising a suitable cell capable of differentiation, and reagents for quantifying the expression levels of selected indicator genes.

Another aspect of the invention comprises a polynucleotide capable of specifically hybridizing to a polynucleotide having the sequence of SEQ ID NO: 5, 7, 9, 11, 13, 15, or 17, or the complement thereof. Another aspect of the invention comprises a set of polynucleotides capable of specifically hybridizing to a plurality of selected indicator genes.

Another aspect of the invention is a microarray comprising a set of polynucleotides capable of specifically hybridizing to a plurality of selected indicator genes.

Another aspect of the invention comprises a polypeptide having the sequence of SEQ ID NO:6, 8, 10, 12, 14, 16, or 18.

Another aspect of the invention comprises an antibody capable of specifically binding to a polypeptide having the sequence of SEQ ID NO: 6, 8, 10, 12, 14, 16, or 18.

Another aspect of the invention comprises a transgenic non-human mammal in which a reporter gene is operably linked to an indicator gene.

All publications cited in this disclosure are incorporated herein by reference in their entirety.

Definitions:

Unless otherwise stated, the following terms used in this Application, including the specification and claims, have the definitions given below. It must be noted that, as used in the specification and the appended claims, the singular forms "a", "an," and "the" include plural referents unless the context clearly dictates otherwise.

The term "test cell" refers to a cell such as a blast cell that is capable of further differentiation, for example to a terminally differentiated state such as a myotubule, adipocyte, erythrocyte, or the like. Test cells are preferably derived from vertebrates such as, for example, zebra fish (*Danio rerio*), chickens (*Gallus gallus*), mouse (*Mus musculus*), rat (*Rattus norvegicus*), chimpanzees (*Pan troglodytes*), human (*Homo sapiens*), and the like. "Test cells" include both primary cell samples and established cell lines, whether recombinant or wild type. Exemplary test cells include, without limitation, mouse C2C12

cells, rat L6E9 cells, pre-adipocytes, 3T3-L1 cells, osteoblasts, and the like. Test cells may be modified to express a detectable label in addition to, or in lieu of, the indicator gene. For example, the test cell may be stably transfected with a construct comprising the regulatory sequences derived from an indicator gene, operably linked to a detectable label gene such as luciferase, green fluorescent protein (GFP), β-galactosidase (βGal), horseradish peroxidase (HRP), or the like.

The term "test sample" refers to a substance, mixture, or test condition with which the test cell can be contacted or treated, for purposes of evaluating the genotoxicity thereof. The method of the invention is useful for evaluating the genotoxic effect of substances other than pure compounds and solutions, and thus may be used to test, for example, radiation; environmental samples (for example of polluted air, water, or soil); viruses or other microorganisms; proteins, polynucleotides, polymers and other macromolecules; and the like. The test cells may be "contacted" with conditions such as radiation by exposing the cell to said conditions in a way that permits the cell to react.

The term "indicator gene" refers to a gene in which modulation of the expression level correlates with genotoxicity (DNA damage). Indicator genes within the scope of this invention include DDA3 (SEQ ID NO:1, SEQ ID NO:3), 4833427G06Rik (SEQ ID NO:5, 7, 9, 11, 13, 15, OR 17), and the genes listed in Table 2 below.

The terms "promoter" and "regulatory region" are used interchangeably herein to refer to polynucleotide sequences that bind transcription factors and transcriptases, regulating the expression of an indicator gene. Promoters are found adjacent to (cis) and (usually) upstream from the coding regions or structural gene.

The term "reporter gene" as used herein refers to a gene that encodes a detectable product. A "reporter gene" is a gene that, upon expression, confers a phenotype on a cell expressing the reporter gene such that the cell can be identified under appropriate conditions. In the present case, the reporter gene is operably linked to a promoter or regulatory sequence, such that expression of the reporter gene indicates activation of the promoter or regulatory sequence. A "heterologous reporter gene" is a reporter gene that is operably linked to a promoter or regulatory region different from the promoter or regulatory region to which it is linked in nature. For example, the reporter gene may produce a polypeptide product that can be easily detected or measured in a routine assay. Suitable reporter genes known in the art which confer this characteristic include those that encode chloramphenicol acetyl transferase (CAT activity), β-galactosidase, luciferase, alkaline phosphatase, human growth hormone, fluorescent proteins, such as green fluorescent protein (GFP), and others. Indeed, any gene that encodes a protein or enzyme that can readily be measured, for example, by an immunoassay such as an enzyme-linked immunosorbent assay (ELISA) or by the enzymatic conversion of a

substrate into a detectable product, and that is substantially not expressed in the host cells (specific expression with no background) can be used as a reporter gene to test for promoter activity. Other reporter genes for use herein include genes that allow selection of cells based on their ability to thrive in the presence or absence of a chemical or other agent that inhibits an essential cell function. Suitable markers, therefore, include genes coding for proteins which confer drug resistance or sensitivity thereto, or change the antigenic characteristics of those cells expressing the reporter gene when the cells are grown in an appropriate selective medium. For example, reporter genes include: cytotoxic and drug resistance markers, whereby cells are selected by their ability to grow on media containing one or more of the cytotoxins or drugs; auxotrophic markers by which cells are selected by their ability to grow on defined media with or without particular nutrients or supplements; and metabolic markers by which cells are selected for, e.g., their ability to grow on defined media containing the appropriate sugar as the sole carbon source. These and other reporter genes are well known in the art.

A "change in the level of reporter gene product" is shown by comparing expression levels of the reporter gene product in a cell exposed to a candidate compound relative to the levels of reporter gene product expressed in a cell that is not exposed to the test compound and/or to a cell that is exposed to a control compound. The change in level can be determined quantitatively for example, by measurement using a spectrophotometer, spectrofluorometer, luminometer, and the like, and will generally represent a statistically significant increase or decrease in the level from background. However, such a change may also be noted without quantitative measurement simply by, e.g., visualization, such as when the reporter gene is one that confers the ability on cells to form colored colonies on chromogenic substrates.

The term "operably linked" indicates a functional relationship between a promoter or regulatory region and a regulated structural gene, such that activation of the promoter or regulatory region leads to increased transcription of the structural gene.

The term "Dda3" or "DDA3" refers to the polynucleotide having the sequence of SEQ ID NO:1 (murine) or SEQ ID NO:3 (human). "Homologs" of DDA3 are polynucleotides (for example, RNA, cDNA or genomic DNA) that are derived from other species and have a similar sequence to murine and/or human Dda3 (sense strand or complement), having a sequence identity of at least 60%. Homologs of the murine and/or human DDA3 protein are polypeptides derived from other species having at least 60% sequence identity with murine or human DDA3 protein (SEQ ID NO:2 or SEQ ID NO:4, respectively).

The term "4833427G06Rik" refers to the polynucleotide having the sequence of SEQ ID NO:5 (murine), SEQ ID NO:7 (human), SEQ ID NO:9 (rat), SEQ ID NO:11

(zebra fish), SEQ ID NO:13 (the second zebra fish homolog), SEQ ID NO:15 (chicken), or SEQ ID NO:17 (chimpanzee). "Homologs" of 4833427G06Rik are polynucleotides (for example, RNA, cDNA or genomic DNA) that are derived from other species and have a similar sequence to murine and/or human 4833427G06Rik (sense strand or complement), having a sequence identity of at least 60%. Homologs of the murine and/or human 4833427G06Rik protein are polypeptides derived from other species having at least 60% sequence identity with murine or human 4833427G06Rik protein (SEQ ID NO:6 or SEQ ID NO:8, respectively).

The term "specific hybridization" as used herein refers to the binding of complementary strands of nucleic acid to each other through hydrogen bonds. Stringency levels used to hybridize a given probe with target DNA can be readily varied by those of skill in the art. The phrase "stringent hybridization" is used herein to refer to conditions under which double-stranded polynucleotide molecules are stable only when highly complementary, having few base mismatches, as reflected in the melting temperature (T_m) of the double-stranded ("ds") polynucleotides. In general, the stability of a ds polynucleotide is a function of sodium ion concentration and temperature. Typically, a hybridization reaction is performed under conditions of lower stringency, followed by washes of increasing stringency. Reference to hybridization stringency relates to such washing conditions.

As used herein, the phrase "moderately stringent hybridization" refers to conditions that permit target-DNA to bind a complementary nucleic acid that has about 60% identity, preferably about 75% identity, more preferably about 85% identity to the target DNA; with greater than about 90% identity to target-DNA being especially preferred. Preferably, moderately stringent conditions are conditions equivalent to hybridization in 50% formamide, 5× Denhart's solution, 5× SSPE, 0.2% SDS at 42°C, followed by washing in 0.2× SSPE, 0.2% SDS, at 65°C. The phrase "high stringency hybridization" refers to conditions that permit hybridization of only those nucleic acid sequences that form stable hybrids in 0.018 M NaCl at 65°C (i.e., if a hybrid is not stable in 0.018 M NaCl at 65°C, it will not be stable under high stringency conditions, as contemplated herein). High stringency conditions can be provided, for example, by hybridization in 50% formamide, 5× Denhart's solution, 5× SSPE, 0.2% SDS at 42°C, followed by washing in 0.1× SSPE, and 0.1% SDS at 65°C. The phrase "low stringency hybridization" refers to conditions equivalent to hybridization in 10% formamide, 5× Denhart's solution, 6× SSPE, 0.2% SDS at 42°C, followed by washing in 1×SSPE, 0.2% SDS, at 50°C. Denhart's solution and SSPE (see, e.g., Sambrook et al., Molecular Cloning, A Laboratory Manual, Cold Spring Harbor Laboratory Press, 1989) are well known to those of skill in the art as are other suitable hybridization buffers.

The term "specifically binding" between two entities means an affinity of at least 10^7 M^{-1}.

The term "substantial identity" means that two polynucleotide or polypeptide sequences, when optimally aligned, such as by the programs GAP or BESTFIT using default gap weights, share at least 65% sequence identity, preferably at least 80% or 90% sequence identity, more preferably at least 95% sequence identity or more (e.g., 99% sequence identity or higher). In the case of polypeptides, residue positions which are not identical preferably differ by conservative amino acid substitutions. For sequence comparison, typically one sequence acts as a reference sequence to which test sequences are compared. When using a sequence comparison algorithm, test and reference sequences are entered into a computer, subsequence coordinates are designated (if necessary), and sequence algorithm program parameters are designated. The sequence comparison algorithm then calculates the percent sequence identity for the test sequence(s) relative to the reference sequence, based on the designated program parameters. Optimal alignment of sequences for comparison can be conducted, e.g., by the local homology algorithm of Smith & Waterman, *Adv. Appl. Math.* (1981) 2:482, by the homology alignment algorithm of Needleman & Wunsch, *J. Mol. Biol.* (1970) 48:443, by the search for similarity method of Pearson & Lipman, *Proc Natl Acad Sci USA* (1988) 85:2444, by computerized implementations of these algorithms (GAP, BESTFIT, FASTA, and TFASTA in the Wisconsin Genetics Software Package, Genetics Computer Group, 575 Science Dr., Madison, Wis.), or by visual inspection. One example of an algorithm that is suitable for determining percent sequence identity and sequence similarity is the BLAST algorithm, described by Altschul et al., *J. Mol. Biol.* (1990) 215:403-10. Software for performing BLAST analyses is publicly available through the National Center for Biotechnology Information (www . ncbi . nlm . nih . gov/). Typically, default program parameters are used to perform the sequence comparison, although customized parameters can also be used. For amino acid sequences, the BLASTP program uses as defaults a wordlength (W) of 3, an expectation (E) of 10, and the BLOSUM62 scoring matrix (see Henikoff & Henikoff, *Proc. Natl. Acad. Sci. USA* (1989) 89:10915).

For purposes of classifying amino acids substitutions as conservative or nonconservative, amino acids are grouped as follows: Hydrophobic sidechains: norleucine, met, ala, val, leu, ile; Neutral hydrophilic side chains: cys, ser, thr; Acidic side chains: asp, glu; Basic side chains: asn, gln, his, lys, arg; Residues influencing chain orientation: gly, pro; and Aromatic side chains: trp, tyr, phe. Conservative substitutions involve substitutions between amino acids in the same class. Non-conservative substitutions constitute exchanging a member of one of these classes for a member of another.

The term "antibody" or "immunoglobulin" is used to include intact antibodies and binding fragments thereof. Typically, fragments compete with the intact antibody from which they were derived for specific binding to an antigen fragment including separate heavy chains, light chains Fab, Fab' $F(ab')_2$, Fabc, and Fv. Fragments are produced by recombinant DNA techniques, or by enzymatic or chemical separation of intact immunoglobulins. The term "antibody" also includes one or more immunoglobulin chains that are chemically conjugated to or expressed as fusion proteins with other proteins. The term "antibody" also includes bispecific antibodies. A bispecific or bifunctional antibody is an artificial hybrid antibody having two different heavy/light chain pairs and two different binding sites. Bispecific antibodies can be produced by a variety of methods including fusion of hybridomas or linking of Fab' fragments. See, e.g., Songsivilai & Lachmann, *Clin. Exp. Immunol.* (1990) 79:315-21; Kostelny et al., *J. Immunol.* (1992) 148:1547-53. An "antigen" is an entity to which an antibody specifically binds.

The term "epitope" or "antigenic determinant" refers to a site on an antigen to which B and/or T cells respond. B-cell epitopes can be formed both from contiguous amino acids or noncontiguous amino acids juxtaposed by tertiary folding of a protein Epitopes formed from contiguous amino acids are typically retained on exposure to denaturing solvents whereas epitopes formed by tertiary folding are typically lost on treatment with denaturing solvents. An epitope typically includes at least 3, and more usually, at least 5 or 8-10 amino acids in a unique spatial conformation. Methods of determining spatial conformation of epitopes include, for example, x-ray crystallography and 2-dimensional nuclear magnetic resonance. See, e.g., Epitope Mapping Protocols in Methods in Molecular Biology, Vol. 66, Glenn E. Morris, Ed. (1996). Antibodies that recognize the same epitope can be identified in a simple immunoassay showing the ability of one antibody to block the binding of another antibody to a target antigen. T-cells recognize continuous epitopes of about nine amino acids for CD8 cells or about 13-15 amino acids for CD4 cells. T cells that recognize the epitope can be identified by *in vitro* assays that measure antigen-dependent proliferation, as determined by ^{3}H-thymidine incorporation by primed T cells in response to an epitope (Burke et al., *J. Inf. Dis.* (1994) 170:1110-19), by antigen-dependent killing (cytotoxic T lymphocyte assay, Tigges et al., *J. Immunol.* (1996) 156:3901-10) or by cytokine secretion.

An "immunogenic agent" or "immunogen" is capable of inducing an immunological response against itself on administration to a mammal, optionally in conjunction with an adjuvant. The term "adjuvant" refers to a compound that when administered in conjunction with an antigen augments the immune response to the antigen, but when administered alone does not generate an immune response to the antigen. Adjuvants can augment an immune response by several mechanisms including

lymphocyte recruitment, stimulation of B and/or T cells, and stimulation of macrophages.

Competition between antibodies is determined by an assay in which the immunoglobulin under test inhibits specific binding of a reference antibody to a common antigen. Numerous types of competitive binding assays are known, for example: solid phase direct or indirect radioimmunoassay (RIA), solid phase direct or indirect enzyme immunoassay (EIA), sandwich competition assay (see Stahli et al., *Meth Enzymol* (1983) 9:242-53); solid phase direct biotin-avidin EIA (see Kirkland et al., *J. Immunol.* (1986) 137:3614-19); solid phase direct labeled assay, solid phase direct labeled sandwich assay (see Harlow and Lane, "Antibodies, A Laboratory Manual," Cold Spring Harbor Press (1988)); solid phase direct label RIA using ^{125}I label (see Morel et al., *Mol. Immunol.* (1988) 25(1):7-15); solid phase direct biotin-avidin EIA (Cheung et al., *Virology* (1990) 176:546-52); and direct labeled RIA (Moldenhauer et al., *Scand. J. Immunol.* (1990) 32:77-82). Typically, such an assay involves the use of purified antigen bound to a solid surface or cells bearing either of these, an unlabelled test immunoglobulin and a labeled reference immunoglobulin. Competitive inhibition is measured by determining the amount of label bound to the solid surface or cells in the presence of the test immunoglobulin. Usually the test immunoglobulin is present in excess. Antibodies identified by competition assay (competing antibodies) include antibodies binding to the same epitope as the reference antibody and antibodies binding to an adjacent epitope sufficiently proximal to the epitope bound by the reference antibody for steric hindrance to occur. Usually, when a competing antibody is present in excess, it will inhibit specific binding of a reference antibody to a common antigen by at least 50 or 75%.

"Treating" or "treatment" of a disease includes: (1) preventing the disease, i.e., causing the clinical symptoms of the disease not to develop in a mammal that may be exposed to or predisposed to the disease but does not yet experience or display symptoms of the disease; (2) inhibiting the disease, i.e., arresting or reducing the development of the disease or its clinical symptoms; or (3) relieving the disease, i.e., causing regression of the disease or its clinical symptoms.

"A therapeutically effective amount" means the amount of a compound that, when administered to a mammal for treating a disease, is sufficient to effect such treatment for the disease. The "therapeutically effective amount" will vary depending on the compound, the disease and its severity and the age, weight, etc., of the mammal to be treated.

"Modulator" means a molecule that interacts with a target. The interactions include, but are not limited to, agonist, antagonist, and the like, as defined herein.

"Optional" or "optionally" means that the subsequently described event or circumstance may but need not occur, and that the description includes instances where the event or circumstance occurs and instances in which it does not.

"Disease state" means any disease, condition, symptom, or indication.

"Subject" means mammals and non-mammals. Mammals means any member of the mammalia class including, but not limited to, humans; non-human primates such as chimpanzees and other apes and monkey species; farm animals such as cattle, horses, sheep, goats, and swine; domestic animals such as rabbits, dogs, and cats; laboratory animals including rodents, such as rats, mice, and guinea pigs; and the like. Examples of non-mammals include, but are not limited to, birds, and the like. The term "subject" does not denote a particular age or sex.

The term "transgenic animal" or "knockout animal" refers to an engineered animal having dysfunctional expression of a target gene or genes, or having expression of a heterologous gene.

General Method

The invention provides a method for detecting genotoxicity in a compound. In essence, test cells are provided which are capable of further differentiation. The test cells are contacted with a test compound or test sample, and incubated for a period of time sufficient for the test compound or test sample to interact with the test cell. The test cell is then induced to differentiate, and the change in expression level of one or more indicator genes is determined.

A suitable test cell is first selected. In general, the test cell used will be capable of further differentiation to an intermediate or terminally-differentiated form, and may comprise a cell line, tissue sample, isolate or explant, and the like. The test cell can be present as a part of the population of cells in a sample or isolate. Alternatively, the cellular response may be studied in situ, administering the test compounds to an animal, particularly a transgenic animal. Preferably, a permanent cell line such as C2C12 is employed.

The suitable cell can be modified by incorporating a reporter construct, for example by replacing the structural DDA3 gene or the coding region of 4833427G06Rik with a reporter gene, e.g., by homologous recombination, or by transforming the cell with a construct having an indicator gene regulatory region operably linked to a reporter gene. One may utilize any of the genes listed in Table 2, or combinations thereof. Additionally,

one may use a panel of two or more different test cells, where each test cell comprises a reporter construct responsive to the regulatory regions of one or more indicator genes. Where the reporter construct provides an observable label, such as green fluorescent protein (GFP), β-galactosidase (βGal), or the like, each test cell preferably comprises no more than two reporter constructs, more preferably no more than one reporter construct. Where the reporter construct provides a transcription label (e.g., a distinct polynucleotide sequence), the cell may contain multiple reporter constructs. In either case, a panel of test cells may be constructed having different types of test cell (for example, myoblasts and osteoblasts), and/or test cells derived from different species (e.g., mouse and human cells).

The particular indicator genes to be assayed are preferably selected on the basis of their selectivity, i.e., they should exhibit a strong response to exposure to genotoxic compounds or conditions, and little or no response to compounds or conditions that are not genotoxic. The "strong response" can be either up-regulation or down-regulation, and is generally evaluated by comparison to the degree of variation in signal in the absence of a genotoxic compound or condition (e.g., by comparison to the "background noise" of the gene). Preferably, the indicator genes used comprise DDA3 and 4833427G06Rik.

The compounds to be tested may be derived from any source, and may be provided as pure compounds or solutions, mixtures, formulated drugs, complex environmental samples (for example, a water or soil sample suspected of containing genotoxic agents), and the like. In the case of pure compounds, such as for example drug candidates, one preferably prepares a series of dilutions, generally limited by the lowest concentration at which an effect may be observed (or the lowest concentration likely to be useful) and the maximum concentration that the selected cells will tolerate (or a dose which is high enough to be toxic). In the case of unknown samples, one will preferably prepare a series of dilutions such as, for example 1:10, 1:30, 1:100, 1:300, and so forth, to determine the potency of any included genotoxic agent. In the case of environmental samples, one may instead first establish a baseline "acceptable" level, and screen samples at that dilution to determine whether or not the sample contains less than the "acceptable" level of genotoxic agents. Environmental samples may optionally be sterilized prior to testing, to avoid possible effects from viruses, bacteria, and fungi that may be present in the sample.

The selected cells are contacted with compounds or samples while being maintained in the resting phase (G0) of the mitotic cycle, and incubated for a period of time sufficient to permit any interaction to occur. In general, this incubation time will be at least about 5 minutes, more preferably at least about 20 minutes, still more preferably at least about 1 hour, still more preferably at least about 4 hours. The incubation time will

preferably be less than about 48 hours, more preferably less than about 36 hours, most preferably about 12 to about 24 hours.

After incubation with the compounds or samples, the cells are optionally washed to remove any remaining compound, then exposed to conditions that would induce the cells to differentiate (the cells may or may not arrest, and fail to actually differentiate). The method for inducing differentiation will generally depend on the particular cells employed, but typically involves adding suitable growth factors, often in the form of serum. The cells are permitted to differentiate for a period of time sufficient for a detectable change in the indicator gene expression levels to occur. In general, this differentiation time will be at least about 5 minutes, preferably at least about 20 minutes, still more preferably at least about 1 hour, still more preferably at least about 4 hours. The differentiation time will generally be less than about 48 hours, more preferably less than about 36 hours, most preferably about 12 to about 24 hours.

After exposure to differentiating conditions, the expression level of one or more indicator genes is determined. The expression level may be detected by directly measuring the indicator gene mRNA transcribed (for example, using RT-PCR or other quantitative or semi-quantitative PCR or target amplification methods), by measuring the protein product, by measuring a detectable label expressed under the control of the indicator gene promoter, or by using other methods known in the art. See, e.g., N. Kruse et al., *J Immunol Meth* (1997) 210:195-203, incorporated herein by reference. The protein product may be measured by a variety of methods known in the art, including directly measuring the protein by binding to a selective antibody (after either *in vivo* or *in vitro* translation of mRNA), measuring the protein by means of its enzymatic activity or the activity of a fusion protein combining the indicator gene product with a detectable label (for example luciferin, green fluorescent protein, horseradish peroxidase, and the like), and the like.

Where polynucleotides are detected directly, the sequences employed will generally be subsets of the sequences (and complements) set forth in the attached Sequence Listing. The selection of sequence will depend on the species of cells employed, and the details of any constructs used and form of amplification employed. Exemplary sequences for RT-PCR include, without limitation, SEQ ID NO:19, SEQ ID NO:20, SEQ ID NO:22, and SEQ ID NO:23.

The change in expression level is typically determined by comparison to a control expression level, which may be either a historically established average value, or preferably the expression level of a test cell not treated with a genotoxic compound (e.g., treated with vehicle alone) but otherwise treated identically with the other test cells. In general, an increase or decrease in expression level by a factor of 1.5 or greater, preferably

a factor of 2.0 or greater, in the expression of an indicator gene signifies that the test compound exhibits genotoxicity.

The gene 4833427G06Rik and its protein product were not previously known to have any activity: our invention here demonstrates that they are involved in cell cycle regulation and differentiation.

The present invention also provides recombinant cloning and expression vectors containing DNA, as well as host cell containing the recombinant vectors. Expression vectors comprising DNA may be used to prepare the polypeptides or fragments of the invention encoded by the DNA. A method for producing polypeptides comprises culturing host cells transformed with a recombinant expression vector encoding the polypeptide, under conditions that promote expression of the polypeptide, then recovering the expressed polypeptides from the culture. The skilled artisan will recognize that the procedure for purifying the expressed polypeptides will vary according to such factors as the type of host cells employed, and whether the polypeptide is membrane-bound or a soluble form that is secreted from the host cell. Any suitable expression system may be employed. The vectors include a DNA encoding a polypeptide or fragment of the invention, operably linked to suitable transcriptional or translational regulatory nucleotide sequences, such as those derived from a mammalian, microbial, viral, or insect gene. Examples of regulatory sequences include transcriptional promoters, operators, or enhancers, an mRNA ribosomal binding site, and appropriate sequences which control transcription and translation initiation and termination. Nucleotide sequences are operably linked when the regulatory sequence functionally relates to the DNA sequence. Thus, a promoter nucleotide sequence is operably linked to a DNA sequence if the promoter nucleotide sequence controls the transcription of the DNA sequence. An origin of replication that confers the ability to replicate in the desired host cells, and a selection gene by which transformants are identified, are generally incorporated into the expression vector.

In addition, a sequence encoding an appropriate signal peptide (native or heterologous) can be incorporated into expression vectors. A DNA sequence for a signal peptide (secretory leader) may be fused in frame to the polynucleotide sequence of the invention so that the DNA is initially transcribed, and the mRNA translated, into a fusion protein comprising the signal peptide. A signal peptide that is functional in the intended host cells promotes extracellular secretion of the polypeptide. The signal peptide is cleaved from the polypeptide upon secretion of polypeptide from the cell.

The skilled artisan will also recognize that the position(s) at which the signal peptide is cleaved may differ from that predicted by computer program, and may vary according to such factors as the type of host cells employed in expressing a recombinant

polypeptide. A protein preparation may include a mixture of protein molecules having different N-terminal amino acids, resulting from cleavage of the signal peptide at more than one site.

Suitable host cells for expression of polypeptides include prokaryotes, yeast or higher eukaryotic cells. Mammalian or insect cells are generally preferred for use as host cells. Appropriate cloning and expression vectors for use with bacterial, fungal, yeast, and mammalian cellular hosts are described, for example, in Pouwels et al., "Cloning Vectors: A Laboratory Manual" (Elsevier, New York, 1985). Cell-free translation systems could also be employed to produce polypeptides using RNA derived from DNA constructs disclosed herein.

Prokaryotes include gram-negative or gram-positive organisms. Suitable prokaryotic host cells for transformation include, for example, *E. coli*, *Bacillus subtilis*, *Salmonella typhimurium*, and various other species within the genera Pseudomonas, Streptomyces, and Staphylococcus. In a prokaryotic host cell, such as *E. coli*, a polypeptide may include an N-terminal methionine residue to facilitate expression of the recombinant polypeptide in the prokaryotic host cell. The N-terminal Met may be cleaved from the expressed recombinant polypeptide.

Expression vectors for use in prokaryotic host cells generally comprise one or more phenotypic selectable marker genes. A phenotypic selectable marker gene is, for example, a gene encoding a protein that confers antibiotic resistance or that supplies an autotrophic requirement. Examples of useful expression vectors for prokaryotic host cells include those derived from commercially available plasmids such as the cloning vector pBR322 (ATCC 37017). pBR322 contains genes for ampicillin and tetracycline resistance, and thus provides simple means for identifying transformed cells. An appropriate promoter and a DNA sequence are inserted into the pBR322 vector. Other commercially available vectors include, for example, pKK223-3 (Pharmacia Fine Chemicals, Uppsala, Sweden) and pGEM1 (Promega Biotec, Madison, Wis., USA).

Promoter sequences commonly used for recombinant prokaryotic host cell expression vectors include β-lactamase (penicillinase), lactose promoter system (Chang et al., *Nature* (1978) 275:615; and Goeddel et al., *Nature* (1979) 281:544), tryptophan (trp) promoter system (Goeddel et al., *Nuc Acids Res.* (1980) 8:4057; and EP036776) and tac promoter (Maniatis, "Molecular Cloning: A Laboratory Manual", Cold Spring Harbor Laboratory, p. 412, 1982). A particularly useful prokaryotic host cell expression system employs a phage λP_L promoter and a cI857ts thermolabile repressor sequence. Plasmid vectors available from the American Type Culture Collection which incorporate derivatives of the λP_L promoter include plasmid pHUB2 (resident in *E. coli* strain JMB9, ATCC 37092) and pPLc28 (resident in *E. coli* RR1, ATCC 53082).

Alternatively, the polypeptides may be expressed in yeast host cells, preferably from the Saccharomyces genus (e.g., *S. cerevisiae*). Other genera of yeast, such as Pichia or Kluyveromyces, may also be employed. Yeast vectors will often contain an origin of replication sequence from a 2μ yeast plasmid, an autonomously replicating sequence (ARS), a promoter region, sequences for polyadenylation, sequences for transcription termination, and a selectable marker gene. Suitable promoter sequences for yeast vectors include, among others, promoters for metallothionein, 3-phosphoglycerate kinase (Hitzeman et al., *J. Biol. Chem.* (1980) 255:2073) or other glycolytic enzymes (Hess et al., *J. Adv. Enzyme Reg.* (1968) 7:149; and Holland et al., *Biochem.* (1978) 17:4900), such as enolase, glyceraldehyde-3-phosphate dehydrogenase, hexokinase, pyruvate decarboxylase, phosphofructokinase, glucose-6-phosphate isomerase, 3-phosphoglycerate mutase, pyruvate kinase, triosephosphate isomerase, phospho-glucose isomerase, and glucokinase. Other suitable vectors and promoters for use in yeast expression are further described in Hitzeman, EP073,657. Another alternative is the glucose-repressible ADH2 promoter described by Russell et al., *J. Biol. Chem.* (1982) 258:2674 and Beier et al., *Nature* (1982) 300:724. Shuttle vectors replicable in both yeast and E. coli may be constructed by inserting DNA sequences from pBR322 for selection and replication in E. coli (Amp^r gene and origin of replication) into the above-described yeast vectors.

The yeast α-factor leader sequence may be employed to direct secretion of the polypeptide. The α-factor leader sequence is often inserted between the promoter sequence and the structural gene sequence. See, e.g., Kurjan et al., *Cell* (1982) 30:933, and Bitter et al., *Proc Natl Acad Sci USA* (1984) 81:5330. Other leader sequences suitable for facilitating secretion of recombinant polypeptides from yeast hosts are known to those of skill in the art. A leader sequence may be modified near its 3' end to contain one or more restriction sites. This will facilitate fusion of the leader sequence to the structural gene.

Yeast transformation protocols are known to those of skill in the art. One such protocol is described by Hinnen et al., *Proc Natl Acad Sci USA* (1978) 75:1929, 1978. The Hinnen et al. protocol selects for Trp^+ transformants in a selective medium, wherein the selective medium consists of 0.67% yeast nitrogen base, 0.5% casamino acids, 2% glucose, 10 mg/ml adenine and 20 mg/ml uracil.

Yeast host cells transformed by vectors containing an ADH2 promoter sequence may be grown for inducing expression in a "rich" medium. An example of a rich medium is one consisting of 1% yeast extract, 2% peptone, and 1% glucose supplemented with 80 mg/ml adenine and 80 mg/ml uracil. Derepression of the ADH2 promoter occurs when glucose is exhausted from the medium.

Mammalian or insect host cell culture systems also may be employed to express recombinant polypeptides. Bacculovirus systems for production of heterologous proteins

in insect cells are reviewed by Luckow and Summers, *Bio/Technology* (1988) 6:47. Established cell lines of mammalian origin also may be employed. Examples of suitable mammalian host cell lines include the COS-7 line of monkey kidney cells (ATCC CRL 1651) (Gluzman et al., *Cell* (1981) 23:175), L cells, C127 cells, 3T3 cells (ATCC CCL 163), Chinese hamster ovary (CHO) cells, HeLa cells, and BHK (ATCC CRL 10) cell lines, and the CV1/EBNA cell line derived from the African green monkey kidney cell line CV1 (ATCC CCL 70) as described by McMahan et al. (*EMBO J.* (1991) 10:2821).

Established methods for introducing DNA into mammalian cells have been described (Kaufman, R.J., "Large Scale Mammalian Cell Culture", 1990, pp. 15-69). Additional protocols using commercially available reagents, such as Lipofectamine lipid reagent (Gibco/BRL) or Lipofectamine-Plus lipid reagent, can be used to transfect cells (Felgner et al., *Proc Natl Acad Sci USA* (1987) 84:7413-17). In addition, electroporation can be used to transfect mammalian cells using conventional procedures, such as those in Sambrook et al. ("Molecular Cloning: A Laboratory Manual", 2d ed. Vol. 1-3, Cold Spring Harbor Laboratory Press, 1989). Selection of stable transformants can be performed using methods known in the art, such as, for example, resistance to cytotoxic drugs. Kaufman et al., *Meth Enzymol* (1990) 185:487-511, describes several selection schemes, such as dihydrofolate reductase (DHFR) resistance. A suitable host strain for DHFR selection can be CHO strain DX-B11, which is deficient in DHFR (Urlaub and Chasin, *Proc Natl Acad Sci USA* (1980) 77:4216-20). A plasmid expressing the DHFR cDNA can be introduced into strain DX-B11, and only cells that contain the plasmid can grow in the appropriate selective media. Other examples of selectable markers that can be incorporated into an expression vector include cDNAs conferring resistance to antibiotics, such as G418 and hygromycin B. Cells harboring the vector can be selected on the basis of resistance to these compounds.

Transcriptional and translational control sequences for mammalian host cell expression vectors can be excised from viral genomes. Commonly used promoter sequences and enhancer sequences are derived from polyoma virus, adenovirus 2, simian virus 40 (SV40), and human cytomegalovirus. DNA sequences derived from the SV40 viral genome, for example, SV40 origin, early and late promoter, enhancer, splice, and polyadenylation sites can be used to provide other genetic elements for expression of a structural gene sequence in a mammalian host cell. Viral early and late promoters are particularly useful because both are easily obtained from a viral genome as a fragment, which can also contain a viral origin of replication (Fiers et al., *Nature* (1978) 273:113; Kaufman, *Meth. Enzymol* (1990). Smaller or larger SV40 fragments can also be used, provided the approximately 250 bp sequence extending from the Hind III site toward the Bgl I site located in the SV40 viral origin of replication site is included.

Additional control sequences shown to improve expression of heterologous genes from mammalian expression vectors include such elements as the expression augmenting sequence element (EASE) derived from CHO cells (Morris et al., WO 97/25420) and the tripartite leader (TPL) and VA gene RNAs from Adenovirus 2 (Gingeras et al., *J. Biol. Chem.* (1982) 257:13475-91). The internal ribosome entry site (IRES) sequences of viral origin allows dicistronic mRNAs to be translated efficiently (Oh and Sarnow, *Cur Op Gen Dev* (1993) 3:295-300; Ramesh et al., *Polynuc Res* (1996) 24:2697-700). Expression of a heterologous cDNA as part of a dicistronic mRNA followed by the gene for a selectable marker (e.g. DHFR) has been shown to improve transfectability of the host and expression of the heterologous cDNA (Kaufman, *Meth Enzymol*, 1990). Exemplary expression vectors that employ dicistronic mRNAs are pTR-DC/GFP described by Mosser et al., *Biotechniques* (1997) 22:150-61, and p2A5I described by Morris et al., "Animal Cell Technology", 1997, pp. 529-34.

A useful high expression vector, pCAVNOT, has been described by Mosley et al., *Cell* (1989) 59:335-48. Other expression vectors for use in mammalian host cells can be constructed as disclosed by Okayama and Berg, *Mol. Cell. Biol.* (1983) 3:280. A useful system for stable high level expression of mammalian cDNAs in C127 murine mammary epithelial cells can be constructed substantially as described by Cosman et al., *Mol. Immunol.* (1986) 23:935. A useful high expression vector, PMLSV N1/N4, described by Cosman et al., *Nature* (1984) 312:768, has been deposited as ATCC 39890. Additional useful mammalian expression vectors are described in EP0367566, and in WO91/18982, incorporated by reference herein. In yet another alternative, the vectors can be derived from retroviruses.

Another useful expression vector, pFLAG.RTM., can be used. FLAG.RTM. technology is centered on the fusion of a low molecular weight (1 kD), hydrophilic, FLAG.RTM. marker peptide to the N-terminus of a recombinant protein expressed by pFLAG.RTM. expression vectors.

Regarding signal peptides that may be employed, the native signal peptide may be replaced by a heterologous signal peptide or leader sequence, if desired. The choice of signal peptide or leader may depend on factors such as the type of host cells in which the recombinant polypeptide is to be produced. To illustrate, examples of heterologous signal peptides that are functional in mammalian host cells include the signal sequence for interleukin-7 (IL-7) described in US 4,965,195; the signal sequence for interleukin-2 receptor described in Cosman et al., *Nature* (1984) 312:768; the interleukin-4 receptor signal peptide described in EP 367,566; the type I interleukin-1 receptor signal peptide described in US 4,968,607; and the type II interleukin-I receptor signal peptide described in EP 460,846.

The "isolated" polypeptides or fragments thereof encompassed by this invention are polypeptides or fragments that are not in an environment identical to an environment in which it or they can be found in nature. The "purified" polypeptides or fragments thereof encompassed by this invention are essentially free of association with other proteins or polypeptides, for example, as a purification product of recombinant expression systems such as those described above or as a purified product from a non-recombinant source such as naturally occurring cells and/or tissues.

With respect to any type of host cell, as is known to the skilled artisan, procedures for purifying a recombinant polypeptide or fragment will vary according to such factors as the type of host cells employed and whether or not the recombinant polypeptide or fragment is secreted into the culture medium.

In general, the recombinant polypeptide or fragment can be isolated from the host cells if not secreted, or from the medium or supernatant if soluble and secreted, followed by one or more concentration, salting-out, ion exchange, hydrophobic interaction, affinity purification or size exclusion chromatography steps. As to specific ways to accomplish these steps, the culture medium first can be concentrated using a commercially available protein concentration filter, for example, an Amicon or Millipore Pellicon ultrafiltration unit. Following the concentration step, the concentrate can be applied to a purification matrix such as a gel filtration medium. Alternatively, an anion exchange resin can be employed, for example, a matrix or substrate having pendant diethylaminoethyl (DEAE) groups. The matrices can be acrylamide, agarose, dextran, cellulose or other types commonly employed in protein purification. Alternatively, a cation exchange step can be employed. Suitable cation exchangers include various insoluble matrices comprising sulfopropyl or carboxymethyl groups. In addition, a chromatofocusing step can be employed. Alternatively, a hydrophobic interaction chromatography step can be employed. Suitable matrices can be phenyl or octyl moieties bound to resins. In addition, affinity chromatography with a matrix which selectively binds the recombinant protein can be employed. Examples of such resins employed are lectin columns, dye columns, and metal-chelating columns. Finally, one or more reverse-phase high performance liquid chromatography (RP-HPLC) steps employing hydrophobic RP-HPLC media, (e.g., silica gel or polymer resin having pendant methyl, octyl, octyldecyl or other aliphatic groups) can be employed to further purify the polypeptides. Some or all of the foregoing purification steps, in various combinations, are well known and can be employed to provide an isolated and purified recombinant protein.

It is also possible to utilize an affinity column comprising a polypeptide-binding protein of the invention, such as a monoclonal antibody generated against polypeptides

of the invention, to affinity-purify expressed polypeptides. These polypeptides can be removed from an affinity column using conventional techniques, e.g., in a high salt elution buffer and then dialyzed into a lower salt buffer for use or by changing pH or other components depending on the affinity matrix utilized, or be competitively removed using the naturally occurring substrate of the affinity moiety, such as a polypeptide derived from the invention.

In this aspect of the invention, polypeptide-binding proteins, such as the anti-polypeptide antibodies of the invention or other proteins that may interact with the polypeptide of the invention, can be bound to a solid phase support such as a column chromatography matrix or a similar substrate suitable for identifying, separating, or purifying cells that express polypeptides of the invention on their surface. Adherence of polypeptide-binding proteins of the invention to a solid phase contacting surface can be accomplished by any means. For example, magnetic microspheres can be coated with these polypeptide-binding proteins and held in the incubation vessel through a magnetic field. Suspensions of cell mixtures are contacted with the solid phase that has such polypeptide-binding proteins thereon. Cells having polypeptides of the invention on their surface bind to the fixed polypeptide-binding protein and unbound cells then are washed away. This affinity-binding method is useful for purifying, screening, or separating such polypeptide-expressing cells from solution. Methods of releasing positively selected cells from the solid phase are known in the art and encompass, for example, the use of enzymes. Such enzymes are preferably non-toxic and non-injurious to the cells and are preferably directed to cleaving the cell-surface binding partner.

Alternatively, mixtures of cells suspected of containing polypeptide-expressing cells of the invention first are incubated with a biotinylated polypeptide-binding protein of the invention. Incubation periods are typically at least one hour in duration to ensure sufficient binding to polypeptides of the invention. The resulting mixture then is passed through a column packed with avidin-coated beads, whereby the high affinity of biotin for avidin provides the binding of the polypeptide-binding cells to the beads. Use of avidin-coated beads is known in the art. See Berenson, et al. *J. Cell. Biochem* (1986) 10D:239. Wash of unbound material and the release of the bound cells is performed using conventional methods.

The desired degree of purity depends on the intended use of the protein. A relatively high degree of purity is desired when the polypeptide is to be administered *in vivo*, for example. In such a case, the polypeptides are purified such that no protein bands corresponding to other proteins are detectable upon analysis by SDS-polyacrylamide gel electrophoresis (SDS-PAGE). It will be recognized by one skilled in the pertinent field that multiple bands corresponding to the polypeptide may be visualized by SDS-PAGE,

due to differential glycosylation, differential post-translational processing, and the like. Most preferably, the polypeptide of the invention is purified to substantial homogeneity, as indicated by a single protein band upon analysis by SDS-PAGE. The protein band may be visualized by silver staining, Coomassie blue staining, or (if the protein is radiolabeled) by autoradiography.

The purified polypeptides of the invention (including proteins, polypeptides, fragments, variants, oligomers, and other forms) may be tested for the ability to bind the binding partner in any suitable assay, such as a conventional binding assay. The polypeptide may be labeled with a detectable reagent (e.g., a radionuclide, chromophore, enzyme that catalyzes a colorimetric or fluorometric reaction, and the like). The labeled polypeptide is contacted with cells expressing the binding partner. The cells then are washed to remove unbound labeled polypeptide, and the presence of cell-bound label is determined by a suitable technique, chosen according to the nature of the label.

Another type of competitive binding assay utilizes radiolabeled soluble binding partner, such as a soluble 4833427G06Rik /Fc fusion protein, and intact cells expressing a specific antibody. Qualitative results can be obtained by competitive autoradiographic plate binding assays, while Scatchard plots (Scatchard, *Ann. N.Y. Acad. Sci.* (1949) 51:660) may be utilized to generate quantitative results. Such binding assays may be useful in evaluating the biological activity of a variant polypeptide by assaying for the variant's ability to compete with the native protein for binding to the binding partner.

The 4833427G06Rik polypeptide of the present invention may also be used in a screening assay for compounds and small molecules which inhibit activation by (antagonize) the 4833427G06Rik polypeptide of the instant invention. Thus, polypeptides of the invention may be used to identify antagonists from, for example, cells, cell-free preparations, chemical libraries, and natural product mixtures. The antagonists may be natural or modified substrates, ligands, enzymes, or receptors of the 4833427G06Rik polypeptide, or may be structural or functional mimetics of the 4833427G06Rik polypeptide. The antagonists may further be small molecules, peptides, antibodies and antisense oligonucleotides.

One embodiment of a method for identifying compounds which antagonize the 4833427G06Rik polypeptide is contacting a candidate compound with cells which respond to 4833427G06Rik polypeptide and observe the binding of 4833427G06Rik to the cells, or stimulation or inhibition of a functional response. The activity of the cells which were contacted with the candidate compound could then be compared with the identical cells which were not contacted for 4833427G06Rik polypeptide activity and 4833427G06Rik polypeptide agonists and antagonists could be identified. A still further embodiment of the instant invention provides a method of identifying compounds that

inhibit the synthesis or secretion of 4833427G06Rik by contacting the candidate compound with cells which express 4833427G06Rik polypeptide and measuring the 4833427G06Rik production. The measurement of 4833427G06Rik production could be performed by a number of well-known methods such as measuring the amount of protein present (for example, by ELISA) or of the protein's activity.

The purified polypeptides according to the invention will facilitate the discovery of inhibitors (or antagonists) and/or agonists of such polypeptides. The use of a purified polypeptide of the invention in the screening of potential inhibitors and/or agonists thereof is important and can eliminate or reduce the possibility of interfering reactions with contaminants.

In addition, polypeptides of the invention can be used for structure-based design of polypeptide-inhibitors and/or agonists. Such structure-based design is also known as "rational drug design." The polypeptides can be three-dimensionally analyzed by, for example, X-ray crystallography, nuclear magnetic resonance or homology modeling, all of which are well-known methods. The use of the polypeptide structural information in molecular modeling software systems to assist in inhibitor design and inhibitor-polypeptide interaction is also encompassed by the invention. Such computer-assisted modeling and drug design can utilize information such as chemical conformational analysis, electrostatic potential of the molecules, protein folding, etc. For example, most of the design of class-specific inhibitors of metalloproteases has focused on attempts to chelate or bind the catalytic zinc atom. Synthetic inhibitors are usually designed to contain a negatively-charged moiety to which is attached a series of other groups designed to fit the specificity pockets of the particular protease. A particular method of the invention comprises analyzing the three dimensional structure of polypeptides of the invention for likely binding sites of substrates, synthesizing a new molecule that incorporates a predictive reactive site, and assaying the new molecule as described above.

Specific screening methods are known in the art and along with integrated robotic systems and collections of chemical compounds/natural products are extensively incorporated in high throughput screening so that large numbers of test compounds can be tested for antagonist or agonist activity within a short amount of time. These methods include homogeneous assay formats such as fluorescence resonance energy transfer, fluorescence polarization, time-resolved fluorescence resonance energy transfer, scintillation proximity assays, reporter gene assays, fluorescence quenched enzyme substrate, chromogenic enzyme substrate and electrochemiluminescence, as well as more traditional heterogeneous assay formats such as enzyme-linked immunosorbant assays (ELISA) or radioimmunoassays. Homogeneous assays are preferred. Also comprehended herein are cell-based assays, for example those utilizing reporter genes, as well as

functional assays that analyze the effect of an antagonist or agonist on biological function(s) or activity(ies) of 4833427G06Rik.

Accordingly, in one aspect of the invention, there is provided a method for screening a test compound to determine whether the test compound affects (or modulates) a biological activity of an 4833427G06Rik polypeptide, the method comprising contacting the test compound and the 4833427G06Rik polypeptide with cells capable of exhibiting the biological activity when contacted with 4833427G06Rik, and analyzing the cells for the occurrence of the biological activity, wherein if the biological activity observed in the presence of the test compound differs from the biological activity that is observed when the test compound is absent, the test compound affects the biological activity of the 4833427G06Rik. The cells may be contacted *in vitro* or *in vivo*.

4833427G06Rik mediated modulation of signaling pathways often involves a cascade of molecular changes, for example as discussed previously wherein a receptor propagates a ligand-receptor mediated signal by specifically activating intracellular kinases which phosphorylate target substrates (which can themselves be kinases that become activated following phosphorylation, or adaptor molecules that facilitate down-stream signaling through protein-protein interaction following phosphorylation), resulting in the activation of other factors (for example, NFκB). When the screening methods of the present invention include assaying for 4833427G06Rik-induced modulation of signaling pathways, the signaling pathways that may be assayed include those involving activation of NFκB. Assaying for activation signaling cascades further includes detecting phosphorylation of molecules that occurs during the signaling cascade, as in the phosphorylation of IκB (including IκB degradation assays, and assays for free IκB), p38 MAP kinase, and Stress-Activated Protein Kinase (SAPK/JNK).

Moreover, those of skill in the art understand that biological activity(ies) is/are most often induced by the binding of a ligand (i.e., 4833427G06Rik) to a receptor (counter-structure or binding moiety) present on a cell; accordingly, as previously described, 4833427G06Rik polypeptides (including 4833427G06Rik polypeptide fragments) can be used in binding studies to identify receptor-expressing cells. Such binding studies also provide assays useful in the inventive methods. 4833427G06Rik polypeptides may also be used to clone receptors (or other molecules that bind 4833427G06Rik) and to screen for molecules that block receptor/ligand interactions. Those of ordinary skill in the art further understand that biological activities include cell proliferation, cell death, and changes in cell morphology and/or function (for example, activation, maturation); assays that evaluate such effects of 4833427G06Rik are known in the art, and will also be useful in the inventive methods. Moreover, animal models of syndromes and/or conditions, such as those disclosed herein, are useful for screening

compounds for biological activity, including screening for antagonism (or agonism) of 4833427G06Rik.

The inventive methods further encompass performing more than one assay to discover and/or analyze agonists or antagonists of 4833427G06Rik activity (i.e., combination methods). Generally, such methods comprise selecting test compounds that affect a property of 4833427G06Rik (i.e., an ability of 4833427G06Rik to bind a 4833427G06Rik counter structure), then testing the selected compounds for an effect on another property of 4833427G06Rik (i.e., contacting the selected test compounds and an 4833427G06Rik polypeptide with cells capable of exhibiting a biological activity when contacted with 4833427G06Rik, and determining whether the compounds affect the biological activity). For example, the inventive methods may comprise a first assay to determine whether a candidate molecule interacts with (binds to) 4833427G06Rik. In one embodiment, the first assay is in a high throughput format, numerous forms of which are known in the art and disclosed herein. Such an assay will generally comprise the steps of: contacting test compounds and an 4833427G06Rik polypeptide with an 4833427G06Rik counter-structure; determining whether the test compounds affect the ability of 4833427G06Rik to bind the counter-structure; and selecting one or more test compounds that affect the ability of 4833427G06Rik to bind the counter-structure. The inventive combination methods further comprise evaluating selected compounds in a second assay, for agonistic or antagonistic effect on biological activity using one or more of the aforementioned assays.

Alternatively, the inventive combination methods may comprise a first assay to determine whether a candidate molecule modulates a biological activity of 4833427G06Rik, as described herein using an *in vitro* assay or an *in vivo* assay (for example, an animal model). According to such combination methods, molecules that modulate an 4833427G06Rik biological activity in this manner are selected using one or more of the aforementioned assays for biological activity, and assayed to determine whether the candidate molecule(s) bind 4833427G06Rik. The selected molecules may be tested to further define the exact region or regions of 4833427G06Rik to which the test molecule binds (for example, epitope mapping for antibodies).

As disclosed previously, the types of assays for biological activities of 4833427G06Rik that can be used in the inventive combination methods include assays for the expression of cytokines, assays for the expression of cell-surface molecules, assays to detect activation of signaling molecules, assays to detect induction of mRNAs, and assays that evaluate cell proliferation or cell death (and combinations thereof), as described herein. Molecules that bind and that have an agonistic or antagonistic effect on biologic

activity will be useful in treating or preventing diseases or conditions with which the polypeptide(s) are implicated.

Those of ordinary skill in the art understand that when the biological activity observed in the presence of the test compound is greater than that observed when the test compound is absent, the test compound is an agonist of 4833427G06Rik, whereas when the biological activity observed in the presence of the test compound is less than that observed when the test compound is absent, the test compound is an antagonist (or inhibitor) of 4833427G06Rik. Generally, an antagonist will decrease or inhibit, an activity by at least 30%; more preferably, antagonists will inhibit activity by at least 50%, most preferably by at least 90%. Similarly, an agonist will increase, or enhance, an activity by at least 20%; more preferably, agonists will enhance activity by at least 30%, most preferably by at least 50%. Those of skill in the art will also recognize that agonists and/or antagonists with different levels of agonism or antagonism respectively may be useful for different applications (i.e., for treatment of different disease states).

Homogeneous assays are mix-and-read style assays that are very amenable to robotic application, whereas heterogeneous assays require separation of free from bound analyte by more complex unit operations such as filtration, centrifugation or washing. These assays are utilized to detect a wide variety of specific biomolecular interactions (including protein-protein, receptor-ligand, enzyme-substrate, and so on), and the inhibition thereof by small organic molecules. These assay methods and techniques are well known in the art (see, e.g., "High Throughput Screening: The Discovery of Bioactive Substances", John P. Devlin (ed.), Marcel Dekker, New York, 1997 ISBN: 0-8247-0067-8). The screening assays of the present invention are amenable to high throughput screening of chemical libraries and are suitable for the identification of small molecule drug candidates, antibodies, peptides, and other antagonists and/or agonists, natural or synthetic. Several useful assays are disclosed in US 2003-0165985 (the relevant disclosure of which is hereby incorporated by reference).

The methods of the invention may be used to identify antagonists (also referred to as inhibitors) and agonists of 4833427G06Rik activity from cells, cell-free preparations, chemical libraries, cDNA libraries, recombinant antibody libraries (or libraries comprising subunits of antibodies) and natural product mixtures. The antagonists and agonists may be natural or modified substrates, ligands, enzymes, receptors, etc. of the polypeptides of the instant invention, or may be structural or functional mimetics of 4833427G06Rik or its binding partner/counter-structure. Potential antagonists of the instant invention include small molecules, peptides and antibodies that bind to and occupy a binding site of the inventive polypeptides or a binding partner thereof, causing them to be unavailable to bind to their natural binding partners and therefore preventing

normal biological activity. Antagonists also include chemicals (including small molecules and peptides) that interfere with the signaling pathways used by 4833427G06Rik (for example, by inhibiting the interaction of receptor subunits, or inhibiting the interaction of intracellular components of the signaling cascade). Potential agonists include small molecules, peptides and antibodies which bind to the instant polypeptides or binding partners thereof, and elicit the same or enhanced biologic effects as those caused by the binding of the polypeptides of the instant invention. Moreover, substances that activate (or enhance) the signaling pathways used by 4833427G06Rik are also included within the scope of agonists of 4833427G06Rik.

Small molecule agonists and antagonists are usually less than 10K molecular weight and may possess a number of physicochemical and pharmacological properties which enhance cell penetration, resist degradation and prolong their physiological half-lives. Antibodies, which include intact molecules as well as fragments such as Fab and F(ab')2 fragments, as well as recombinant molecules derived therefrom (including antibodies expressed on phage, intrabodies, single chain antibodies such as scFv and other molecules derived from immunoglobulins that are known in the art), may be used to bind to and inhibit the polypeptides of the instant invention by blocking the propagation of a signaling cascade. It is preferable that the antibodies are humanized, and more preferable that the antibodies are human. The antibodies of the present invention may be prepared by any of a variety of well-known methods, as disclosed herein.

Additional examples of candidate molecules, also referred to herein as "test molecules" or "test compounds," to be tested for the ability to modulate 4833427G06Rik activity include, but are not limited to, carbohydrates, small molecules (usually organic molecules or peptides), proteins, and nucleic acid molecules (including oligonucleotide fragments typically consisting of from 8 to 30 nucleic acid residues). Peptides to be tested typically consist of from 5 to 25 amino acid residues. Also, candidate nucleic acid molecules can be antisense nucleic acid sequences, and/or can possess ribozyme activity.

The methods of the invention can be used to screen for antisense molecules that inhibit the functional expression of one or more mRNA molecules that encode one or more proteins that mediate an 4833427G06Rik -dependent cellular response. An antisense nucleic acid molecule is a DNA sequence that is capable of can hybridizing to the target mRNA molecule through Watson-Crick base pairing, and inhibiting translation thereof. Alternatively, the DNA may be inverted relative to its normal orientation for transcription and so express an RNA transcript that is complementary to the target mRNA molecule (i.e., the RNA transcript of the anti-sense nucleic acid molecule can hybridize to the target mRNA molecule through Watson-Crick base pairing). An anti-sense nucleic acid molecule may be constructed in a number of different ways provided

that it is capable of interfering with the expression of a target protein. Typical anti-sense oligonucleotides to be screened preferably are 30-40 nucleotides in length. The anti-sense nucleic acid molecule generally will be substantially identical (although in antisense orientation) to the target gene. The minimal identity will typically be greater than about 80%, but a higher identity might exert a more effective repression of expression of the endogenous sequences. Substantially greater identity of more than about 90% is preferred, though about 95% to absolute identity would be most preferred.

Candidate nucleic acid molecules can possess ribozyme activity. Thus, the methods of the invention can be used to screen for ribozyme molecules that inhibit the functional expression of one or more mRNA molecules that encode one or more proteins that mediate an IL-1 eta dependent cellular response. Ribozymes are catalytic RNA molecules that can cleave nucleic acid molecules having a sequence that is completely or partially homologous to the sequence of the ribozyme. It is possible to design ribozyme transgenes that encode RNA ribozymes that specifically pair with a target RNA and cleave the phosphodiester backbone at a specific location, thereby functionally inactivating the target RNA. In carrying out this cleavage, the ribozyme is not itself altered, and is thus capable of recycling and cleaving other molecules. The inclusion of ribozyme sequences within antisense RNAs confers RNA-cleaving activity upon them, thereby increasing the activity of the antisense constructs.

The design and use of target RNA-specific ribozymes is described in Haseloff et al., *Nature* (1988) 334:585, and US 5,646,023, both of which publications are incorporated herein by reference. Tabler et al., *Gene* (1991) 108:175 have greatly simplified the construction of catalytic RNAs by combining the advantages of the anti-sense RNA and the ribozyme technologies in a single construct. Smaller regions of homology are required for ribozyme catalysis, therefore this can promote the repression of different members of a large gene family if the cleavage sites are conserved.

Among the uses of polynucleotides of the invention is the use of fragments as probes or primers. Such fragments generally comprise at least about 17 contiguous nucleotides of a DNA sequence. In other embodiments, a DNA fragment comprises at least 30, or at least 60, contiguous nucleotides of a DNA sequence.

Because homologs of 4833427G06Rik from other mammalian species are contemplated herein, probes based on the mouse DNA sequence of 4833427G06Rik may be used to screen cDNA libraries derived from other mammalian species, using conventional cross-species hybridization techniques. Using knowledge of the genetic code in combination with the amino acid sequences set forth above, sets of degenerate oligonucleotides can be prepared. Such oligonucleotides are useful as primers, e.g., in polymerase chain reactions (PCR), whereby DNA fragments are isolated and amplified.

DNA of the present invention may be used in developing treatments for any disorder mediated (directly or indirectly) by defective, or insufficient amounts of, the genes corresponding to the polynucleotides of the invention. Disclosure herein of native nucleotide sequences permits the detection of defective genes, and the replacement thereof with normal genes. Defective genes may be detected in *in vitro* diagnostic assays, and by comparison of a native nucleotide sequence disclosed herein with that of a gene derived from a person suspected of harboring a defect in this gene.

Other useful fragments of the polynucleotides of this invention include antisense or sense oligonucleotides comprising a single-stranded polynucleotide sequence (either RNA or DNA) capable of binding to target mRNA (sense) or DNA (antisense) sequences. Antisense or sense oligonucleotides according to the present invention comprise a fragment of DNA (SEQ ID NO:5). Such a fragment generally comprises at least about 14 nucleotides, preferably from about 14 to about 30 nucleotides. The ability to derive an antisense or a sense oligonucleotide, based upon a cDNA sequence encoding a given protein is described in, for example, Stein and Cohen, *Cancer Res.* (1988) 48:2659 and van der Krol et al., *BioTechniques* (1988) 6:958.

Binding antisense or sense oligonucleotides to target polynucleotide sequences results in the formation of duplexes that block or inhibit protein expression by one of several means, including enhanced degradation of the mRNA by RNAseH, inhibition of splicing, premature termination of transcription or translation, or by other means. The antisense oligonucleotides thus may be used to block expression of proteins. Antisense or sense oligonucleotides further comprise oligonucleotides having modified sugar-phosphodiester backbones (or other sugar linkages, such as those described in W091/06629) and wherein such sugar linkages are resistant to endogenous nucleases. Such oligonucleotides with resistant sugar linkages are stable *in vivo* (i.e., capable of resisting enzymatic degradation) but retain sequence specificity to be able to bind to target nucleotide sequences.

Other examples of sense or antisense oligonucleotides include those oligonucleotides which are covalently linked to organic moieties, such as those described in WO 90/10448, and other moieties that increases affinity of the oligonucleotide for a target polynucleotide sequence, such as poly-(L-lysine). Further still, intercalating agents, such as ellipticine, and alkylating agents or metal complexes may be attached to sense or antisense oligonucleotides to modify binding specificities of the antisense or sense oligonucleotide for the target nucleotide sequence.

Antisense or sense oligonucleotides may be introduced into a cell containing the target polynucleotide sequence by any gene transfer method, including, for example,

lipofection, $CaPO_4$ -mediated DNA transfection, electroporation, or by using gene transfer vectors such as Epstein-Barr virus.

Sense or antisense oligonucleotides also may be introduced into a cell containing the target nucleotide sequence by formation of a conjugate with a ligand binding molecule, as described in WO 91/04753. Suitable ligand binding molecules include, but are not limited to, cell surface receptors, growth factors, other cytokines, or other ligands that bind to cell surface receptors. Preferably, conjugation of the ligand binding molecule does not substantially interfere with the ability of the ligand binding molecule to bind to its corresponding molecule or receptor, or block entry of the sense or antisense oligonucleotide or its conjugated version into the cell.

Alternatively, a sense or an antisense oligonucleotide may be introduced into a cell containing the target polynucleotide sequence by formation of an oligonucleotide-lipid complex, as described in WO 90/10448. The sense or antisense oligonucleotide-lipid complex is preferably dissociated within the cell by an endogenous lipase.

Polypeptides of the present invention find use as a protein purification reagent. The polypeptides may be attached to a solid support material and used to purify the binding partner proteins by affinity chromatography. In particular embodiments, a polypeptide (in any form described herein that is capable of binding the binding partner) is attached to a solid support by conventional procedures. As one example, chromatography columns containing functional groups that will react with functional groups on amino acid side chains of proteins are available (Pharmacia Biotech, Inc., Piscataway, N.J.). In an alternative, a polypeptide/Fc protein (as discussed above) is attached to Protein A- or Protein G-containing chromatography columns through interaction with the Fc moiety.

The polypeptide also finds use in purifying or identifying cells that express the binding partner on the cell surface. Polypeptides are bound to a solid phase such as a column chromatography matrix or a similar suitable substrate. For example, magnetic microspheres can be coated with the polypeptides and held in an incubation vessel through a magnetic field. Suspensions of cell mixtures containing the binding partner expressing cells are contacted with the solid phase having the polypeptides thereon. Cells expressing the binding partner on the cell surface bind to the fixed polypeptides, and unbound cells then are washed away. Alternatively, the polypeptides can be conjugated to a detectable moiety, then incubated with cells to be tested for binding partner expression. After incubation, unbound labeled matter is removed and the presence or absence of the detectable moiety on the cells is determined.

In a further alternative, mixtures of cells suspected of containing cells expressing the binding partner are incubated with biotinylated polypeptides. Incubation periods are

typically at least one hour in duration to ensure sufficient binding. The resulting mixture then is passed through a column packed with avidin-coated beads, whereby the high affinity of biotin for avidin provides binding of the desired cells to the beads. Procedures for using avidin-coated beads are known (see Berenson, et al. *J Cell Biochem.* (1986) 10D:239). Washing to remove unbound material, and the release of the bound cells, are performed using conventional methods.

Polypeptides also find use in measuring the biological activity of the binding partner protein in terms of their binding affinity. The polypeptides thus may be employed by those conducting "quality assurance" studies, e.g., to monitor shelf life and stability of protein under different conditions. For example, the polypeptides may be employed in a binding affinity study to measure the biological activity of a binding partner protein that has been stored at different temperatures, or produced in different cell types. The proteins also may be used to determine whether biological activity is retained after modification of a binding partner protein (e.g., chemical modification, truncation, mutation, etc.). The binding affinity of the modified binding partner protein is compared to that of an unmodified binding partner protein to detect any adverse impact of the modifications on biological activity of the binding partner. The biological activity of a binding partner protein thus can be ascertained before it is used in a research study, for example.

Detectable (diagnostic) and therapeutic agents that may be attached to a polypeptide include, but are not limited to, toxins, other cytotoxic agents, drugs, radionuclides, chromophores, enzymes that catalyze a calorimetric or fluorometric reaction, and the like, with the particular agent being chosen according to the intended application. Among the toxins are ricin, abrin, diphtheria toxin, Pseudomonas aeruginosa exotoxin A, ribosomal inactivating proteins, mycotoxins such as trichothecenes, and derivatives and fragments (e.g., single chains) thereof. Radionuclides suitable for diagnostic use include, but are not limited to, ^{123}I, ^{131}I, ^{99m}Tc, ^{111}In, and ^{76}Br. Examples of radionuclides suitable for therapeutic use are ^{131}I, ^{211}At, ^{77}Br, ^{186}Re, ^{188}Re, ^{212}Pb, ^{212}Bi, ^{109}Pd, ^{64}Cu, and ^{67}Cu.

Such agents may be attached to the polypeptide by any suitable conventional procedure. The polypeptide comprises functional groups on amino acid side chains that can be reacted with functional groups on a desired agent to form covalent bonds, for example. Alternatively, the protein or agent may be derivatized to generate or attach a desired reactive functional group. The derivatization may involve attachment of one of the bifunctional coupling reagents available for attaching various molecules to proteins (Pierce Chemical Company, Rockford, Ill.). A number of techniques for radiolabeling

proteins are known. Radionuclide metals may be attached to polypeptides by using a suitable bifunctional chelating agent, for example.

Conjugates comprising polypeptides and a suitable diagnostic or therapeutic agent (preferably covalently linked) are thus prepared. The conjugates are administered or otherwise employed in an amount appropriate for the particular application.

Polypeptides of the invention may be used in developing treatments for any disorder mediated (directly or indirectly) by defective, or insufficient amounts of the polypeptides. Further, the polypeptides of the invention may be used in developing treatments for any disorder resulting (directly or indirectly) from an excess of the polypeptide. The polypeptides of the instant invention may be administered to a mammal afflicted with such disorders.

The polypeptides may also be employed in inhibiting a biological activity of the binding partner, in *in vitro* or *in vivo* procedures. For example, a purified 4833427G06Rik polypeptide can be used to inhibit binding of endogenous 4833427G06Rik to its cellular receptor.

Polypeptides of the invention may be administered to a mammal to treat a binding partner-mediated disorder. Such binding partner-mediated disorders include conditions caused (directly or indirectly) or exacerbated by the binding partner.

Compositions of the present invention may contain a polypeptide in any form described herein, such as native proteins, variants, derivatives, oligomers, and biologically active fragments. In particular embodiments, the composition comprises a soluble polypeptide or an oligomer comprising soluble polypeptides of the invention.

Compositions comprising an effective amount of a polypeptide of the present invention, in combination with other components such as a physiologically acceptable diluent, carrier, or excipient, are provided herein. The polypeptides can be formulated according to known methods used to prepare pharmaceutically useful compositions. They can be combined in admixture, either as the sole active material or with other known active materials suitable for a given indication, with pharmaceutically acceptable diluents (e.g., saline, Tris-HCl, acetate, and phosphate buffered solutions), preservatives (e.g., thimerosal, benzyl alcohol, parabens), emulsifiers, solubilizers, adjuvants and/or carriers. Suitable formulations for pharmaceutical compositions include those described in "Remington's Pharmaceutical Sciences", 16th ed. 1980, Mack Publishing Company, Easton, PA.

In addition, such compositions can be complexed with polyethylene glycol (PEG), metal ions, or incorporated into polymeric compounds such as polyacetic acid,

polyglycolic acid, hydrogels, dextran, and the like, or incorporated into liposomes, microemulsions, micelles, unilamellar or multilamellar vesicles, erythrocyte ghosts or spheroblasts. Such compositions will influence the physical state, solubility, stability, rate of *in vivo* release, and rate of *in vivo* clearance, and are thus chosen according to the intended application.

The compositions of the invention can be administered in any suitable manner, e.g., topically, parenterally, or by inhalation. The term "parenteral" includes injection, e.g., by subcutaneous, intravenous, or intramuscular routes, also including localized administration, e.g., at a site of disease or injury. Those of ordinary skill in the art recognize that other types of localized administration (e.g., intraarticular, intracapsular, intracarpal, intracelial, intracerebroventricular, intrasynovial, intraspinal, intraligamentus, intrameningeal, intraocular, epidural, transepithelially, and/or administration by one or more of these routes at a site near or adjacent to a site of disease or injury) are suitable for use in administering the compositions of the present invention. Sustained release from implants is also contemplated.

One skilled in the pertinent art will recognize that suitable dosages will vary, depending upon such factors as the nature of the disorder to be treated, the patient's body weight, age, and general condition, and the route of administration. Preliminary doses can be determined according to animal tests, and the scaling of dosages for human administration is performed according to art-accepted practices.

Compositions comprising polynucleotides in physiologically acceptable formulations are also contemplated. DNA may be formulated for injection, for example. Moreover, inasmuch as those of ordinary skill in the art are aware that nucleic acid compositions (including DNA) are taken up by cells and result in the expression of protein in or near the area where the nucleic acid composition was administered, the inventive nucleic acid compositions will be useful for localized administration of polypeptides encoded thereby.

Another use of the polypeptide of the present invention is as a research tool for studying the biological effects that result from the interactions of 4833427G06Rik with its binding partner, or from inhibiting these interactions, on different cell types. Polypeptides also may be employed in *in vitro* assays for detecting 4833427G06Rik, the binding partner or the interaction thereof. The inventive polypeptides will also be useful in elucidating the signaling pathways of p53 family members, and in identifying molecules that modulate various aspects of such signaling pathways. The modulators identified by studies utilizing the inventive polypeptides have utility in treating or ameliorating a wide variety of diseases and syndromes in which cell cycle regulation or apoptosis plays a role.

Antibodies that are immunoreactive with the polypeptides of the invention are provided herein. Such antibodies specifically bind to the polypeptides via the antigen-binding sites of the antibody (as opposed to non-specific binding). Thus, the polypeptides, fragments, variants, fusion proteins, etc., as set forth above may be employed as "immunogens" in producing antibodies immunoreactive therewith. More specifically, the polypeptides, fragment, variants, fusion proteins, etc. contain antigenic determinants or epitopes that elicit the formation of antibodies.

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

Thus, one aspect of the present invention relates to the antigenic epitopes of the polypeptides of the invention. Such epitopes are useful for raising antibodies, in particular monoclonal antibodies, as described in more detail below. Additionally, epitopes from the polypeptides of the invention can be used as research reagents, in assays, and to purify specific binding antibodies from substances such as polyclonal sera or supernatants from cultured hybridomas. Such epitopes or variants thereof can be produced using techniques well known in the art such as solid-phase synthesis, chemical or enzymatic cleavage of a polypeptide, or using recombinant DNA technology.

As to the antibodies that can be elicited by the epitopes of the polypeptides of the invention, whether the epitopes have been isolated or remain part of the polypeptides, both polyclonal and monoclonal antibodies may be prepared by conventional techniques. See, for example, Monoclonal Antibodies, Hybridomas: A New Dimension in Biological Analyses, Kennet et al. (eds.), Plenum Press, New York (1980); and Antibodies: A Laboratory Manual, Harlow and Land (eds.), Cold Spring Harbor Laboratory Press, Cold Spring Harbor, N.Y., (1988).

Hybridoma cell lines that produce monoclonal antibodies specific for the polypeptides of the invention are also contemplated herein. Such hybridomas may be produced and identified by conventional techniques. One method for producing such a hybridoma cell line comprises immunizing an animal with a polypeptide; harvesting

spleen cells from the immunized animal; fusing said spleen cells to a myeloma cell line, thereby generating hybridoma cells; and identifying a hybridoma cell line that produces a monoclonal antibody that binds the polypeptide. The monoclonal antibodies may be recovered by conventional techniques.

The monoclonal antibodies of the present invention include chimeric antibodies, e.g., humanized versions of murine monoclonal antibodies. Such humanized antibodies may be prepared by known techniques and offer the advantage of reduced immunogenicity when the antibodies are administered to humans. In one embodiment, a humanized monoclonal antibody comprises the variable region of a murine antibody (or just the antigen binding site thereof) and a constant region derived from a human antibody. Alternatively, a humanized antibody fragment may comprise the antigen binding site of a murine monoclonal antibody and a variable region fragment (lacking the antigen-binding site) derived from a human antibody. Procedures for the production of chimeric and further engineered monoclonal antibodies include those described in Riechmann et al., *Nature* (1988) 332:323, Liu et al. (*Proc Natl Acad Sci USA* (1987) 84:3439, Larrick et al., *Bio/Technology* (1989) 7:934, and Winter and Harris (TIPS 14:139, May, 1993). Procedures to generate antibodies transgenically can be found in GB 2,272,440, US 5,569,825 and US 5,545,806 and related patents claiming priority therefrom, all of which are incorporated by reference herein.

Antigen-binding fragments of the antibodies, which may be produced by conventional techniques, are also encompassed by the present invention. Examples of such fragments include, but are not limited to, Fab and $F(ab')_2$ fragments. Antibody fragments and derivatives produced by genetic engineering techniques are also provided.

In one embodiment, the antibodies are specific for the polypeptides of the present invention and do not cross-react with other proteins. Screening procedures by which such antibodies may be identified are well known, and may involve immunoaffinity chromatography, for example.

The antibodies of the invention can be used in assays to detect the presence of the polypeptides or fragments of the invention, either *in vitro* or *in vivo*. The antibodies also may be employed in purifying polypeptides or fragments of the invention by immunoaffinity chromatography.

Those antibodies that additionally can block binding of the polypeptides of the invention to the binding partner may be used to inhibit a biological activity that results from such binding. Such blocking antibodies may be identified using any suitable assay procedure, such as by testing antibodies for the ability to inhibit binding of 4833427G06Rik to certain cells expressing the 4833427G06Rik receptors. Alternatively,

blocking antibodies may be identified in assays for the ability to inhibit a biological effect that results from polypeptides of the invention binding to their binding partners to target cells. Antibodies may be assayed for the ability to inhibit 4833427G06Rik, or binding partner-mediated cell lysis, for example.

Such an antibody may be employed in an *in vitro* procedure, or administered *in vivo* to inhibit a biological activity mediated by the entity that generated the antibody. Disorders caused or exacerbated (directly or indirectly) by the interaction of the polypeptides of the invention with the binding partner thus may be treated. A therapeutic method involves *in vivo* administration of a blocking antibody to a mammal in an amount effective in inhibiting a binding partner-mediated biological activity. Monoclonal antibodies are generally preferred for use in such therapeutic methods. In one embodiment, an antigen-binding antibody fragment is employed.

Antibodies may be screened for agonistic (i.e., ligand-mimicking) properties. Such antibodies, upon binding to cell surface receptor, induce biological effects (e.g., transduction of biological signals) similar to the biological effects induced when IL-1 binds to cell surface IL-1 receptors. Agonistic antibodies may be used to activate vascular endothelial cells and lymphocytes, induce local tissue destruction and fever (Janeway et al., 1996, *supra*), stimulate macrophages and vascular endothelial cells to produce IL-6, and up-regulate molecules on the surface of vascular endothelial cells.

Compositions comprising an antibody that is directed against polypeptides of the invention, and a physiologically acceptable diluent, excipient, or carrier, are provided herein. Suitable components of such compositions are as described above for compositions containing polypeptides of the invention.

Also provided herein are conjugates comprising a detectable (e.g., diagnostic) or therapeutic agent, attached to the antibody. Examples of such agents are presented above. The conjugates find use in *in vitro* or *in vivo* procedures.

The present invention also encompasses transgenic animals with altered indicator gene activity. Recombinant clones derived from the genomic sequences, e.g., containing introns, will be useful for transgenic and knockout studies, including transgenic cells, organisms, and knockout animals, and for gene therapy. (See, e.g., Goodnow (1992) "Transgenic Animals" in Roitt (ed.) Encyclopedia of Immunology, Academic Press, San Diego, Calif., pp. 1502-1504; Travis, *Science* (1992) 254:707-10; Capecchi, *Science* (1989) 244:1288-92; Robertson (ed.) (1987) "Teratocarcinomas and Embryonic Stem Cells: A Practical Approach", IRL Press, Oxford; Rosenberg, *J. Clinical Oncology* (1992) 10:180-99; Hogan, et al. (eds.) (1994) "Manipulating the Mouse Embryo: A Laboratory Manual",

2nd edition, Cold Spring Harbor Press, NY; Wei, *Ann. Rev. Pharmacol. Toxicol.* (1997) 37:119-41; and Rajewsky, et al., *J. Clin. Inves.* (1996) 98:S51-S53.)

Examples of these techniques include: 1) Insertion of reporter genes operably linked to promoter regions from an indicator gene by microinjection, retroviral infection, or other means known to those skilled in the art, into appropriate fertilized embryos in order to produce a transgenic animal (see, e.g., Hogan, *supra*); and 2) homologous recombination (see, e.g., Capecchi, *supra*; and Zimmer and Gruss, *Nature* (1989) 338:150-53) into embryonic stem cells allowing for the introduction of mutant or normal, human or animal versions of genes into the germ line of an animal. The resulting knock-out animals can express the reporter gene in response to a stimulus that would otherwise induce transcription of the indicator gene, e.g., administration of a genotoxic compound.

The technique of homologous recombination is already known in the art. It replaces substitutes an inserted gene for the native gene in the animal genome, and is thus useful for producing an animal that cannot express the original native gene but does express, for example, no receptor, an inserted mutant receptor, or an alternative form of the receptor. In the present invention, this technique results in an animal that produces a reporter gene product in response to stimulus with a genotoxic compound, instead of the native indicator gene products.

With respect to creation of transgenic animals, microinjection adds genes to the genome, but does not remove them, and so is useful for producing an animal which expresses its own and added proteins. One means available for producing a transgenic animal, for example a mouse, is as follows: Female mice are mated, and the resulting fertilized eggs are dissected from the oviducts. The eggs are stored in an appropriate medium such as M2 medium (see, e.g., Hogan, *supra*). DNA or cDNA encoding an indicator gene regulatory region or promoter operably linked to a reporter gene is purified from an appropriate vector by methods known in the art. Additional inducible promoters may be fused with the coding region of the DNA to provide an experimental means to regulate expression of the transgene. Alternatively, or in addition, additional tissue specific regulatory elements may be fused with the coding region to permit tissue-specific expression of the transgene. The DNA, in an appropriately buffered solution, is inserted into a microinjection needle, and the egg to be injected is put in a depression slide. The needle is inserted into the pronucleus of the egg, and the DNA solution is injected. The injected egg is then transferred into the oviduct of a pseudopregnant mouse (a mouse stimulated by the appropriate hormones to maintain pregnancy, but which is not actually pregnant), where it proceeds to the uterus, implants, and develops to term.

As noted above, microinjection is not the only method for inserting DNA into the egg, and is used here only for exemplary purposes.

Transgenic animals of the invention can be used to screen or test compounds for genotoxicity, with the added advantage that one may simultaneously examine the effect of any metabolites of the compound that arise.

The methods and reagents of the invention are useful for determining the potential of a compound to cause genotoxicity upon administration to an animal. The methods of the invention can be practiced, for example, using available microarray technology, or by inserting reporter genes operably linked to heterologous or endogenous promoter sequences corresponding to or derived from the indicator genes. By administering test compounds to test cells *in vitro*, one can eliminate drug candidates exhibiting unacceptable genotoxicity without requiring expensive and time-consuming *in vivo* testing.

Having the invention now generally described, the same will become better understood by reference to the specific examples, which are included herein for purpose of illustration only and are not intended to be limiting unless otherwise specified, in connection with the following figure:

Figures:

Figure 1: shows a diagram of the siRNA-mediated knock-down of Dog mRNA. siRNA-mediated knockdown of Dog1 mRNA allows myogenic cells to differentiate even after incurring DNA damage. C2C12 cells were transfected with 20 nM of the indicated *Dog1*-specific siRNA (D1-1; D1-2), control siRNA (C) or lipid only (M) for 28 hours. They were then treated with 75 μM MMS or vehicle for 24 hours, prior to washing and culture in differentiation media for 72 hours.

A) Twenty eight hours after transfection, *Dog1*-specific siRNAs decreased *Dog1* mRNA by 80-96% in C2C12 cells. Control siRNAs did not significantly decrease *Dog1* mRNA level.

B) Mock or control siRNA transfected C2C12 cells did not differentiate into myotubes after mutagen exposure. However, mutagen treated C2C12 cells that were transfected with *Dog1*-specific siRNA differentiated into myotubes.

EXAMPLES

The following preparations and examples are given to enable those skilled in the art to more clearly understand and to practice the present invention. They should not be considered as limiting the scope of the invention, but merely as being illustrative and representative thereof.

Example 1: Phenotypic Assay

Drug formulation. All compounds were purchased from Sigma-Aldrich Fine Chemicals. The drugs were dissolved in DMSO, except for pyrene which was dissolved in MeOH. The concentration of each drug used for genotoxicity testing was based upon the concentration known to induce micronuclei formation *in vitro*. Where that concentration was not known, a wide range of drug concentrations ranging from 1 nM to 5 mM was tested. For both genotoxic and non-genotoxic agents, the highest concentration tested was determined by either cellular toxicity or compound solubility (Table 1).

Genotoxicity assay. C2C12 cells (ATCC) were grown in DMEM with 20% FBS, sodium pyruvate, pen-strep-glutamine, maintaining sub-confluent condition. The differentiation assay was performed according to the method described by P.L. Puri et al., *Nature Gen* (2002) 32:585-93, in growth media further containing 1% DMSO or compound in 1% DMSO final (see Table I for compounds and concentrations). The cells were incubated for 24 hours, washed with PBS and placed into differentiation media (DMEM, 2% horse serum, sodium pyruvate and Pen-strep-glutamine), without drug or vehicle. Cells were assayed visually for differentiation at 48 and 72 hours: differentiated cells form myotubes, while blocked or delayed cells maintain a monolayer with very few myotubes. If the block is extreme, the cells begin to die after 3 days in differentiation media (e.g. treatment with etoposide or cisplatin). Drugs were titrated for cytotoxicity by assessing the cell count after a 24 hour exposure to compound, relative to vehicle.

Table I

Compound	ChemAbs ref.	Dose range (μg/ml)	Lowest effective dose (μg/ml)
DMSO	67-68-5	NA	NA
Famotidin	76824-35-6	0.5-316$^{(s)}$	NA
Pilocarpine HCl	54-71-7	1.6-100$^{(s)}$	NA
Cefoperazone (Na salt)	62893-20-3	0.2-200$^{(s)}$	NA
Clozapine	5786-21-0	0.1-250$^{(s)}$	NA
Clofibrate	637-07-0	0.5-180$^{(t)}$	NA
Benzylacetate	140-11-4	0.5-50$^{(t)}$	NA

Compound	ChemAbs ref.	Dose range (μg/ml)	Lowest effective dose (μg/ml)
Methylurea	598-50-5	0.4-40[t]	NA
Phthalic acid diester	117-87-7	0.1-100[s]	NA
Methanol	67-56-1	1-12,206[t]	NA
Propafenone HCl	54063-53-5	0.1-100[t]	NA
Mesalamine	89-57-6	0.1-74[s]	NA
Timolol maleate	26921-17-5	0.5-100[s]	NA
Tetracycline HCl	64-75-5	0.1-50[s]	NA
Levamisole HCl	16595-80-5	0.5-250[s]	NA
Terazosin HCl	63590-64-7	0.5-500[t]	NA
Prostaglandin I_2 (Na salt)	61849-14-7	0.5-55[t]	NA
Trichloroethylene	79-01-6	0.7-254[s]	NA
Urethane	51-79-6	0.03-35[t]	NA
Pyrene	129-00-0	0.1-55[t]	NA
Methanesulfonate methyl ester (MMS)	62-27-3	0.002-0.016[t]	0.002
Methanesulfonate ethyl ester (EMS)	62-50-0	100-800[t]	100
5-fluorouracil	51-21-8	0.0008-0.0032[t]	0.0008
2-nitrofluorene	602-57-8	1.5-100[s]	5.2
4-nitroquinoline N-oxide	56-57-5	0.05-0.8[t]	0.05
1-methyl-3-nitro-nitrosoguanidine (MNNG)	70-25-7	0.1-0.8[t]	0.1
Diethylstilbestrol (DES)	56-53-1	1.8-7.4[t]	1.8
Bleomycin sulfate	9041-93-4	1-8[t]	1
Mitomycin C	50-07-7	0.15-0.6[t]	0.15
Actinomycin D	50-76-0	0.00075-0.003[t]	0.00075
Doxorubicin HCl	25316-40-9	0.005-0.02[t]	0.005
Etoposide	33419-42-0	0.25-2[t]	0.5
Cisplatin	15663-27-1	0.15-0.8[t]	0.15
Vincristine sulfate	206878-2	0.002-0.012[t]	0.002
Vinblastine sulfate	143-67-9	0.0006-0.003[t]	0.0006
Amsacrine HCl	54301-15-4	0.001-0.004[t]	0.001
Griseofulvin	126-07-8	2-79[t]	14
Paclitaxel	33069-62-4	0.002-1.4[t]	0.002

[s] range limited by compound solubility
[t] range limited by compound toxicity

The genotoxic and non-genotoxic compounds were classified according to published results using the *in vitro* micronucleus formation test (W. von der Hude et al., *Mut Res* (2000) 468:137-63) or the chromosomal aberration test (S. Kalweit et al., *Mut Res* (1999) 439:183-90; B. Miller et al., *Mut Res* (1998) 410:81-116; B. Miller et al., *Mut Res* (1997) 392:45-59). The non-genotoxic compounds tested covered a wide range of chemical structures and therapeutic uses, including an anti-psychotic (clozapine), an anti-hyperlipoproteinemic (clofibrate), and an anesthetic (urethane) agent (Table 1). All 19 non-genotoxic agents, even when assayed over a wide range of concentrations, failed to block myogenic differentiation. In contrast, all 18 genotoxic drugs blocked C2C12 cell differentiation into myotubes at multiple concentrations tested. These compounds blocked differentiation at concentrations that did not cause detectable cellular cytotoxicity. The genotoxic compounds acted through a variety of different mechanisms, which included induction of breaks in double stranded DNA (bleomycin sulfate and etoposide), DNA alkylation (MMS and EMS), adduct formation (cisplatin and DES), DNA-intercalation (5-FU) and mitotic spindle formation inhibitors (Vincristine, Vinblastine and Paclitaxel). The results from this panel of compounds demonstrates that myocyte differentiation system can be used to identify genotoxic compounds.

Example 2: Genomic Assay

Gene expression analysis. After treatment with vehicle (DMSO) or compound (MMS – 0.008 μg/ml; MNNG – 4 μg/ml; cisplatin – 0.6 μg/ml; etoposide – 0.5 μg/ml; belomycin – 0.5 μg/ml; vincristine sulfate – 0.6 μg/ml) for 24 hours, C2C12 cells were washed to remove drug, changed to differentiation media to induce differentiation, and harvested at 6, 18 or 24 hours after induction. Three independent replicates were generated for each drug and time point. Sample processing was carried out according to protocols described in the Affymetrix Expression Analysis Technical Manual. Briefly, total RNA was isolated from cells by the acid guanidinium thiocyanate-phenol-chloroform extraction method (Trizol®, Invitrogen, Carlsbad, CA). Twice purified poly(A+) RNA was isolated and reverse transcribed using a T7-promoter coupled oligo(dT) primer, followed by *in vitro* transcription. The labeled samples were applied to the Affymetrix Murine Genome MOE430 set and were hybridized overnight at 45°C/60 rpm, washed using a FS450 Fluidics station, and scanned on a GS3000 scanner. The resulting image files were analyzed using Affymetrix software (Microarray Analysis Suite version 5.0).

To measure the effect of drug treatment on cellular gene expression, replicate data obtained from each drug and time point were compared with replicates for vehicle-matched controls using the Student t-test. The gene expression levels were Log transformed before applying the Student t-test. The fold change of the average expression level between the control and drug-treated cells was also calculated. A gene expression change after drug treatment was considered significant if all of the following conditions were satisfied for at least one gene and time point: First, the gene had to be expressed in either the drug-treated or vehicle-treated cells. A gene was considered expressed if the Affymetrix software determined that the gene was "present" in two out of the three replicates. This ensured that true expression changes were identified, and could be distinguished from background variability. Second, the calculated expression change for each of five tested drugs was at least 2 fold, and the calculated p-value for the expression change using the Student t-test was less than 0.01.

To further validate this experimental system, and to examine the mechanism by which these genotoxic agents inhibited myogenic differentiation, we used oligonucleotide microarrays to identify genes whose expression was altered in response to treatment with genotoxic drugs. Five of the profiled drugs were known to directly cause damage to cellular DNA. Vincristine sulfate causes genotoxicity by an indirect mechanism: it inhibits mitotic spindle formation by blocking tubulin polymerization. Consistent with having a different mechanism of action, vincristine induced a distinct pattern of gene expression changes relative to the five other drugs tested. Vinca alkaloids induced distinctly different changes in gene expression than did other tested drugs (see also U. Scherf et al., *Nature Gen* (2000) 24:236-44). Because of this, gene expression changes that were commonly induced after exposure to the five direct-acting genotoxic drugs were analyzed. Analysis of the gene expression data revealed that 86 genes had a significant change in the level of mRNA expression after treatment with the five direct-acting genotoxic drugs (the vincristine results were not used to select genes) (see Table 2). Each gene selected exhibited at least a 1.5-fold change in expression level after treatment with each of the five drugs, and the calculated p-value for each drug-induced expression change was less than 0.01. The expression of 28 genes was up-regulated after drug treatment, while that of 58 other genes was down-regulated.

Table 2: Fold change in expression in response to genotoxic compounds

Symbol	Description	BLEO	CIS	ETOP	MMS	MNNG	VINC

Symbol	Description	BLEO	CIS	ETOP	MMS	MNNG	VINC
Prelp	Proline arginine-rich end leucine-rich repeat	0.23	0.12	0.34	0.19	0.11	0.58
Sesn2	Sestrin 2	4.20	3.80	4.20	5.30	5.80	2.38
4833427G06 Rik	RIKEN cDNA	5.40	3.70	11.30	3.70	4.00	0.98
Dda3-pending	Differential display and activated by p53	5.00	3.30	4.50	3.70	3.80	2.00
Usp30	Ubiquitin specific protease 30	2.50	2.70		3.70	2.60	2.00
0610013D04 Rik	RIKEN cDNA	2.80	2.60		2.60	2.50	2.00
Slc19a2	Solute carrier family 19 (thiamine transporter), member 2	3.10	2.30	5.50	2.70	3.30	1.40
Trp53inp1	Transformation related protein, 53 inducible nuclear protein 1	3.30	2.30	5.30	2.90	3.00	1.60
D4Ertd421e	DNA segment, Chr 4, ERATO Doi 421, expressed	0.24	0.34		0.44	0.40	0.64
Shcbp1	Shc SH2-domain binding protein 1	0.28	0.38	0.25	0.37	0.44	0.52
Mki67	Antigen identified by MAb Ki67	0.27	0.44	0.29	0.31	0.34	0.43
Phex	Phosphate regulating neutral endopeptidase (X chromosome)	2.40	2.50		2.20	2.20	0.67
Tk1	Thymidine kinase 1	0.24	0.32	0.17	0.46	0.46	0.62
Mmhead	Mus musculus 15 day embryo head cDNA clone	2.50	2.10		3.00	2.50	0.95
Osbpl6	Oxysterol binding protein-like 6	2.10	2.10		2.20	2.10	1.10

Symbol	Description	BLEO	CIS	ETOP	MMS	MNNG	VINC
Mphosph1	M-phase phosphoprotein	0.23	0.50	0.47	0.27	0.38	0.37
Ephx1	Epoxide hydrolase 1 (microsomal xenobiotic hydrolase)	2.70	2.00	4.20	2.10	2.10	1.10
Top2a	Topoisomerase (DNA) II alpha	0.29	0.50	0.39	0.37	0.47	0.52
Ccng1	Cyclin G1	2.60	2.00	3.20	2.40	3.10	1.80
Plf	Proliferin	2.40	2.30		2.60	2.00	1.10
Np95	Nuclear protein 95	0.31	0.47		0.41	0.51	0.71
Rad51ap1	RAD51-associated protein 1	0.32	0.50	0.36	0.45	0.52	0.59
Nos3	Nitric oxide synthase 3, endothelial cell	2.60	2.00	5.20	1.90	2.10	1.30
2610005B21 Rik	RIKEN cDNA	0.25	0.39		0.53	0.47	0.81
Brca1	Breast cancer 1	0.37	0.50	0.53	0.47	0.53	0.51
Stk18	Serine/threonine kinase 18	0.45	0.52	0.45	0.49	0.53	0.63
Calmbp1	Calmodulin binding protein 1	0.28	0.54	0.43	0.30	0.41	0.40
Lek1	Leucine, glutamic acid, lysine family 1 protein	0.30	0.54	0.46	0.36	0.36	0.45
Smc2l1	SMC2 structural maintenance of chromosomes 2-like 1	0.37	0.48	0.31	0.49	0.54	0.75
E2f7	E2F transcription factor 7	0.34	0.35	0.24	0.55	0.53	0.63
Hmmr	Hyaluronan mediated motility receptor (RHAMM)	0.26	0.55	0.53	0.36	0.47	0.52
Nusap1	Nucleolar and spindle associated protein 1	0.32	0.51	0.40	0.48	0.55	0.56

Symbol	Description	BLEO	CIS	ETOP	MMS	MNNG	VINC
Fbxo5	f-box only protein 31	0.40	0.55	0.32	0.42	0.51	0.54
Slc19a2	Solute carrier family 19 (thiamine transporter), member 2	2.50	1.80	4.30	2.30	2.20	1.10
9030617O03 Rik	RIKEN cDNA	2.20	1.80	3.80	2.40	2.20	1.20
Ly6e	Lymphocyte antigen 6 complex, locus E	2.60	2.00	2.50	1.80	2.30	1.30
6530401L14 Rik	RIKEN cDNA	0.29	0.53	0.50	0.39	0.56	0.53
Mad3	Max dimerization protein 3	0.30	0.38		0.52	0.56	0.89
Hmgb2	High mobility group box 2	0.31	0.46		0.56	0.45	0.57
Kif11	Kinesin 11	0.30	0.57	0.31	0.43	0.53	0.46
Mad2l1	MAD2 (mitotic arrest deficient, homolog)-like 1 (yeast)	0.30	0.57	0.40	0.43	0.55	0.64
Asf1b	ASF1 anti-silencing function 1 homolog B (Saccharomyces)	0.34	0.47	0.34	0.47	0.57	0.71
Mcm3	Minichromosome maintenance deficient 3 (Saccharomyces)	0.41	0.48	0.40	0.56	0.57	0.69
MGC: 32192	Mus musculus cDNA clone MGC:32192 IMAGE:5006129	0.27	0.40	0.32	0.46	0.58	0.71
Foxm1	Forkhead box M1	0.35	0.53	0.41	0.41	0.58	0.68
Anxa8	Annexin A8	2.60	1.70	5.60	2.50	2.80	1.80
Slc35a5	Solute carrier family 35, member A5	1.70	2.90		2.60	2.50	1.30
E030024M05 Rik	RIKEN cDNA	2.10	1.70	2.70	2.00	2.00	1.20

Symbol	Description	BLEO	CIS	ETOP	MMS	MNNG	VINC
Cks2	CDC28 protein kinase regulatory subunit 2	0.34	0.41		0.59	0.57	0.78
Cilp	Cartilage intermediate layer pro	0.59	0.38		0.57	0.49	0.77
Tacc3	Transforming, acidic coiled-coil containing protein 3	0.43	0.42		0.48	0.59	0.73
Prc1	Protein regulator of cytokinesis 1	0.45	0.58	0.42	0.44	0.59	0.63
2610509G12 Rik	RIKEN cDNA	0.49	0.50	0.46	0.55	0.59	0.55
2810417H13 Rik	RIKEN cDNA	0.25	0.36		0.48	0.60	0.96
Pbk	PDZ binding kinase	0.27	0.45	0.26	0.46	0.60	0.62
Capn6	Calpain 6	0.57	0.56	0.36	0.60	0.60	0.83
Gmnn	Geminin	0.47	0.52	0.60	0.54	0.58	0.65
Mcmd4	Minichromosome maintenance deficient 4 homolog	0.60	0.59	0.47	0.57	0.57	0.64
Ccna2	Cyclin A2	0.33	0.51	0.35	0.46	0.61	0.82
Pola1	DNA polymerase alpha 1, 180 kDa	0.46	0.61	0.55	0.37	0.36	0.51
Hmgb3	High mobility group box 3	0.51	0.61	0.38	0.45	0.46	0.67
Tagln	Transgelin (smooth muscle 22 protein)	0.51	0.61		0.47	0.55	0.84
1600013K19 Rik	RIKEN cDNA	0.48	0.60		0.62	0.62	0.98
Serpine1	Ser (or Cys) proteinase inhibitor, clade E, member 1	0.54	0.54		0.58	0.62	1.00
Wig1	Wild-type p53-induced gene 1	2.70	1.60	3.50	2.40	1.90	1.20

Symbol	Description	BLEO	CIS	ETOP	MMS	MNNG	VINC
Hgf	Hepatocyte growth factor (scatter factor)	1.60	1.60	2.20	2.20	3.20	2.00
Gnpi	Glucosamine-6-phosphate deaminase	1.70	1.70		1.60	1.90	1.60
Birc5	Baculoviral IAP repeat-containing 5	0.28	0.42		0.51	0.63	0.87
Prim1	DNA primase, p49 subunit	0.45	0.63	0.44	0.51	0.51	0.54
Rbl1	Retinoblastoma-like 1 (p107)	0.48	0.58	0.38	0.59	0.64	0.67
Pcna	Proliferating cell nuclear antigen	0.57	0.62	0.47	0.60	0.64	0.70
E130315B21 Rik	RIKEN cDNA	0.58	0.56	0.55	0.64	0.60	0.70
2610019I03 RIK	RIKEN cDNA	0.46	0.41		0.43	065	0.76

Sixty of the 86 differentially expressed genes had a known annotated function in the Gene Ontology (www.geneontology.org/) index. The annotated functions of these genes indicated that the genotoxic drugs affected pathways relevant to cellular transformation and the DNA damage response. Of interest, p53 or c-Myc are known to regulate the transcription of 26 (58%) of these genes. The p53-regulated genes (2610509G12Rik, Birc5, Brca1, Calmbp1, Ccna2, Ccng1, Dda3, Hmgb2, Hmmr, Mcm3, Mcm4, Mki67, Nos3, Np95, Nusap1, Pcna, Pola1, Prc1, Rad51ap1, Slc19a2, Smc2l1, Tk1, Top2a, Trp53inp1, Wig1, Cks2, Lmnb1, Pbk) had been identified in published literature. The c-Myc regulated genes (Brca1, Ccna2, Ccng1, Cks2, Ephx1, Fabp5, Foxm1, Hmmr, Lmnb1, Mad2l1, Mcm3, Mcm4, Mcm5, Mki67, Pcna, Rad51ap1, Serpine1, Tk1, Ugt1a1) were identified using the Myc target gene database (http://www.myccancergene.org/index.asp). Furthermore, 32 of the 53 affected genes with functional annotation to a specific biological process were known to be involved in the response to DNA damage. In particular, 14 (26%) of these genes were annotated as being involved in DNA metabolism and 21 (40%) in cell cycle control. By comparison, only 3% and 5% of all annotated mouse genes are involved in DNA metabolism or cell cycle control.

The data demonstrate that a unique pattern of gene expression alteration occurs when cells that are not terminally differentiated are exposed to agents that directly

damage DNA. This expression pattern (and subsets of the pattern) is thus useful for classifying other compounds and identifying compounds that are likely to cause direct DNA damage.

Example 3: RT-PCR Assay

An expression change in a subset of genes in this *in vitro* differentiation system could provide a universal indicator of DNA damage. Therefore, RT-PCR assays were developed for two genes whose expression was markedly increased after exposure to all of the direct-acting genotoxic agents. One was a novel gene of unknown function, 4833427G06Rik. The other was Dda3, a gene whose expression has been shown to be both p53 and p73 responsive (P.K. Lo et al., *Oncogene* (1999) 18:7765-74), and which suppressed cell growth when over-expressed (S.C. Hsieh et al., *Oncogene* (2002) 21:3050-57). The RT-PCR assays were used to analyze mRNA prepared from C2C12 cell after exposure to 12 genotoxic (Actinomycin D (ACTD), diethylstilbestrol (DES), doxorubicin HCl (DOX), methane sulfonic acid ethyl ester (EMS), bleomycin sulfate (BLEO), cisplatin (CIS), etoposide (ETOP), methane sulfonic acid methyl ester (MMS), 1-methyl-3-nitro-nitrosoguanidine (MNG), vincristine sulfate (VINC), vinblastine sulfate (VINB), and paclitaxel (PACL)) and 9 non-genotoxic compounds (dimethyl sulfoxide (DMSO), cefoperazone sodium (CER), famotidin (FAM), pilocarpine HCl (PILO), timolol maleate (TIM), benzylacetate (BA), clofibrate (CLOF), mesalamine (MES), methylurea (MU), and phthalic acid diester (PTD)). After the cells were exposed to each drug for 24 hour, they were induced to differentiate for 18 hour before RNA was prepared.

Total RNA was Dnase1-treated and converted to cDNA using Multiscribe reverse transcriptase (Applied Biosystems Inc., Foster City, CA). The cDNA SYBR green real-time quantitative PCR assay was performed using the cDNA as template, and analyzed using an ABI PRISM 7900 Sequence Detector. The following primers and probes were designed for Dda3 and the novel Riken clone using Primer Express V. 2.0 software (Applied Biosystems Inc. Foster City, CA):

Dda3-139F 5' -GATCGGGTGCCTTGAGCTT-3' (SEQ ID NO:19);

Dda3-213R 5'-ACCTCTGCCCCTCTCTTCTTCT-3' (SEQ ID NO:20);

Dda-P-167T 5'-CAACCCCACCCTACCCTGCCCTG-3' (SEQ ID NO:21)

Rik-93F 5'-CAAATCAAAGGAAGTTTTATCAGAGTCA-3' (SEQ ID NO:22);

Rik-182R 5'-GTCGATACCATATGTCAATCAAATCAT-3' (SEQ ID NO:23);

Rik-P-126T 5'-CCAAGGCTTTGACTTCTTCTTGGTCCCTT-3' (SEQ ID NO:24).

The expression of these two genes was significantly increased after exposure to each of the 12 genotoxic agents, but not after exposure to any of the 9 non-genotoxic drugs. The relative expression of 4833427G06Rik mRNA was increased by 2.3 to 13.9-fold after exposure to these genotoxic agents, and Dda3 was increased by 1.6 to 12.7 fold. The calculated p-value for the change in 4833427G06Rik mRNA expression after exposure to each drug relative to vehicle control was less than 0.001; and the p-values for the Dda3 mRNA expression change ranged from 0.04 (Paclitaxel) to 0.0001 (vinblastine). It was also important to determine if the change in expression of these two genes was relatively constant during the period after genotoxic compound exposure. To do this, the time course during which the expression of these two genes was elevated in differentiating C2C12 cells after exposure to genotoxic compounds was assessed. RT-PCR assays were performed on RNA samples obtained 6, 18 and 24 hours after induction of cellular differentiation after compound exposure. The expression of both genes was consistently elevated during the 6 to 24 hour period of differentiation induction after genotoxin exposure. It was surprising that vinblastine caused a much larger increase in expression of these indicator genes than did vincristine. Although vincristine and vinblastine are structurally similar Vinca alkaloids, and both act through inhibition of microtubule formation, they have a different clinical spectrum of activity (B.A. Chabner et al., "Goodman and Gilman's The Pharmacological Basis of Therapeutics" (J.G. Hardman and L.E. Limbard, Eds., McGraw-Hill, NH, 2001) chapter 52). Vincristine is used in treating pediatric leukemia and solid tumors, and is frequently used in adult lymphoma treatment. Vinblastine is used primarily of treating testicular carcinomas and lymphomas, and as second line therapy of various solid tumors.

To identify the Gene Ontology (GO) terms that were significantly enriched among the set of genes whose expression was affected by genotoxic drugs, we collected all of the annotated GO terms for each gene. For each term used in the GO annotation, the number of differentially expressed genes annotated with that term, or any subsidiary terms, was counted. The proportion of the differentially expressed genes with each GO annotation was compared with the proportion of the total number of mouse genes annotated with that GO term. This process enabled the GO terms that were enriched among the differentially expressed genes to be identified. Among the 53 genes with Genome Ontology annotation for biological processes, 32 were involved in the cellular response to DNA damage or regulation of the cell cycle.

Example 4: RNAi experiments.

The following siRNAs against Dog1 (4833427G06RIK) were designed using the SMARTPOOL (Dharmacon);

Dog1-2 is a pool of the following sequences:

Dog1-4; GAAAGGAUCUCGAAAGAACUU (SEQ. ID NO: 25);

Dog1-5;GAAGAGAGAGCAAAGUAUCUU (SEQ. ID NO: 26);

Dog1-6; GCGGAACUCUAAAGUCGUUUU (SEQ. ID NO: 27);

Dog1-7; CAAAGGAAGUUUUAUCAGAUU (SEQ. ID NO: 28);

or STEALTH (Invitrogen) algorithms:

Dog1-1; GGAUGCCAAUUUGGCUAAGCAGUUU (SEQ. ID NO: 29);

Dog1-3; CCUUUGAUCAGGACAAGGAUGCAAU (SEQ. ID NO: 30).

Control siRNAs were obtained from Dharmacon:

Control-1; CCCUAUUCUCCUUCUUCGCTT (firefly luciferase control) (SEQ. ID NO: 31);

Control-2; RISC-free proprietary sequence

The four SMARTPOOL oligos were used as a pool (Dog1-2). Control siRNAs, including the siCONTROL RISC-free RNA with a proprietary sequence and firefly luciferase control were obtained from Dharmacon. C2C12 cells were transfected in solution (M. Amarzguioui, *Biotechniques* (2004) 36: 766-768). with Optimem medium (Invitrogen) containing the siRNA at concentrations ranging from 10 to 80 nM for 5 hours and Lipofectamine 2000 (Invitrogen) at 2 ul lipid/well (12 well plate). The culture media was then changed to growth media without antibiotics. At 28 hours post-transfection, the culture media was changed to growth media plus antibiotics and vehicle or 75 μM MMS. After an additional 24 hours of incubation, the cells were washed, and the media was changed to differentiation media. The formation of myotubes was observed over the next 72 hours. The level of gene knockdown was quantitated by RT-PCR analysis at 28 hours post-transfection.

The effect of RNAi-mediated knockdown of *Dog1* mRNA on C2C12 differentiation after mutagen-induced DNA damage was analyzed. To ensure that a biologic effect was specifically caused by a decrease in the targeted gene, 3 different *Dog1*-specific siRNAs were utilized in these experiments. In addition, these siRNAs were designed using two different algorithms and obtained from two different companies. Analysis of *Dog1* mRNA in these cells 28 hours after transfection revealed that each Dog1-specific siRNA reduced the amount of *Dog1* mRNA by 80 to 96% relative to control (Figure 1A). In contrast, control siRNAs did not significantly decrease *Dog1* mRNA. C2C12 cell differentiation into myotubes was completely inhibited after genotoxin exposure (Figure 1B). Neither mock transfection nor transfection with 2 different control siRNAs at 80 nM concentration could overcome the mutagen-induced blockade of C2C12 differentiation into myotubes (Figure 1B). In contrast, transfection with each of the three Dog1-specific siRNAs at 20 nM enabled myocyte differentiation to proceed after mutagen exposure (Figure 1B). Therefore, a specific reduction in *Dog1* mRNA enabled C2C12 cells to undergo myogenic differentiation in the presence of damaged DNA.

While the present invention has been described with reference to the specific embodiments thereof, it should be understood by those skilled in the art that various changes may be made and equivalents may be substituted without departing from the true spirit and scope of the invention. In addition, many modifications may be made to adapt a particular situation, material, composition of matter, process, process step or steps, to the objective spirit and scope of the present invention. All such modifications are intended to be within the scope of the claims appended hereto.

CLAIMS:

1. A method for determining the genotoxicity of a test compound, said method comprising:

(a) contacting a viable test cell with said test compound;

(b) determining the change in expression level of an indicator gene selected from the group consisting of Prelp (Proline arginine-rich end leucine-rich repeat); Sesn2 (Sestrin 2); 4833427G06 Rik (RIKEN cDNA); Dda3 (Differential display and activated by p53); Usp30 (Ubiquitin specific protease 30); 0610013D04 Rik (RIKEN cDNA); Slc19a2 (Solute carrier family 19 (thiamine transporter), member 2); Trp53inp1 (Transformation related protein 53, inducible nuclear protein 1); D4Ertd421e (DNA segment, Chr 4, ERATO Doi 421, expressed); Shcbp1 (Shc SH2-domain binding protein 1); Mki67 (Antigen identified by MAb Ki67); Phex (Phosphate regulating neutral endo-peptidase (X chromosome)); Tk1 (Thymidine kinase 1); Mmhead (Mus musculus 15 day embryo head cDNA clone); Osbpl6 (Oxysterol binding protein-like 6); Mphosph1 (M-phase phosphoprotein); Ephx1 (Epoxide hydrolase 1 (microsomal xenobiotic hydrolase)); Top2a (Topoisomerase (DNA) II alpha); Ccng1 (Cyclin G1); Plf (Proliferin); Np95 (Nuclear protein 95); Rad51ap1 (RAD51-associated protein 1); Nos3 (Nitric oxide synthase 3, endothelial cell); 2610005B21 Rik (RIKEN cDNA); Brca1 (Breast cancer 1); Stk18 (Serine/threonine kinase 18); Calmbp1 (Calmodulin binding protein 1); Lek1 (Leucine, glutamic acid, lysine family 1 protein); Smc2l1 (SMC2 structural maintenance of chromosomes 2-like 1); E2f7 (E2F transcription factor 7); Hmmr (Hyaluronan mediated motility receptor (RHAMM)); Nusap1 (Nucleolar and spindle associated protein 1); Fbxo5 (f-box only protein 31); Slc19a2 (Solute carrier family 19 (thiamine transporter), member 2); 9030617O03 Rik (RIKEN cDNA); Ly6e (Lymphocyte antigen 6 complex, locus E); 6530401L14 Rik (RIKEN cDNA); Mad3 (Max dimerization protein 3); Hmgb2 (High mobility group box 2); Kif11 (Kinesin 11); Mad2l1 (MAD2 (mitotic arrest deficient, homolog)-like 1 (yeast)); Asf1b (ASF1 anti-silencing function 1 homolog B (Saccharomyces)); Mcm3 (Minichromosome maintenance deficient 3 (Saccharomyces)); MGC: 32192 (Mus musculus cDNA clone MGC:32192 IMAGE:5006129); Foxm1 (Forkhead box M1); Anxa8 (Annexin A8); Slc35a5 (Solute carrier family 35, member A5); E030024M05 Rik (RIKEN cDNA); Cks2 (CDC28 protein kinase regulatory

subunit 2); Cilp (Cartilage intermediate layer pro); Tacc3 (Transforming, acidic coiled-coil containing protein 3); Prc1 (Protein regulator of cytokinesis 1); 2610509G12 Rik (RIKEN cDNA); 2810417H13 Rik (RIKEN cDNA); Pbk (PDZ binding kinase); Capn6 (Calpain 6); Gmnn (Geminin); Mcmd4 (Minichromosome maintenance deficient 4 homolog); Ccna2 (Cyclin A2); Pola1 (DNA polymerase alpha 1, 180 kDa); Hmgb3 (High mobility group box 3); Tagln (Transgelin (smooth muscle 22 protein)); 1600013K19 Rik (RIKEN cDNA); Serpine1 (Ser (or Cys) proteinase inhibitor, clade E, member 1); Wig1 (Wild-type p53-induced gene 1); Hgf (Hepatocyte growth factor (scatter factor)); Gnpi (Glucosamine-6-phosphate deaminase); Birc5 (Baculoviral IAP repeat-containing 5); Prim1 (DNA primase, p49 subunit); Rbl1 (Retinoblastoma-like 1 (p107)); Pcna (Proliferating cell nuclear antigen); E130315B21 Rik (RIKEN cDNA); 2610019I03 RIK (RIKEN cDNA);

wherein an increase in expression of at least 1.5-fold indicates that said test compound exhibits genotoxicity.

2. The method of claim 1, wherein said indicator gene is selected from the group consisting of 4833427G06Rik and Dda3.

3. The method of claim 1 or 2, wherein said test cell comprises a myoblast cell.

4. The method of claim 1 or 2, wherein said test cell is selected from mouse, rat, zebrafish, human, chimpanzee, and chicken blast cells.

5. The method of any one of the claims 1 to 4, wherein determining the change in expression level comprises measuring the amount of mRNA produced using RT-PCR.

6. The method of any one of the claims 1 to 4, wherein determining the change in expression level comprises measuring the increase in signal produced by increased expression of a label.

7. A method, a kit, a polynucleotide, a polypeptide, a microarray, an antibody or a transgenic non-human mammal as described hereinbefore

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