US 20110263675A1

(19) United States

(12) Patent Application Publication

Federov et al.

(10) Pub. No.: US 2011/0263675 A1

(43) Pub. Date: Oct. 27, 2011

(54) **METHODS OF MODULATING MESENCHYMAL STEM CELL DIFFERENTIATION**

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(21) Appl. No.: **12/672,881**

(22) PCT Filed: **Aug. 7, 2008**

(86) PCT No.: **PCT/US08/72491**

§ 371 (c)(1), (2), (4) Date: **May 12, 2011**

Related U.S. Application Data

(60) Provisional application No. 61/035,253, filed on Mar. 10, 2008, provisional application No. 61/034,926, filed on Mar. 7, 2008, provisional application No. 60/954,963, filed on Aug. 9, 2007.

Publication Classification

(51) **Int. Cl.**

A61K 31/713	(2006.01)
A61K 31/7088	(2006.01)
A61P 19/08	(2006.01)
C12N 5/0775	(2010.01)

(52) **U.S. Cl.** ..... **514/44 A**; 435/377

(57) **ABSTRACT**

The present disclosure includes compositions and methods for modulating the differentiation of cells having osteogenic differentiation potential (such as mesenchymal stem cells (MSCs)) towards the osteogenic fate, and for obtaining diagnostic and prognostic information relating to diseases and disorders characterized by defects in osteogenic differentiation. The compositions include miRNAs, rm'RNA mimics, miRNA inhibitors, and siRNAs.

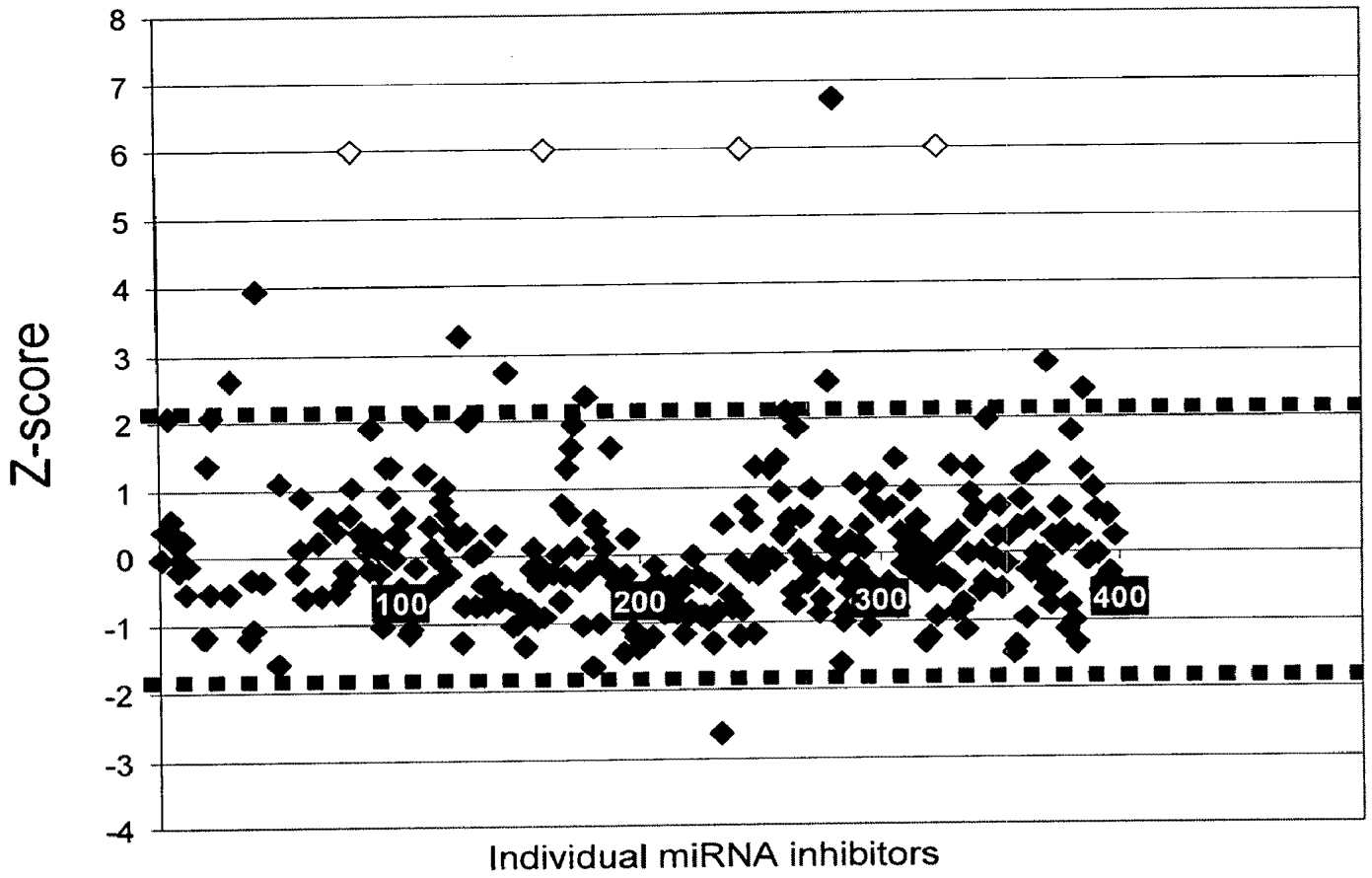

Z-score
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
100
200
300
400
Individual miRNA inhibitors

FIG. 1

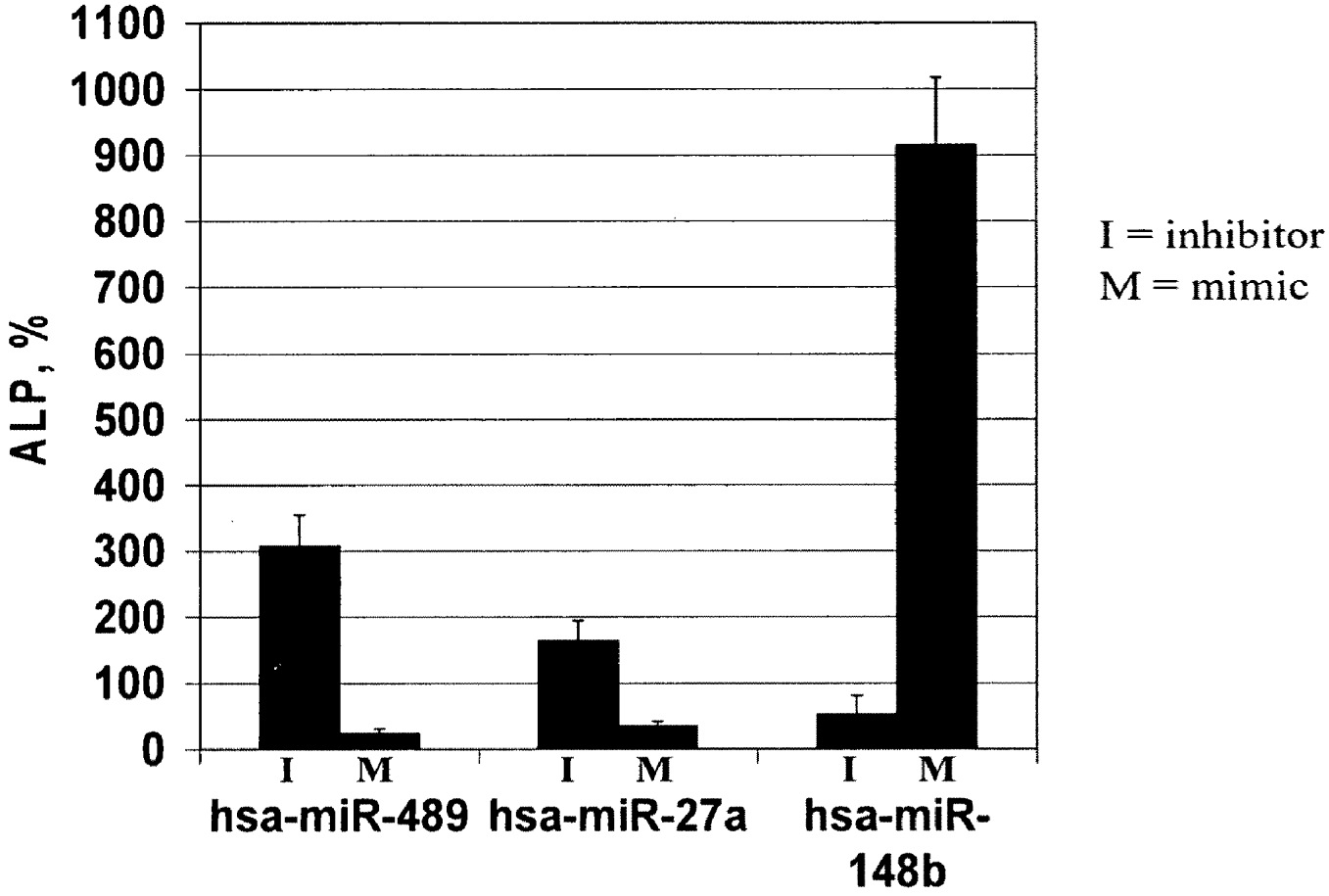

1100
1000
900
800
700
600
500
400
300
200
100
0
ALP, %
I M
I M
I M
hsa-miR-489
hsa-miR-27a
hsa-miR-148b
I = inhibitor
M = mimic

FIG. 2A

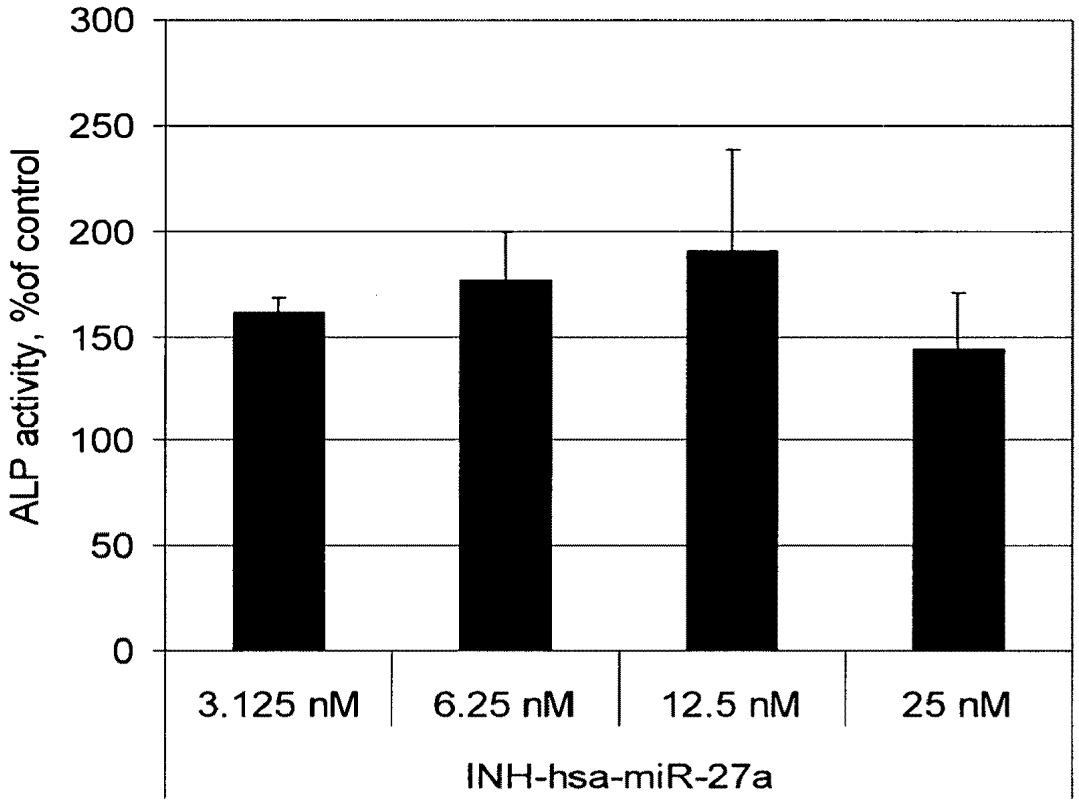

300
250
200
150
100
50
0
ALP activity, %of control
3.125 nM
6.25 nM
12.5 nM
25 nM
INH-hsa-miR-27a

FIG. 2B

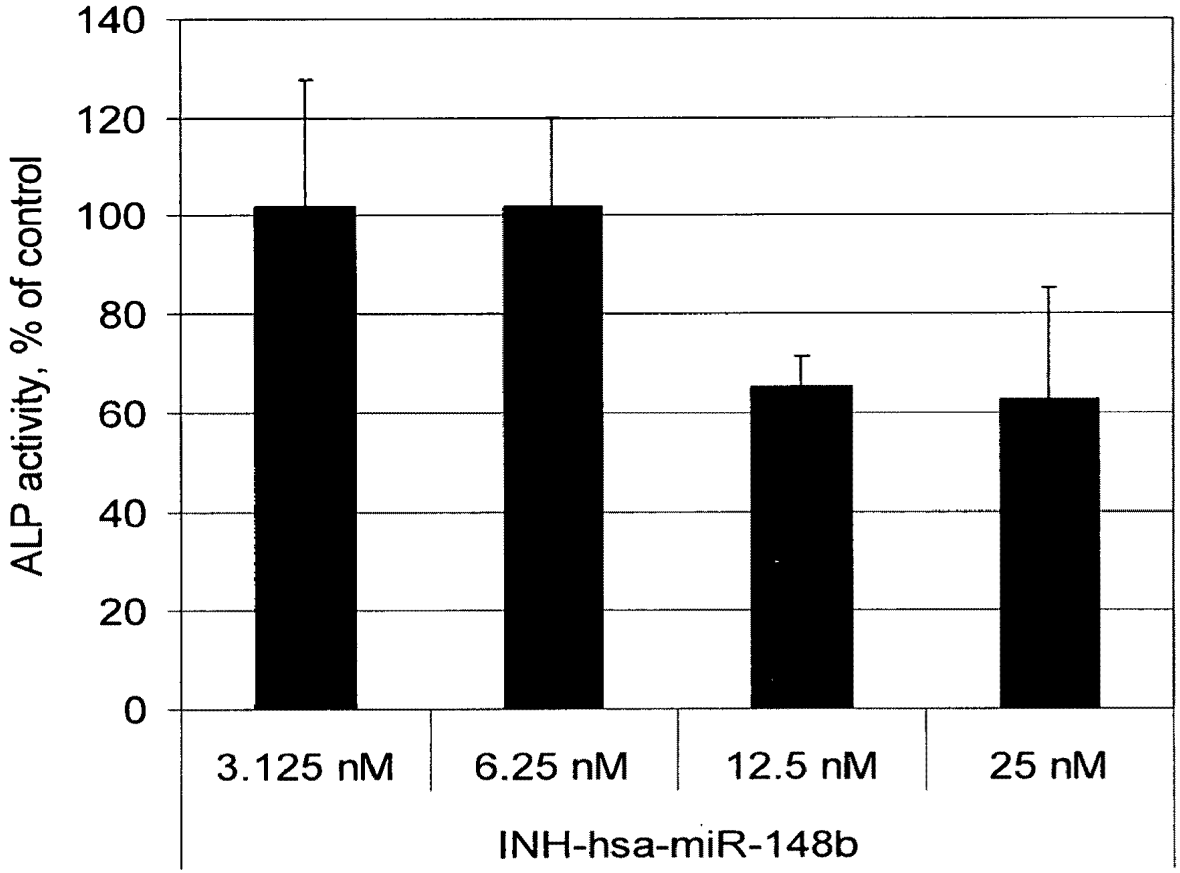

140
120
100
80
60
40
20
0
ALP activity, % of control
3.125 nM
6.25 nM
12.5 nM
25 nM
INH-hsa-miR-148b

FIG. 2C

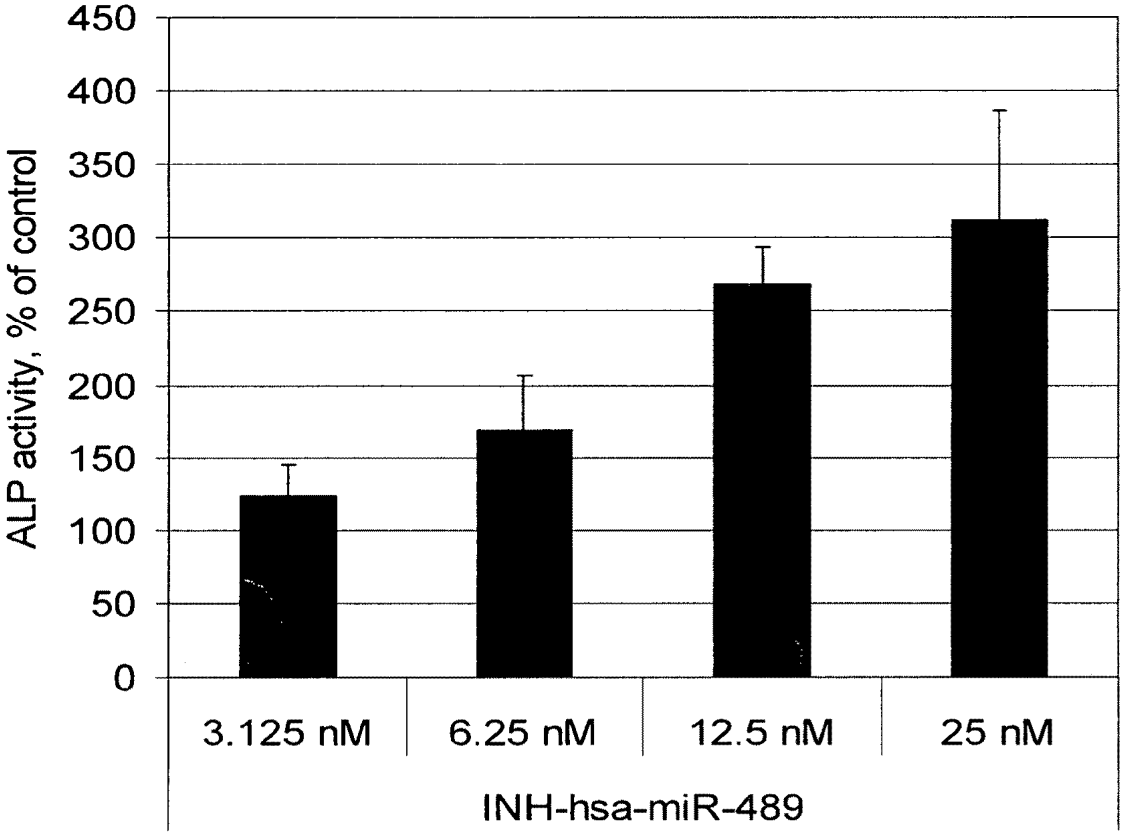

450
400
350
300
250
200
150
100
50
0
ALP activity, % of control
3.125 nM
6.25 nM
12.5 nM
25 nM
INH-hsa-miR-489

FIG. 2D

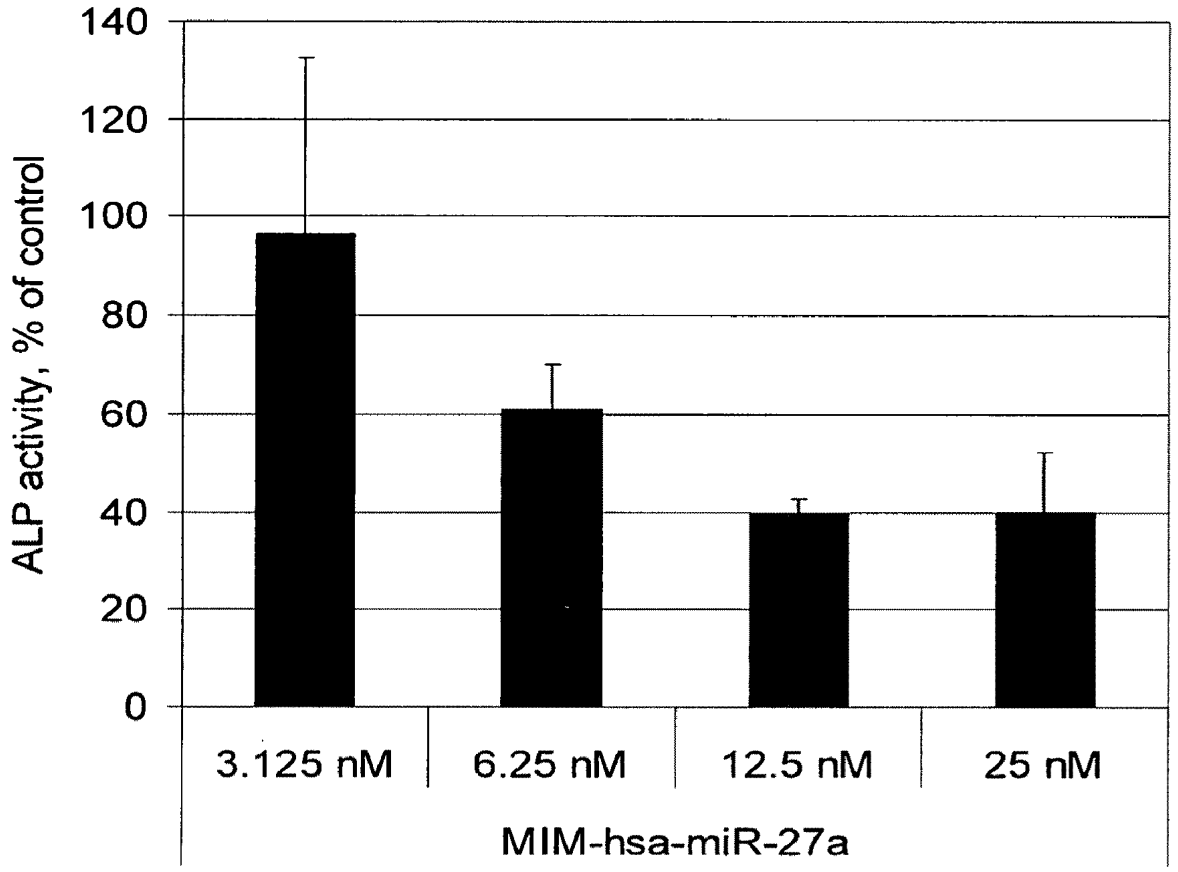

140
120
100
80
60
40
20
0
ALP activity, % of control
3.125 nM
6.25 nM
12.5 nM
25 nM
MIM-hsa-miR-27a

FIG. 2E

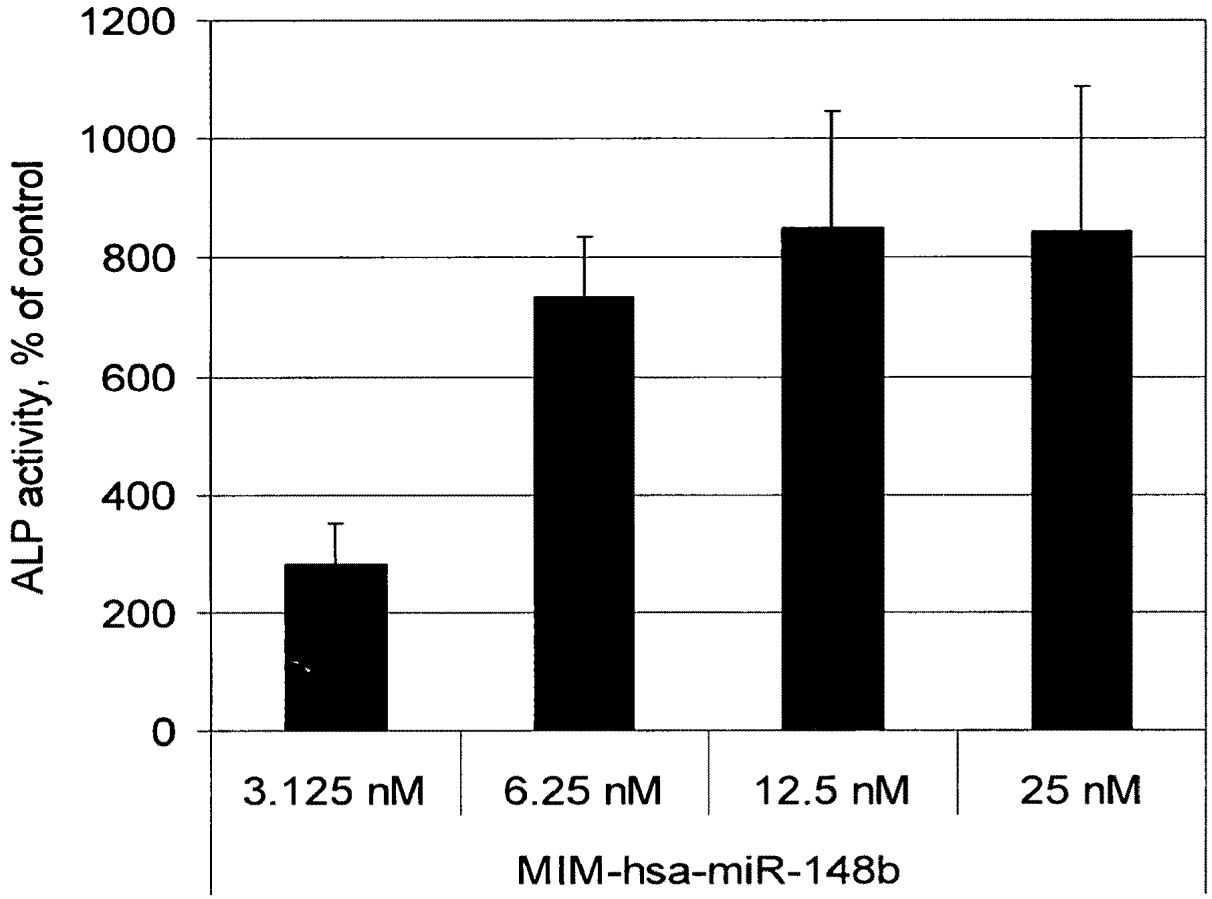

1200
1000
800
600
400
200
0
ALP activity, % of control
3.125 nM
6.25 nM
12.5 nM
25 nM
MIM-hsa-miR-148b

FIG. 2F

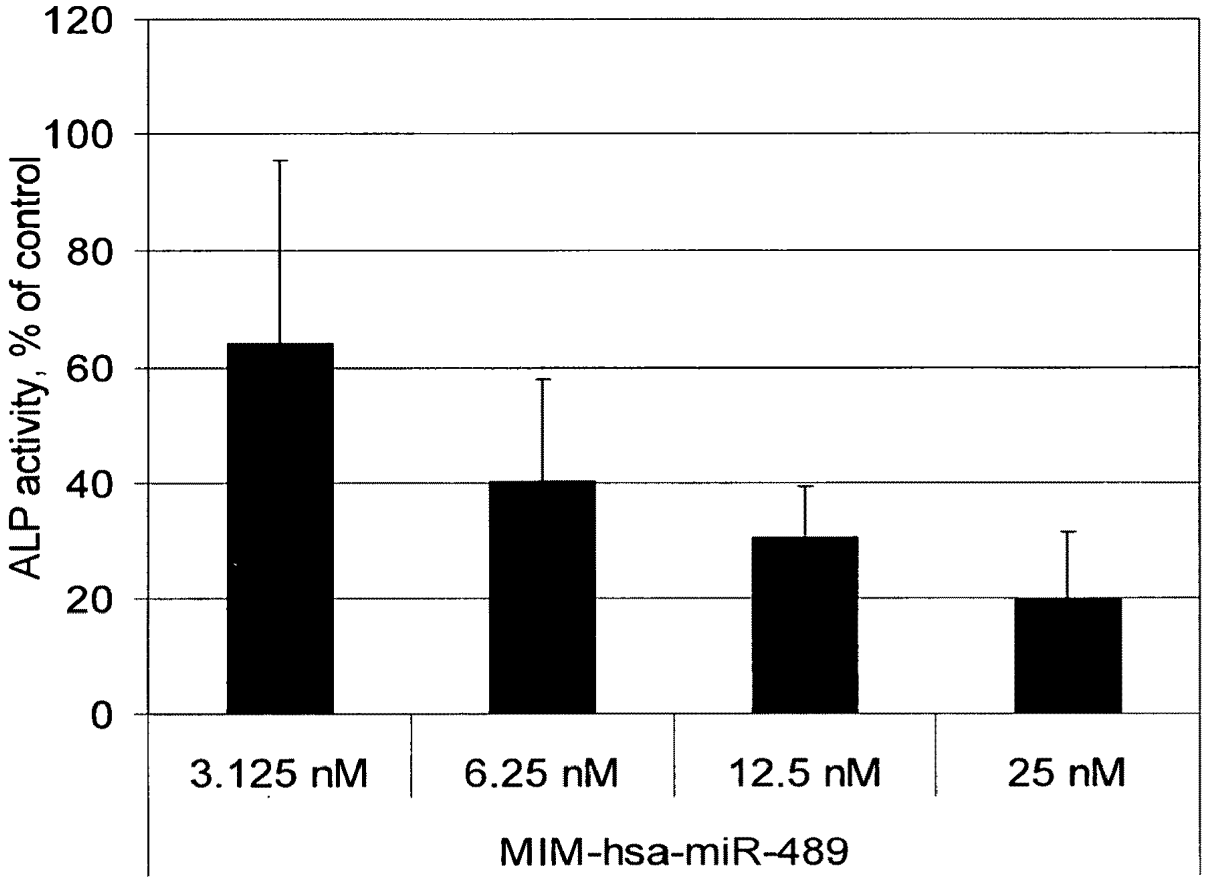

120
100
80
60
40
20
0
ALP activity, % of control
3.125 nM
6.25 nM
12.5 nM
25 nM
MIM-hsa-miR-489

FIG. 2G

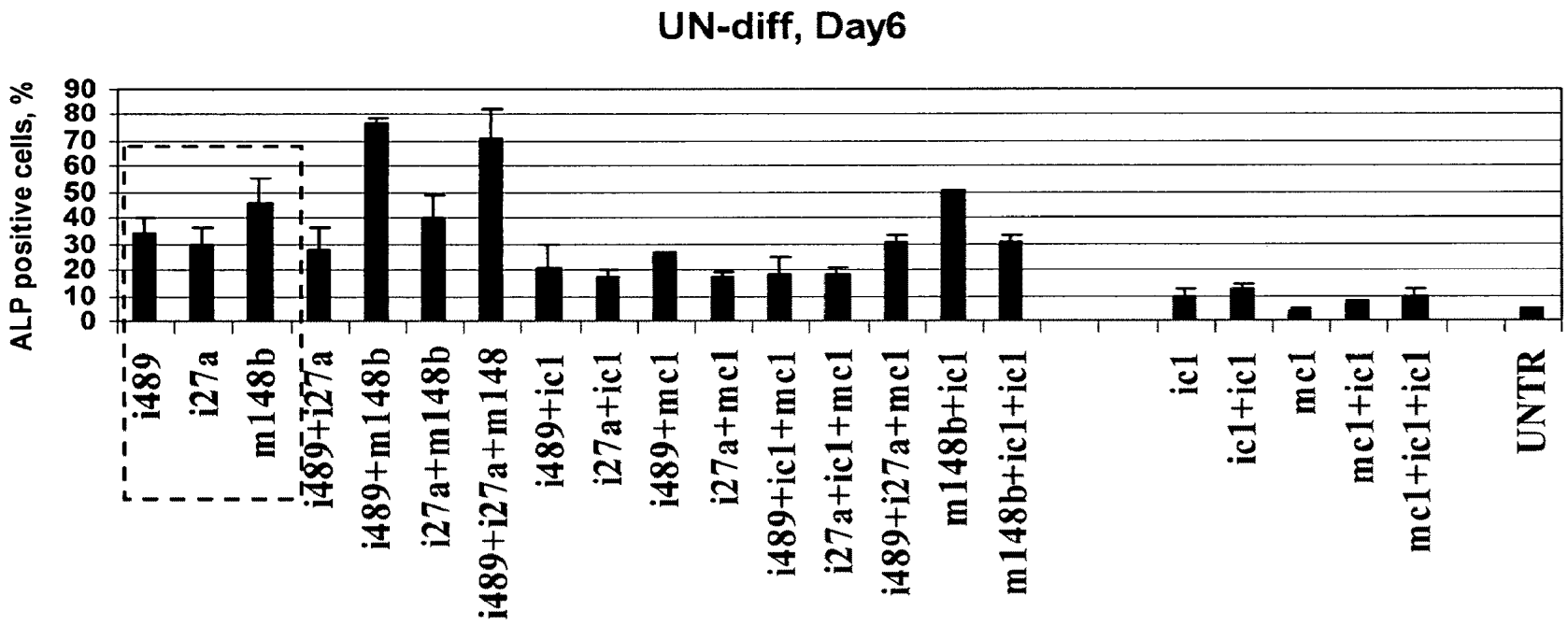

UN-diff, Day6
ALP positive cells, %
90
80
70
60
50
40
30
20
10
0
i489
i27a
m148b
i489+i27a
i489+m148b
i27a+m148b
i489+i27a+m148
i489+ic1
i27a+ic1
i489+mc1
i27a+mc1
i489+ic1+mc1
i27a+ic1+mc1
i489+i27a+mc1
m148b+ic1
m148b+ic1+ic1
ic1
ic1+ic1
mc1
mc1+ic1
mc1+ic1+ic1
UNTR

FIG. 3A

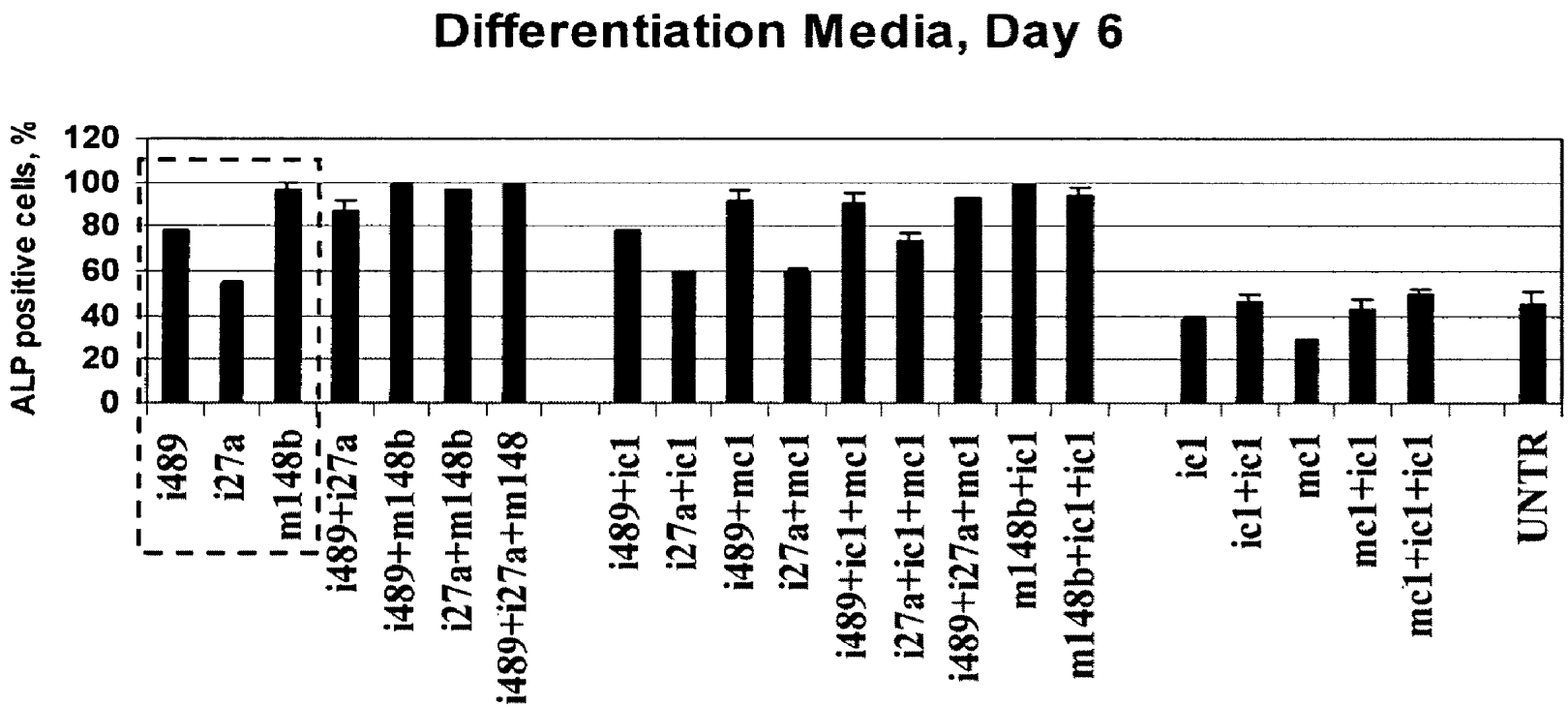

Differentiation Media, Day 6
ALP positive cells, %
120
100
80
60
40
20
0
i489
i27a
m148b
i489+i27a
i489+m148b
i27a+m148b
i489+i27a+m148
i489+ic1
i27a+ic1
i489+mc1
i27a+mc1
i489+ic1+mc1
i27a+ic1+mc1
i489+i27a+mc1
m148b+ic1
m148b+ic1+ic1
ic1
ic1+ic1
mc1
mc1+ic1
mc1+ic1+ic1
UNTR

FIG. 3B

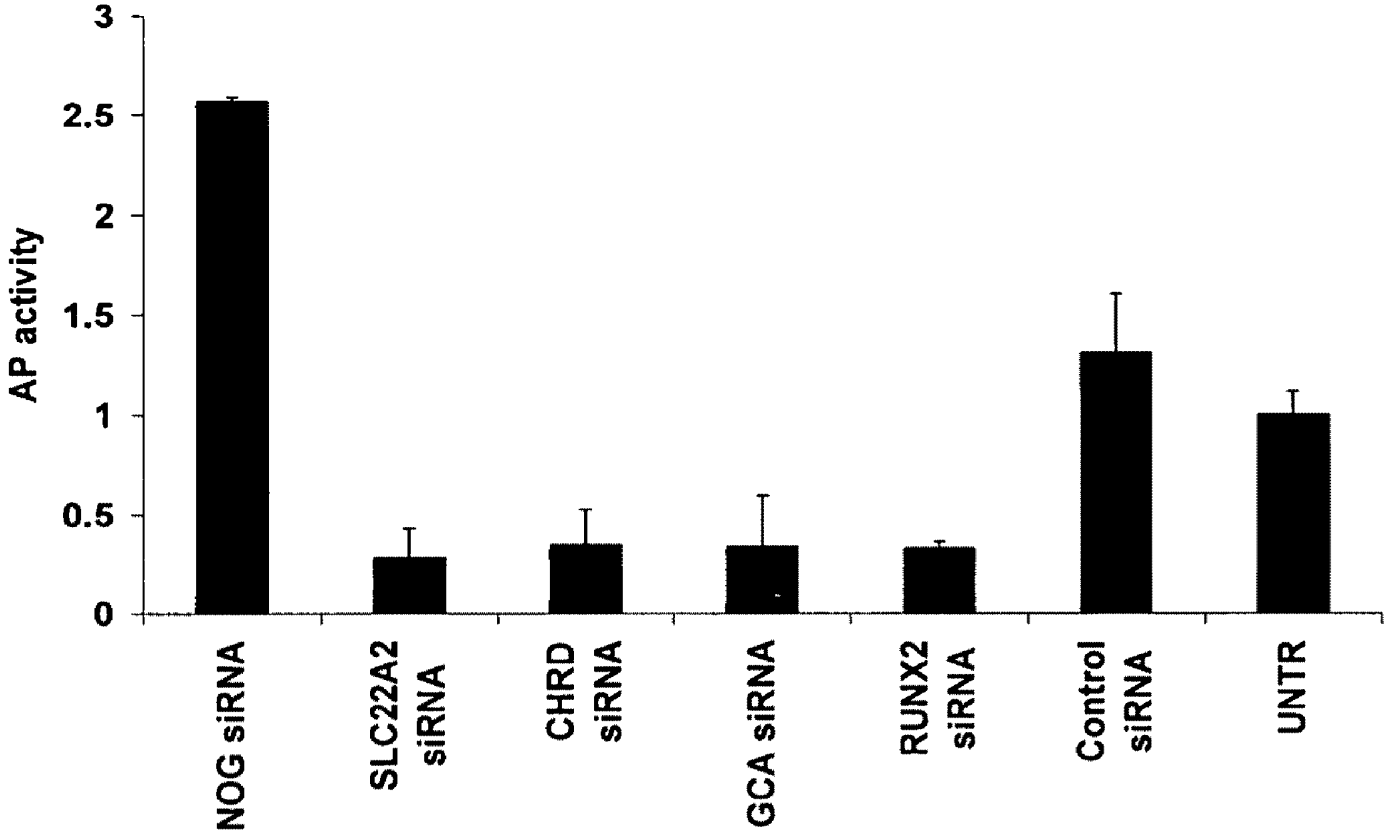

AP activity
3
2.5
2
1.5
1
0.5
0
NOG siRNA
SLC22A2 siRNA
CHRD siRNA
GCA siRNA
RUNX2 siRNA
Control siRNA
UNTR

FIG. 4

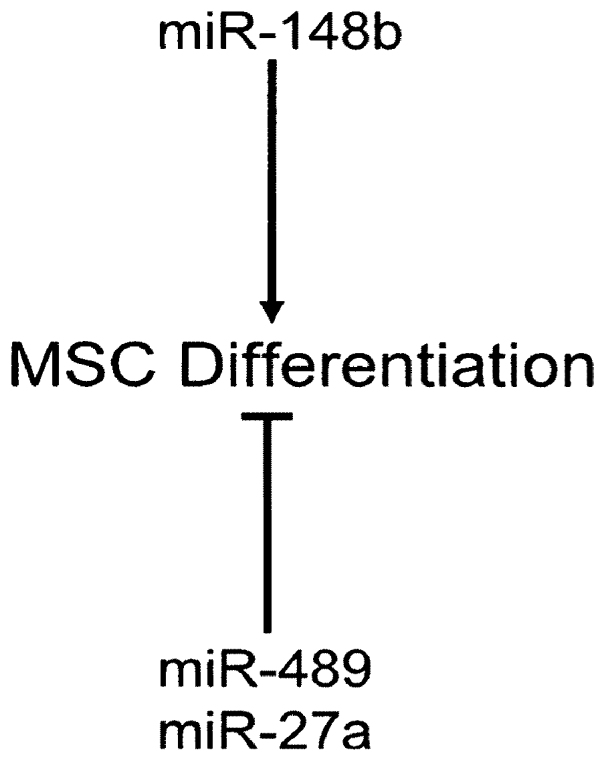


FIG. 5A

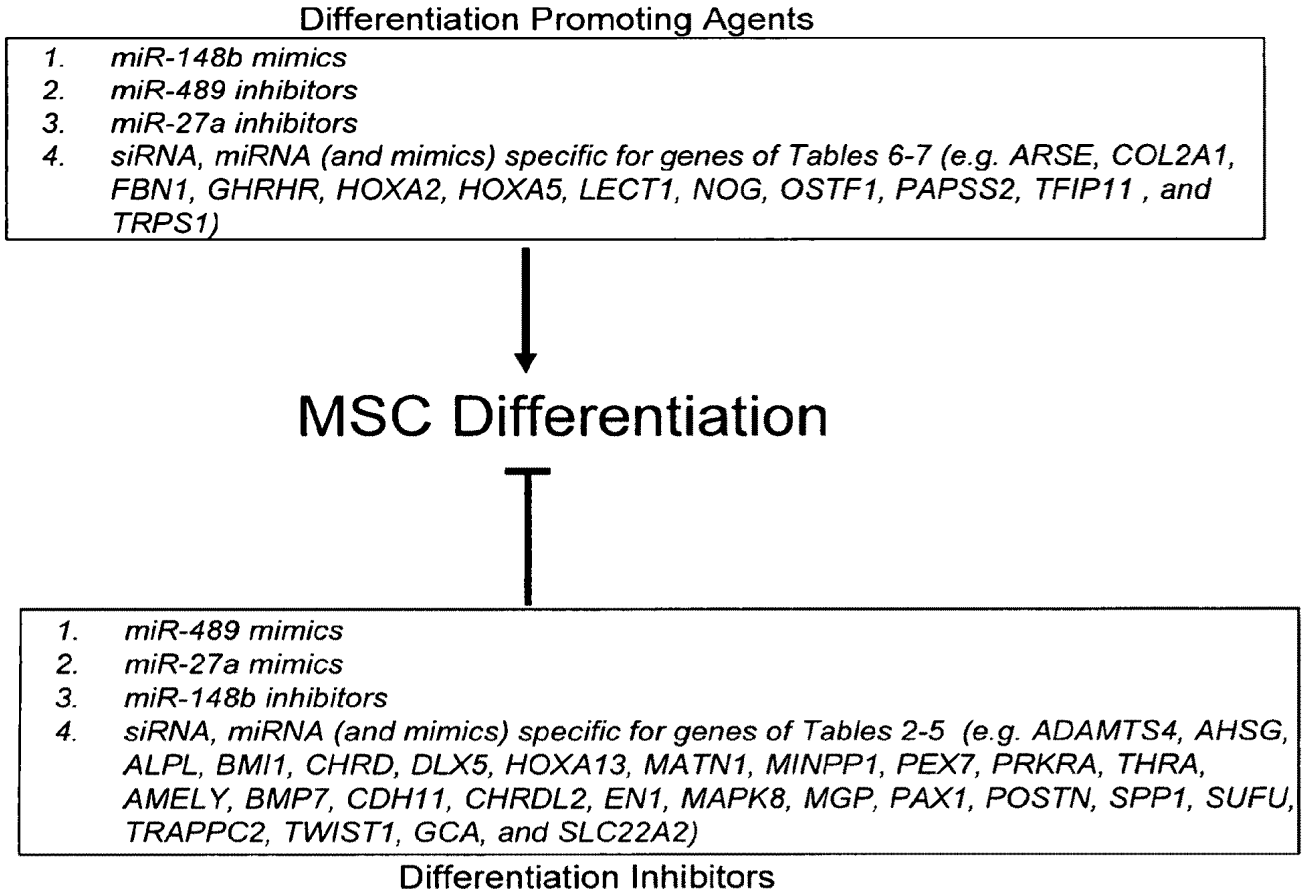

Differentiation Promoting Agents
1. miR-148b mimics
2. miR-489 inhibitors
3. miR-27a inhibitors
4. siRNA, miRNA (and mimics) specific for genes of Tables 6-7 (e.g. ARSE, COL2A1, FBN1, GHRHR, HOXA2, HOXA5, LECT1, NOG, OSTF1, PAPSS2, TFIP11 , and TRPS1)
MSC Differentiation
1. miR-489 mimics
2. miR-27a mimics
3. miR-148b inhibitors
4. siRNA, miRNA (and mimics) specific for genes of Tables 2-5 (e.g. ADAMTS4, AHSG, ALPL, BMI1, CHRD, DLX5, HOXA13, MATN1, MINPP1, PEX7, PRKRA, THRA, AMELY, BMP7, CDH11, CHRDL2, EN1, MAPK8, MGP, PAX1, POSTN, SPP1, SUFU, TRAPPC2, TWIST1, GCA, and SLC22A2)
Differentiation Inhibitors

FIG. 5B

METHODS OF MODULATING MESENCHYMAL STEM CELL DIFFERENTIATION

RELATED APPLICATION INFORMATION

[0001] This application is being filed as a PCT International Patent Application in the name of Dharmacon, Inc., a U.S. national corporation, applicant for the designation of all countries except the U.S., and Yuriy FEDEROV, a citizen of the U.S., and Devin LEAKE, a citizen of the U.S., applicants for the designation of the U.S. only and claims priority to U.S. Provisional Patent Application Ser. No. 60/954,963, filed Aug. 9, 2007, U.S. Provisional Patent Application Ser. No. 61/034,926, filed Mar. 7, 2008, and also U.S. Provisional Patent Application Ser. No. 61/035,253, filed Mar. 10, 2008. The disclosures of each prior application are incorporated herein by reference in their entirety.

FIELD OF THE DISCLOSURE

[0002] The present disclosure relates to the field of mesenchymal stem cell (MSC) differentiation. In particular, the disclosure provides a method of directing MSCs (and other cell type having osteogenic potential) toward osteogenic differentiation, or inhibiting MSCs (and other cell type having osteogenic potential) from osteogenic differentiation, using microRNA (miRNA) inhibitors, mimics, and siRNA.

BACKGROUND

[0003] Mesenchymal stem cells (MSCs) are capable of differentiating into a wide range of cell types including those associated with the bone development and maintenance (osteoblasts, osteocytes), cartilage, tendons, muscle, adipose, and more. The pluripotent nature of MSCs makes them a potentially valuable tool in therapeutics, particularly in the fields of disease (e.g. osteogenesis imperfecta), tissue repair and regeneration.

[0004] The molecular mechanisms underlying MSC differentiation are poorly understood. Microarray profiling studies have clearly identified genomic profiles that distinguish mother and daughter cell lineages, yet the triggers that orchestrate these processes have not been identified.

[0005] RNA interference (RNAi) is a near-ubiquitous pathway involved in post-transcriptional gene modulation. A key effector molecule of RNAi is the microRNA (miRNA or miR). These small, non-coding RNAs are transcribed as primary miRNAs (pri-miRNA) and processed in the nucleus by Drosha (a Type III ribonuclease) to generate short hairpin structures referred to as pre-miRNAs. The resulting molecules are transported to the cytoplasm and processed by a second nuclease (Dicer) before being incorporated into the RNA Induced Silencing Complex (RISC). Interaction between the mature miRNA-RISC complex and messenger RNA (mRNA), particularly between the seed region of the miRNA guide strand (nucleotides 2-7) and regions of the 3' UTR of the mRNA, leads to gene knockdown by transcript cleavage and/or translation attenuation.

SUMMARY

[0006] In one aspect, the disclosure provides a method of promoting mesenchymal stem cell (MSC) differentiation towards the osteogenic cell fate. The method comprises introducing into a MSC an effective amount of a composition comprising at least one differentiation promoting agent selected from the group consisting of inhibitors of miR-489, inhibitors of miR-27a, mimics of miR-148b, and siRNAs specific for genes from Tables 6-7.

[0007] In another aspect, the disclosure provides a method of inhibiting mesenchymal stem cell (MSC) differentiation towards the osteogenic cell fate. The method comprises introducing into a MSC an effective amount of a composition comprising at least one differentiation inhibitor selected from the group consisting of mimics of miR-489, mimics of miR-27a, siRNA specific for genes from Tables 2-5, and inhibitors of miR-148b.

[0008] In another aspect, the disclosure provides a pharmaceutical composition comprising at least one MSC differentiation promoting agent selected from the group consisting of inhibitors of miR-489, inhibitor of miR-27a, siRNAs specific for genes from Tables 6-7, mimics of miR-148b, and further comprising at least one pharmaceutically acceptable excipient.

[0009] In another aspect, the disclosure provides a pharmaceutical composition comprising at least one MSC differentiation inhibitor selected from the group consisting of mimics of miR-489, mimics of miR-27a, siRNAs specific for genes from Tables 2-5, and inhibitors of miR-148b, and further comprising at least one pharmaceutically acceptable excipient.

[0010] In another aspect, the disclosure discloses the use of at least one of an inhibitor of miR-489, an inhibitor of miR-27a, a mimic of miR-148b, or a siRNA specific for a gene from Tables 6-7 in the manufacture of a medicament for promoting mesenchymal stem cell (MSC) differentiation towards the osteogenic cell fate.

[0011] In another aspect, the disclosure discloses the use of at least one of a mimic of miR-489, a mimic of miR-27a, a siRNA specific for a gene from Tables 2-5, or an inhibitor of miR-148b in the manufacture of a medicament for inhibiting mesenchymal stem cell (MSC) differentiation toward the osteogenic cell fate.

[0012] In another aspect, the disclosure provides a method for treating an individual suffering from a disease characterized by a decreased degree of mesenchymal stem cell (MSC) differentiation relative to a normal individual. The method comprises administering to an individual in need thereof a pharmaceutically effective amount of a composition comprising at least one differentiation promoting agent selected from the group consisting of inhibitors of miR-489, inhibitors of miR-27a, mimics of miR-148b, and siRNAs specific for genes from Tables 6-7.

[0013] In another aspect, the disclosure provides a method for treating an individual suffering from a disease characterized by an increased degree of mesenchymal stem cell (MSC) differentiation relative to a normal individual. The method comprises administering to an individual in need thereof a pharmaceutically effective amount of a composition comprising at least one differentiation inhibitor selected from the group consisting of a mimic of miR-489, a mimic of miR-27a, a siRNA specific for a gene from Tables 2-5, and an inhibitor of miR-148b.

[0014] In another aspect, the disclosure provides a method for obtaining diagnostic or prognostic information relating to a disease characterized by an abnormal degree of mesenchymal stem cell (MSC) differentiation. The method comprises 1) determining the expression level of at least one miRNA selected from the group consisting of miR-148b, miR-489, and miR-27a in an individual suspected of having the disease;

and 2) comparing the expression level of the at least one miRNA with that observed in a normal individual known to not have the disease, whereby diagnostic or prognostic information may be obtained.

[0015] In another aspect, the disclosure provides a method for obtaining diagnostic or prognostic information relating to a disease characterized by an abnormal degree of mesenchymal stem cell (MSC) differentiation. The method comprises 1) determining the expression level of at least one gene from Tables 2-7 in an individual suspected of having the disease; and 2) comparing the expression level of the at least gene with that observed in a normal individual known to not have the disease, whereby diagnostic or prognostic information may be obtained.

[0016] In another aspect, the disclosure provides an isolated mesenchymal stem cell (MSC) comprising at least one differentiation modulating agent selected from the group consisting of inhibitors of miR-489, inhibitors of miR-27a, mimics of miR-148b, siRNAs specific for genes from Tables 6-7, mimics of miR-489, mimics of miR-27a, siRNA specific for genes from Tables 2-5, and inhibitors of miR-148b.

[0017] In another aspect, the disclosure provides a method for performing a bone graft at a site in an individual in need thereof. The method comprises 1) introducing into a mesenchymal stem cell (MSC) ex vivo an effective amount of a composition comprising at least one differentiation promoting agent selected from the group consisting of inhibitors of miR-489, inhibitors of miR-27a, mimics of miR-148b, and siRNAs specific for genes from Tables 6-7; and 2) transplanting the MSC into the individual at the site.

[0018] In another aspect, the disclosure provides a method of promoting mesenchymal stem cell (MSC) differentiation towards the osteogenic cell fate. The method comprises at least partially inhibiting in a MSC the expression of a gene selected from the group consisting of ARSE, COL2A1, FBN1, GHRHR, HOXA2, HOXA5, LECT1, NOG, OSTF1, PAPSS2, TFIP11, and TRPS1 using RNA interference.

[0019] In another aspect, the disclosure provides a method of inhibiting mesenchymal stem cell (MSC) differentiation towards the osteogenic cell fate. The method comprises at least partially inhibiting in a MSC the expression of a gene selected from the group consisting of ADAMTS4, AHSG, ALPL, BMI1, CHRD, DLX5, HOXA13, MATN1, MINPP1, PEX7, PRKRA, THRA, AMELY, BMP7, CDH11, CHRD, CHRDL2, EN1, MAPK8, MGP, PAX1, POSTN, SPP1, SUFU, TRAPPC2, TWIST1, GCA, and SLC22A2 using RNA interference.

[0020] In another aspect, the disclosure provides a method for increasing osteogenesis in individual. The method comprises administering to an individual in need thereof a pharmaceutically effective amount of at least one mesenchymal stem cell (MSC) differentiation promoting agent selected from the group consisting of inhibitors of miR-489, inhibitors of miR-27a, mimics of miR-148b, and siRNAs specific for genes from Tables 6-7.

[0021] In another aspect, the disclosure provides a method of promoting differentiation towards the osteogenic cell fate of a cell having osteogenic potential. The method comprising introducing into the cell an effective amount of a composition comprising at least one differentiation promoting agent selected from the group consisting of inhibitors of miR-489, inhibitors of miR-27a, mimics of miR-148b, and siRNAs specific for genes from Tables 6-7.

[0022] In another aspect, the disclosure provides a method of inhibiting differentiation towards the osteogenic cell fate of a cell having osteogenic potential. The method comprises introducing into the cell an effective amount of a composition comprising at least one differentiation inhibitor selected from the group consisting of mimics of miR-489, mimics of miR-27a, siRNA specific for genes from Tables 2-5, and inhibitors of miR-148b.

[0023] In another aspect, the disclosure provides mimics and inhibitors of miR-148b, mimics and inhibitors of miR-489, mimics and inhibitors of miR-27a (including, but not limited to, the mimics and inhibitors of Table 1), and siRNAs specific for the genes of Tables 2-7.

[0024] Other aspects to the disclosure are provided below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] FIG. **1**. Inhibitor Screen.

[0026] Approximately 400 human miRNA inhibitors targeting human miRNAs (derived from miRbase, http://microrna.sanger.ac.uk/sequences/) were transfected into human MSC cells in differentiation media to assess the importance of various miRNAs in MSC osteogenic differentiation. Cultures that exhibited two-fold greater or lesser levels of alkaline phosphatase expression in this primary screen were identified as playing a role in MSC differentiation. X-axis represents individual miRNA inhibitors tested. Y-axis represents the z-score for each inhibitor relative to controls. Studies were performed in triplicate.

[0027] FIGS. **2**A-**2**G. Identification of miRNA Inhibitor and Mimic Pairs that Alter MSC Osteogenic Differentiation.

[0028] FIG. **2**A provides a graph showing inhibitor (I) and mimic (M) pairs that induce opposite effects in the MSC osteogenic differentiation assay. Studies were performed in differentiation media. For hsa-miR-489 and hsa-miR-27a, inhibitors increase alkaline phosphatase (AP) expression and mimics decrease AP expression (Note: 100% represents the amount of activity observed in control experiments). In contrast, an inhibitor of hsa-miR148b decreases alkaline phosphatase expression while a mimic greatly enhances AP expression. FIG. **2**B provides a graph showing that the effects of miRNA-27a inhibitors at different doses. FIG. **2**C provides a graph showing the effects of miRNA-148b inhibitors at different doses. FIG. **2**D provides a graph showing the effects of miRNA-489 inhibitors at different doses. FIG. **2**E provides a graph showing the effects of miRNA-27a mimics at different doses. FIG. **2**F provides a graph showing the effects of miRNA-148b mimics at different doses. FIG. **2**G provides a graph showing the effects of miRNA-489 mimics at different doses. Inhibitors for miR148b and miR 489 exhibit a strong dose dependency. Mimics for miR-27a, miR-148b, and miR-489 all exhibit dose dependency. All experiments were performed in triplicate.

[0029] FIGS. **3**A-**3**B. Induction of Osteocyte Differentiation from MSC can Take Place in Both Differentiation Media and Propagation Media.

[0030] FIGS. **3**A-**3**B depict graphs that show the percentage of alkaline phosphatase positive cells (Y axes) obtained using various combinations of inhibitors and mimics in the presence of differentiation media and propagation media ("UN-Diff"). The boxed regions shows the ability of miR489 and miR27a inhibitors ("i489" and "i27" respectively), as well as miR148b mimics ("m148b") to induce osteogenic differentiation in propagation media (FIG. **3**A) and differentiation media (FIG. **3**B). See control inhibitors ("ic1") and

control mimics ("mc1") for comparison. FIGS. **3**A and **3**B demonstrate the ability of these molecules to induce differentiation under both conditions. FIG. **3**A also demonstrates the ability of various combinations of molecules to act additively to provide enhanced levels of osteogenic differentiation. Pairs of molecules including 1) i489+i27a, 2) i489+m148b, and 3) i27a+m148b (25 nM of each, 50 nM total), or a combination of all three molecules (i489+i27a+m148b, 25 nM each, 75 nM total) were compared with the effects of individual inhibitors or mimics (i489, i27a, or m148b, 25 nM). The results show that one combination of molecules (i489+m148b) induces greater number of cells to undergo osteogenic differentiation than either of the individual molecule treatments (i.e. i489 or m148b). In FIGS. **3**A-**3**B, the letters "i", "m", and "c" symbolize "inhibitor", "mimic", and "control", respectively.

[0031] FIG. **4**. siRNA-Mediated Knockdown of Genes Targeted By miR-27a, miR-489, and miR-148b.

[0032] FIG. **4** provides a graphical representation of the effects of siRNA mediated knockdown of genes targeted by miRNAs of the disclosure. siRNAs targeting CHRD, GCA and SLC22A2 (targets of miRNAs 27a and 489) leads to a decrease in MSC differentiation as measured by AP expression. In contrast, siRNA mediated knockdown of NOG leads to an increase in MSC differentiation as measured by AP expression. UNTR indicates untreated cells.

[0033] FIGS. **5**A-**5**B. Summary of the Activity of miRs, miR Mimics, siRNAs, miRNA Inhibitors, and Genes in Modulating MSC Differentiation.

[0034] FIG. **5**A depicts schematically the roles of the miRs identified by the disclosure (miR-148b, miR-489, miR-27a) in MSC differentiation. Specifically, MSC differentiation towards the osteogenic cell fate is promoted by miR-148b and is inhibited by miR-489 and miR-27a. FIG. **5**B depicts schematically the MSC differentiation promoting or inhibiting activity of various agents identified in the disclosure. Specifically, MSC differentiation is promoted by miR-148b mimics, miR-489 inhibitors, miR-27a inhibitors, and by siRNAs and miRNAs (and other mediators of RNAi) specific for the genes of Tables 6-7. MSC differentiation is inhibited by miR-489 mimics, miR-27a mimics, miR-148b inhibitors, and by siRNAs and miRNAs (and other mediators of RNAi) specific for the genes of Tables 2-5.

DETAILED DESCRIPTION

[0035] All references referred to herein are specifically incorporated herein in their entirety.

Definitions

[0036] The terms "alkaline phosphatase," "ALP," or "AP" are interchangeable and refer to a hydrolase enzyme responsible for removing phosphate groups from many types of molecules. As the name suggests, alkaline phosphatases are most effective in an alkaline environment.

[0037] The term "differentiate" refers to the process cells undergo to become a more specialized cell type.

[0038] The term "gene silencing" refers to a process by which the expression of a specific gene product is lessened or attenuated by RNA interference. The level of gene silencing (also sometimes referred to as the degree of "knockdown") can be measured by a variety of means, including, but not limited to, measurement of transcript levels by Northern Blot Analysis, B-DNA techniques, transcription-sensitive reporter constructs, expression profiling (e.g. DNA chips), qRT-PCR and related technologies. Alternatively, the level of silencing can be measured by assessing the level of the protein encoded by a specific gene. This can be accomplished by performing a number of studies including Western Analysis, measuring the levels of expression of a reporter protein that has e.g. fluorescent properties (e.g., GFP) or enzymatic activity (e.g. alkaline phosphatases), or several other procedures.

[0039] The term "mesenchymal stem cell" or "MSC" refers to pluripotent stem cells that can be derived from a variety of species (e.g. human, mouse, rat) and that can differentiate into osteoblasts, chondrocytes, myocytes, adipocytes and more. Typical MSC molecular markers can vary considerably depending upon the tissue origin of the cells, but can include CD29 and CD105. MSCs can be derived from a number of tissues including, but not limited to, bone marrow, cartilage, tendon, muscle, and adipose tissues.

[0040] The term "microRNA", "miRNA", and "miR" are synonymous and refer to a collection of non-coding single-stranded RNA molecules of about 19-28 nucleotides in length, which regulate gene expression. miRNAs are found in a wide range of organisms (from viruses to humans) and have been shown to play a role in development, homeostasis, and disease etiology. MicroRNAs are processed from single stranded primary transcripts known as pri-miRNA to short stem-loop structures (hairpins) called pre-miRNA and finally to mature miRNA. One or both strands of the mature miRNA molecules are partially complementary to one or more messenger RNA (mRNA) molecules, and function to downregulate gene expression by either cleavage or translation attenuation mechanisms.

[0041] The term "mature strand" refers to the strand of a fully processed miRNA, or an siRNA that enters RISC. In some cases, miRNAs have a single mature strand that can vary in length between about 17-28 nucleotides in length. In other instances, miRNAs can have two mature strands (i.e. two unique strands that can enter RISC), and the length of the strands can vary between about 17 and 28 nucleotides. In the present disclosure, the terms "mature strand," "guide strand" and "antisense strand" are used interchangeably.

[0042] The term "miRNA seed" or "seed" refers to a region of the mature strand(s) of a microRNA or microRNA mimic. The region generally includes nucleotides 2-6 or 2-7 counting from the 5' end of the mature strand.

[0043] The term "miRNA seed complement" or "seed complement" refers to a sequence of nucleotides in a target gene, preferably in the 3' UTR of a target gene, that is complementary to some or all of the miRNA seed.

[0044] The term "nucleotide" refers to a ribonucleotide or a deoxyribonucleotide or modified form thereof, as well as an analog thereof. Nucleotides include species that comprise purines, e.g., adenine, hypoxanthine, guanine, and their derivatives and analogs, as well as pyrimidines, e.g., cytosine, uracil, thymine, and their derivatives and analogs. Nucleotide analogs include nucleotides having modifications in the chemical structure of the base, sugar and/or phosphate, including, but not limited to, 5-position pyrimidine modifications, 8-position purine modifications, modifications at cytosine exocyclic amines, and substitution of 5-bromouracil; and 2'-position sugar modifications, including but not limited to, sugar-modified ribonucleotides in which the 2'-OH is replaced by a group such as an H, OR, R, halo, SH, SR, NH_2, NHR, NR_2, or CN, wherein R is an alkyl moiety. Nucleotide analogs are also meant to include nucleotides with

bases such as inosine, queuosine, xanthine, sugars such as 2'-methyl ribose, non-natural phosphodiester linkages such as in ethylphosphonates, phosphorothioates and peptides.

[0045] Modified bases refer to nucleotide bases such as, for example, adenine, guanine, cytosine, thymine, uracil, xanthine, inosine, and queuosine that have been modified by the replacement or addition of one or more atoms or groups. Some examples of types of modifications that can comprise nucleotides that are modified with respect to the base moieties include but are not limited to, alkylated, halogenated, thiolated, aminated, amidated, or acetylated bases, individually or in combination. More specific examples include, for example, 5-propynyluridine, 5-propynylcytidine, 6-methyladenine, 6-methylguanine, N,N,-dimethyladenine, 2-propyladenine, 2-propylguanine, 2-aminoadenine, 1-methylinosine, 3-methyluridine, 5-methylcytidine, 5-methyluridine and other nucleotides having a modification at the 5 position, 5-(2-amino)propyl uridine, 5-halocytidine, 5-halouridine, 4-acetylcytidine, 1-methyladenosine, 2-methyladenosine, 3-methylcytidine, 6-methyluridine, 2-methylguanosine, 7-methylguanosine, 2,2-dimethylguanosine, 5-methylaminoethyluridine, 5-methyloxyuridine, deazanucleotides such as 7-deaza-adenosine, 6-azouridine, 6-azocytidine, 6-azothymidine, 5-methyl-2-thiouridine, other thio bases such as 2-thiouridine and 4-thiouridine and 2-thiocytidine, dihydrouridine, pseudouridine, queuosine, archaeosine, naphthyl and substituted naphthyl groups, any O- and N-alkylated purines and pyrimidines such as N6-methyladenosine, 5-methylcarbonylmethyluridine, uridine 5-oxyacetic acid, pyridine-4-one, pyridine-2-one, phenyl and modified phenyl groups such as aminophenol or 2,4,6-trimethoxy benzene, modified cytosines that act as G-clamp nucleotides, 8-substituted adenines and guanines, 5-substituted uracils and thymines, azapyrimidines, carboxyhydroxyalkyl nucleotides, carboxyalkylaminoainleotides, and alkylcarbonylalkylated nucleotides. Modified nucleotides also include those nucleotides that are modified with respect to the sugar moiety, as well as nucleotides having sugars or analogs thereof that are not ribosyl. For example, the sugar moieties may be, or be based on, mannoses, arabinoses, glucopyranoses, galactopyranoses, 4'-thioribose, and other sugars, heterocycles, or carbocycles.

[0046] The term nucleotide is also meant to include what are known in the art as universal bases. By way of example, universal bases include, but are not limited to, 3-nitropyrrole, 5-nitroindole, or nebularine. The term "nucleotide" is also meant to include the N3' to P5' phosphoramidate, resulting from the substitution of a ribosyl 3'-oxygen with an amine group. Further, the term nucleotide also includes those species that have a detectable label, such as for example a radioactive or fluorescent moiety, or mass label attached to the nucleotide.

[0047] As used herein, the term "osteogenic differentiation" refers to processes by which cells become progressively more specialized and adopt attributes typically associated with cells of an osteoblast/osteocyte cell lineage. Typically, this process of specialization for the cell comes at the expense of its breadth of differentiation potential and can be monitored by following the expression of a number of molecular markers including, but not limited to, alkaline phosphatase.

[0048] The term "osteoblast" and "osteocyte" refers to abundant cell types found in bone.

[0049] The term "pluripotent" refers to a cell's ability to differentiate into multiple cell types.

[0050] The term "polynucleotide" refers to polymers of two or more nucleotides, and includes, but is not limited to, DNA, RNA, DNA/RNA hybrids including polynucleotide chains of regularly and/or irregularly alternating deoxyribosyl moieties and ribosyl moieties (i.e., wherein alternate nucleotide units have an —OH, then and —H, then an —OH, then an —H, and so on at the 2' position of a sugar moiety), and modifications of these kinds of polynucleotides, wherein the attachment of various entities or moieties to the nucleotide units at any position are included.

[0051] The term "ribonucleotide" and the term "ribonucleic acid" (RNA), refer to a modified or unmodified nucleotide or polynucleotide comprising at least one ribonucleotide unit. A ribonucleotide unit comprises an hydroxyl group attached to the 2' position of a ribosyl moiety that has a nitrogenous base attached in N-glycosidic linkage at the 1' position of a ribosyl moiety, and a moiety that either allows for linkage to another nucleotide or precludes linkage.

[0052] The term "RNA interference" and the term "RNAi" are synonymous and refer to the process by which a polynucleotide (a miRNA or siRNA) comprising at least one polyribonucleotide unit exerts an effect on a biological process. The process includes, but is not limited to, gene silencing by degrading mRNA, attenuating translation, interactions with tRNA, rRNA, hnRNA, cDNA and genomic DNA, as well as methylation of DNA with ancillary proteins.

[0053] The term "siRNA" and the phrase "short interfering RNA" refer to unimolecular nucleic acids and to nucleic acids comprised of two separate strands that are capable of performing RNAi and that have a duplex region that is between 14 and 30 base pairs in length. Additionally, the term siRNA and the phrase "short interfering RNA" include nucleic acids that also contain moieties other than ribonucleotide moieties, including, but not limited to, modified nucleotides, modified internucleotide linkages, non-nucleotides, deoxynucleotides and analogs of the aforementioned nucleotides.

[0054] siRNAs can be duplexes, and can also comprise short hairpin RNAs, RNAs with loops as long as, for example, 4 to 23 or more nucleotides, RNAs with stem loop bulges, micro-RNAs, and short temporal RNAs. RNAs having loops or hairpin loops can include structures where the loops are connected to the stem by linkers such as flexible linkers. Flexible linkers can be comprised of a wide variety of chemical structures, as long as they are of sufficient length and materials to enable effective intramolecular hybridization of the stem elements. Typically, the length to be spanned is at least about 10-24 atoms. When the siRNAs are hairpins, the sense strand and antisense strand are part of one longer molecule.

[0055] Detailed descriptions of the criteria for the rational design of siRNA antisense strands for efficient gene silencing can be found in WO 2004/045543, WO 2006/006948, WO 2005/078095, WO 2005/097992, and WO 2005/090606, each of which is incorporated herein by reference in its entirety.

[0056] siRNAs can target any sequence including protein encoding sequences (e.g., open reading frames, ORFs), and non-coding sequences (e.g., 3' UTRs, 5' UTRs, intronic regions, promoter regions, microRNAs, piRNAs, enhancer regions, repetitive sequences, and more). In contrast, microRNA and piRNA mimics of the disclosure generally target a subset of genes and tools for predicting miRNA

targets can be found in any number of publications including but not limited to Griffith-Jones, S. et al., Nucleic Acids Research, 2007.

[0057] The term "piRNAs" refers to Piwi-interacting RNAs, a class of small RNAs that are believed to be involved in transcriptional silencing (see Lau, N. C. et al (2006) *Science,* 313:305-306).

[0058] The term "z score" refers to a statistical measurement that quantifies the distance (measured in standard deviations) a data point is from the mean of a data set. A z score is a dimensionless quantity derived by subtracting the sample mean from an individual (raw) score and then dividing the difference by the sample standard deviation.

[0059] The inventors have identified several microRNAs that participate in determining whether or not MSCs differentiate toward cells of an osteogenic cell fate. In addition, it has been discovered by the inventors that inhibitors and mimics of these microRNAs can be used (singularly or in combination) to induce or inhibit MSC osteogenic differentiation or to prevent MSC differentiation into other cell identities (e.g. adipocytes). In addition, the target genes of those microRNAs have been identified by the inventors (see Tables 2-7), and the inventors have further demonstrated that siRNA-mediated knockdown of those target genes can induce or inhibit MSC osteogenic differentiation in the manner predicted by the microRNA results. Thus, modulation of the expression of those target genes by any method known in the art (e.g., siRNA, piRNA, antisense, antibodies, and aptamers against the proteins produced by the target genes etc), or by using the miRNAs, miRNA mimics, and inhibitors of the disclosure can be used to modulate MSC differentiation, including in a therapeutic or prophylactic context. Moreover, measuring the expression level of the target genes of Tables 2-7 and/or the miRNAs identified herein can yield diagnostic or prognostic medical information relating to diseases or disorders characterized by abnormal degrees of MSC differentiation.

[0060] The sequences of currently known human, mouse, and rat miRNAs are available at miRBase which is maintained by the Wellcome Trust Sanger Institute (http://microma.sanger.ac.uk/sequences/). As such, a person of ordinary skill in the art can select a sequence from the database for a desired miRNA and design a mimic useful for the methods disclosed herein.

[0061] The miRNAs of the disclosure can be identified as single stranded pri-miRNA or pre-miRNA hairpin structures (wherein a hairpin is defined as an oligonucleotide that is 40-150 nucleotides in length and contains secondary structures that result in regions of duplex and loops) or characterized as mature double stranded miRNAs. The miRNAs are capable of entering the RNAi pathway, being processed by gene products associated with the pathway (e.g., Drosha, Dicer, and the RNA interference Silencing Complex, RISC), and inhibiting gene expression by translation attenuation or message (mRNA) cleavage. As such, all of the miRNAs of the invention can be described by multiple labels depicting the level of processing.

[0062] With respect to the sequence of pri-, pre-, and mature miRNA sequences, it is worth noting that the field of RNAi and thus the sequences and structures associated with human, mouse and rat miRNAs varies slightly as versions of the miRNA database evolve. Though these newer versions of e.g. miRbase can have sequences that are extended and/or truncated on either the 5' or 3' end of the mature and passenger sequences, the changes do not alter the overall identity of the miRNA nor the ability to utilize these sequences in the context of the described embodiments.

[0063] In a first aspect, the present disclosure provides a method of modulating (e.g. inducing/promoting or inhibiting) mesenchymal stem cell osteogenic differentiation by using microRNA inhibitors and/or mimics. The methods of the disclosure may be performed ex vivo or in vivo.

[0064] MCS cells can be obtained commercially (e.g. Lonza, Inc) and cultured in vitro using medium (also referred to as a "pro-osteogenic cocktails" or "differentiation media") that sensitize cells to differentiate. Such media often comprise standard constituents plus dexamethasone, ascorbic acid-2-phosphate, beta-glycerophosphate, or other factors that enhance MSC differentiation. Alternatively, MSCs can be cultured on one or more media that do not sensitize cells toward osteogenic differentiation. Relevant references that pertain to characterization and differentiation of MSCs include: Baksh, D et al. (2004) *J. Cell. Mol. Med.* 8(3): 301-316; Aggarwal, S. et al. (2005) *Blood* 105: 1815-22; Akino, K. et al. (2006) *Wound Repair Regen.* 14:343-9; Jian, H. et al. (2006) *Genes Dev.* 20:666-74, each of which is incorporated herein by reference in its entirety.

[0065] The terms "microRNA inhibitor", "miR inhibitor", or "inhibitor" are synonymous and refer to oligonucleotides or modified oligonucleotides that interfere with the ability of specific miRNAs, or siRNAs to silence their intended targets. In general, the inhibitors are nucleic acid or modified nucleic acids in nature including oligonucleotides comprising RNA, modified RNA, DNA, modified DNA, locked nucleic acids (LNAs), or any combination of the above. Modifications include 2' modifications (including 2'-O alkyl modifications and 2' F modifications) and internucleotide modifications (e.g. phosphorothioate modifications) that can affect delivery, stability, specificity, intracellular compartmentalization, or potency. In addition, miRNA inhibitors can comprise conjugates that can affect delivery, intracellular compartmentalization, stability, and/or potency.

[0066] Inhibitors can adopt a variety of configurations including single stranded, double stranded (RNA/RNA or RNA/DNA duplexes), and hairpin designs. In general, microRNA inhibitors comprise contain one or more sequences or portions of sequences that are complementary or partially complementary with the mature strand (or strands) of the miRNA to be targeted. In addition, the miRNA inhibitor may also comprise additional sequences located 5' and 3' to the sequence that is the reverse complement of the mature miRNA. The additional sequences may be the reverse complements of the sequences that are adjacent to the mature miRNA in the pri-miRNA from which the mature miRNA is derived, or the additional sequences may be arbitrary sequences (having a mixture of A, G, C, or U). In some embodiments, one or both of the additional sequences are arbitrary sequences capable of forming hairpins. Thus, in some embodiments, the sequence that is the reverse complement of the miRNA is flanked on the 5' side and on the 3' side by hairpin structures. Micro-RNA inhibitors, when double stranded, may include mismatches between nucleotides on opposite strands. Furthermore, micro-RNA inhibitors may be linked to conjugate moieties in order to facilitate uptake of the inhibitor into a cell. For example, a micro-RNA inhibitor may be linked to cholesteryl 5-(bis(4-methoxyphenyl)(phenyl) methoxy)-3 hydroxypentylcarbamate) which allows passive uptake of a micro-RNA inhibitor into a cell. Micro-RNA inhibitors, including hairpin miRNA inhibitors, are described

in detail in Vermeulen et al., "Double-Stranded Regions Are Essential Design Components Of Potent Inhibitors of RISC Function," RNA 13: 723-730 (2007) and in WO2007/095387 and WO 2008/036825 each of which is incorporated herein by reference in its entirety. A person of ordinary skill in the art can select a sequence from the database for a desired miRNA and design an inhibitor useful for the methods disclosed herein. The sequences of known human, mouse, and rat miRNAs discovered by wet-lab experimentation or bioinformatic methods are available at miRBase which is maintained by the Wellcome Trust Sanger Institute (http://microma.sanger.ac.uk/sequences/).

[0067] The miRNA inhibitors used in the Examples of this disclosure consisted of single stranded, 54 nucleotides, fully 2'-O-methylated, oligonucleotides having a central region that is complementary to the mature miRNA target sequence and 5' and 3' flanking sequences of equivalent length.

[0068] Exemplified herein are the inhibitors designed to target hsa-miR-489, hsa-miR-27a, hsa-miR-148b, or any of the closely related family members (see Table 1). As shown in Example 1, transfection of microRNA inhibitors individually targeting the majority of human miRNAs has little or no effect on MSCs osteogenic differentiation. In contrast, transfection of inhibitors targeting hsa-miR-489 or hsa-miR-27a into mesenchymal stem cells enhances the production of alkaline phosphatase, a key cellular marker of osteoblasts. The differentiation is highly specific to osteogenic differentiation and does not include differentiation into other cell types (e.g. adipose cell, hematopoietic cells). Of equal importance, the inventors have discovered that inhibitors of hsa-miR-489, hsa-miR-27a and related family members induce osteogenic differentiation both in the presence and absence of pro-osteogenic cocktails being added to the media (see Example 4). Moreover, inhibitors of hsa-miR-148b (unlike inhibitors of hsa-miR-489 and hsa-miR-27a) are capable of inhibiting osteogenic differentiation.

[0069] miRNA mimics represent a class of molecules that can be used to imitate the gene silencing ability of one or more miRNAs. Thus, the term "microRNA mimic" refers to synthetic non-coding RNAs (i.e. the miRNA is not obtained by purification from a source of the endogenous miRNA) that are capable of entering the RNAi pathway and regulating gene expression. miRNA mimics can be designed as mature molecules (e.g. single stranded) or mimic precursors (e.g., pri- or pre-miRNAs). miRNA mimics can be comprised of nucleic acid (modified or modified nucleic acids) including oligonucleotides comprising, without limitation, RNA, modified RNA, DNA, modified DNA, locked nucleic acids, or 2'-O,4'-C-ethylene-bridged nucleic acids (ENA), or any combination of the above (including DNA-RNA hybrids). In addition, miRNA mimics can comprise conjugates that can affect delivery, intracellular compartmentalization, stability, specificity, functionality, strand usage, and/or potency.

[0070] In one design, miRNA mimics are double stranded molecules (e.g., with a duplex region of between about 16 and about 31 nucleotides in length) and contain one or more sequences that have identity with the mature strand of a given miRNA. Modifications can comprise 2' modifications (including 2'-O methyl modifications and 2' F modifications) on one or both strands of the molecule and internucleotide modifications (e.g. phorphorthioate modifications) that enhance nucleic acid stability and/or specificity. In addition, miRNA mimics can include overhangs. The overhangs can consist of 1-6 nucleotides on either the 3' or 5' end of either strand and can be modified to enhance stability or functionality.

[0071] In one embodiment, a miRNA mimic comprises a duplex region of between 16 and 31 nucleotides and one or more of the following chemical modification patterns: the sense strand contains 2'-O-methyl modifications of nucleotides 1 and 2 (counting from the 5' end of the sense oligonucleotide), and all of the Cs and Us; the antisense strand modifications can comprise 2' F modification of all of the Cs and Us, phosphorylation of the 5' end of the oligonucleotide, and stabilized internucleotide linkages associated with a 2 nucleotide 3' overhang.

[0072] The mimics used in the Examples of this disclosure are 19-28 bp, double stranded RNA molecules comprising a 5' phosphorylated antisense strand that is identical to the mature strand of the miRNA under study. In addition, all mimics used in the Examples contain 2'-O-methyl modifications on the first two nucleotides of the 5' end of the non-targeting strand (also referred to as the passenger strand or the star strand).

[0073] In one aspect, the mimic is a mimic of hsa-miR-148b and related family members (see Table 1). As shown in Example 2, transfection of a mimic of hsa-miR-148b into mesenchymal stem cells enhances the production of alkaline phosphatase, a key cellular marker of osteoblasts. Again, the differentiation process is specific to osteogenic differentiation (i.e. cells do not differentiate into other cell lineages). And, as was the case with miRNA inhibitors targeting hsa-miR-489, hsa-miR-27a and related family members, the hsa-miR-148b mimic can induce osteogenic differentiation in the presence and absence of pro-osteogenic cocktails being added to the culture media. Simultaneously, the inventors have discovered that mimics of hsa-miR-489 and hsa-miR27a inhibit MSC osteogenic differentiation.

[0074] Thus, in one aspect the disclosure provides a method of promoting MSC differentiation towards the osteogenic cell fate, the method comprising introducing into a MSC (ex vivo or in vivo) a composition comprising at least one differentiation promoting agent selected from the group consisting of inhibitors of miR-489, inhibitors of miR-27a, and mimics of miR-148b. The miRs, mimics and inhibitors can be used singly or in any combination to promote MSC differentiation. By way of non-limiting example, MSC differentiation may be promoted by introducing (e.g., by transfection, passive uptake etc) into a MSC a composition comprising:

[0075] 1. at least one miR-489 inhibitor (e.g. 1, 2, 3, or more different miR-489 inhibitors);

[0076] 2. at least one miR-27a inhibitor (e.g. 1, 2, 3, or more different miR-27a inhibitors);

[0077] 3. at least one miR-148b mimic (e.g. 1, 2, 3, or more different miR-148b mimics);

[0078] 4. at least one miR-489 inhibitor in combination with at least one miR-27a inhibitor and at least one miR-148b mimic; or

[0079] 5. at least one miR-489 inhibitor in combination with at least one miR-148b mimic.

[0080] In another aspect the disclosure provides a method of inhibiting MSC differentiation toward the osteogenic cell fate, the method comprising introducing into a MSC (ex vivo or in vivo) a composition comprising at least one differentiation inhibitor selected from the group consisting of mimics of miR-489, mimics of miR-27a, and inhibitors of miR-148b. The mimics and inhibitors can be used singly or in any combination to inhibit MSC differentiation. By way of non-lim-

iting example, MSC differentiation may be inhibited by introducing (e.g., by transfection, passive uptake etc) into a MSC a composition comprising:

[0081] 1. at least one miR-489 mimic (e.g. 1, 2, 3, or more different miR-489 mimics);

[0082] 2. at least one miR-27a mimic (e.g. 1, 2, 3, or more different miR-27a mimics);

[0083] 3. at least one miR-148b inhibitor (e.g. 1, 2, 3, or more different miR-148b inhibitors);

[0084] 4. at least one miR-489 mimic in combination with at least one miR-27a mimic and at least one miR-148b inhibitor; or

[0085] 5. at least one miR-489 mimic in combination with at least one miR-148b inhibitor.

[0086] Given the similarities in miRNAs amongst mammalian systems, equivalent mimic and inhibitor molecules derived from different species are expected to have similar effects on their respective organisms.

[0087] In another aspect, the disclosure provides inhibitors and mimics of miR-489, miR-27a, and miR-148b including, but not limited to, the mimics and inhibitors of Table 1. In view of the utility of such mimics and inhibitors disclosed herein by the inventors, the design of other mimics and inhibitors of miR-489, miR-27a, and miR-148b is within the skill of the ordinary artisan.

[0088] Synthetic mimics and inhibitors can be delivered to cells to influence MSC differentiation by a variety of methods including, but not limited to, lipid (e.g. DharmaFECT1, Thermo Fisher Scientific) or chemical (e.g. calcium phosphate) mediated transfection, electroporation, lipid-independent delivery via conjugation to one or more entities that mediate lipid- or chemical-independent delivery (e.g. conjugation of cholesterol), or any other method that has been identified or will be identified for nucleic acid transfer to target cells. In addition, mimics and inhibitors can be delivered to a cell using a plasmid vector that expresses the sequence(s) that encode the mimic or inhibitor of choice. Such expression vectors can be introduced into cells (including cells within an organism such as a human being) by art-recognized transfection methods (e.g. Lipofectamine 2000, Invitrogen) or via viral-mediated delivery (e.g. lentiviral, adenoviral). One preferred expression system is described in PCT/US2008/64462, which is incorporated herein by reference in its entirety

[0089] Studies have demonstrated that not all miRNAs are processed with equal efficiency. For that reason, incorporation of the therapeutic miRNAs (e.g. mimics and inhibitors) of the disclosure into a highly processed scaffold (e.g., miR-196a-2) would ensure efficient processing and expression.

[0090] Synthetic mimics and inhibitors may be modified with a wide range of chemical modifications to enhance stability, functionality, cellular uptake, and specificity, and strand usage. For instance, studies presented in U.S. patent application Ser. No. 11/051,195, which is incorporated herein by reference in its entirety, and other documents have identified multiple chemical modification patterns, including 2'-O-methyl modifications, locked nucleic acids (LNAs), morpholinos, ethylene-bridged analogs (ENAs), 2'-F modifications, and phosphorothioate modifications, that greatly enhance the stability of double stranded RNAs in serum. Similarly, addition of 2'-O-methyl modifications to positions 1 and 2 (counting from the 5' end of the molecule) in the passenger strand can enhance functionality and specificity (see patent application Ser. No. 11/019,831, which is incorporated herein by reference in its entirety).

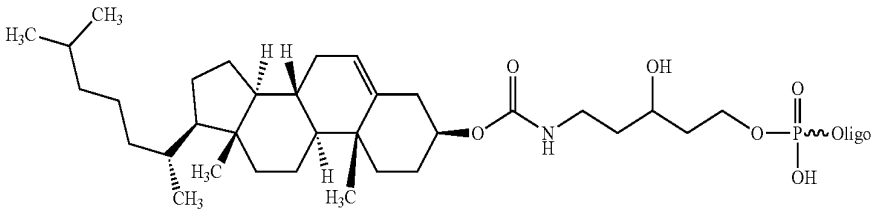
[0091] In some embodiments, the miRNA inhibitor or mimic is conjugated to a lipid molecule such as cholesterol (preferably using a linker) in order to allow passive delivery of the inhibitor to a MSC (in vivo or ex vivo). See WO 2008/036825 which is incorporated herein by reference in its entirety. In preferred embodiments, the mimics and inhibitors contain the modification patterns and conjugate moieties disclosed in WO 2008/036825. For example, in one embodiment, a miRNA mimic of the disclosure comprises an RNA duplex having:

[0092] 1. a sense strand that ranges in size from about 18 to about 30 nucleotides wherein nucleotides 1 and 2 (numbered from the 5' end) are 2' O-methyl modified and wherein all C nucleotides and all U nucleotides are 2'O-methyl modified;

[0093] 2. an antisense strand that ranges in size from about 18 to about 30 nucleotides, wherein all C nucleotides and all U nucleotides are 2' F modified, and wherein the antisense strand has significant levels of complementarity to the sense strand as well as to the target gene of the endogenous miR;

[0094] 3. a 2 nucleotide overhang at the 3' end of the antisense strand comprising phosphorothioate linkages;

[0095] 4. a cholesterol molecule attached to the 3' end of the sense strand via a C5 linker molecule wherein the cholesterol-linker-sense strand can have the structure:



[0096] 5. optionally a phosphate group at the 5' end of the antisense strand; and

[0097] 6. optionally, a mismatch between at least one of nucleotides 1, 7, and 14 on the antisense strand (numbered from the 5' end) and the opposite nucleotide on the sense strand. The cholesterol molecule allows passive uptake of the mimic into cells.

[0098] The mimics and inhibitors of the disclosure can be generated using a range of art-recognized techniques (e.g. ACE chemistry, see U.S. Pat. Nos. 6,111,086; 6,590,093;

5,889,136; and 6,008,400, each of which is incorporated herein by reference in its entirety).

[0099] Mimics and inhibitors can be introduced into MSCs either ex vivo (e.g. in vitro) or in vivo (e.g., within a whole organism such as a human being or any other mammal). Thus, in another aspect the disclosure provides isolated cells and isolated tissues comprising the inhibitors and mimics of the disclosure, and also provides isolated, cells and isolated tissues comprising siRNAs specific for the genes disclosed below. Moreover, as detailed below, the mimics and inhibitors of the disclosure can be formulated as pharmaceutical compositions for the treatment (e.g. therapeutic or prophylactic use) of diseases or disorders in which MSC differentiation (or lack thereof) is implicated (e.g. osteogenesis imperfecta) or for the treatment of disease, conditions, and disorders in which increased osteogenesis or decreased osteogenesis is desirable.

[0100] The level of osteogenic differentiation by MSCs can be assessed by a variety of methods including 1) measuring alkaline phosphatase activity by one or more enzymatic assays, 2) staining cells with Alizarin-Red S solution or silver nitrate which identifies calcium phosphate deposits, or 3) measuring expression of osteogenic marker genes including osterix, cbfal, osteopontin, osteocalcin, or bone sialoprotein, which can be performed at the RNA or protein level.

[0101] Small molecule compounds that have effects on osteogenesis have been shown to exhibit effects in in vivo systems (e.g. TAK-778 [(2R,4S)-(−)-N-(4-diethoxyphosphorylmethylphenyl)-1,2,4,5-tetrahydro-4-methyl-7,8-methylenedioxy-5-oxo-3-benzothiepin-2-carboxyamide, see, Notoya, K. et al. (1999) J Pharmacol Exp Ther. 290:1054-64). Thus, the mimics and inhibitors described here will also prove efficacious in whole animal (human and non-human) systems as therapeutic and/or prophylactic agents. Methods for the delivery of miRNA mimics and inhibitors to an organism are known in the art.

[0102] In another aspect, the level of expression of one or more of miR-489, miR-27a, and miR-148b (and/or the level (s) of any corresponding pri-miRNA and/or pre-miRNA) is measured. The results of measurements can be used for disease detection, disease diagnosis, disease prognosis (e.g. an estimate of disease outcome), and to determine or predict the efficacy of a therapeutic treatment. For example, because an inhibitor of miR-489 promotes MSC differentiation towards the osteogenic cell fate, then this suggests that individuals with a high level of expression of miR-489 may have a reduced degree of MSC differentiation compared to individuals with a relatively lower level of miR-489 expression. Conversely, because a mimic of miR-148b promotes MSC differentiation towards the osteogenic cell fate, then this suggests that individuals with a high level of expression of miR-148b may have a higher degree of MSC differentiation compared to individuals with a relatively lower level of miR-489 expression. In one embodiment, the method comprises the steps of 1) determining the expression level of one or more of the miRNAs of the disclosure from an individual suspected of having a disease or disorder characterized by abnormal MSC differentiation (e.g., osteogenesis imperfecta) and 2) comparing the level of the one or more miRNAs with that observed in a normal individual known to not have the disease or disorder, whereby diagnostic or prognostic information may be obtained.

[0103] The miRNAs used as diagnostic or prognostic markers may be utilized individually or in combination with other molecular markers for bone disorders, including without limitation other miRNAs, mRNAs, proteins, and nucleotide polymorphisms.

[0104] A range of techniques well known in the art can be used to quantitate amounts of one or more miRNA sequences of the disclosure from e.g., a biological sample. For instance, complements of the mature miRNA sequences of the disclosure can be associated with a solid support (e.g., a microarray) and purified RNA from e.g., clinical or control samples can be fluorescently labeled and profiled to determine whether the patient is suffering from a disease resulting from improper osteogenic differentiation (see Baskerville, S. et al. RNA 11:241-7). One preferred microarray platform is described in the document in WO/2008/048342 (filed as PCT/US2007/003116) which is incorporated herein by reference in its entirety. Alternatively, Northern blotting and/or quantitative PCR-based techniques can be used to assess the relative amounts of any of the miRNAs of the disclosure derived from e.g., control and/or test samples (Duncan, D. D. et al. 2006 Anal. Biochem. 359:268-70). In addition, affinity matrices, in situ hybridization, and in situ PCR may be used. These techniques are all well known in the art.

[0105] Preferably, statistical methods are used to identify significant changes in miRNA levels for the aforementioned prognostic and diagnostic assays. For example, in one embodiment, p values are calculated using known methods to determine the significance in the change of the level of expression of a miRNA. In some embodiments, a value of $p<0.05$ is used as a threshold value for significance.

[0106] Samples for the prognostic and diagnostic assays of the disclosure may be obtained from an individual (e.g., a human or animal subject) suspected of having a disease or disorder characterized by abnormal MSC differentiation (e.g., osteogenesis imperfecta) using any technique known in the art. For example, the sample may be obtained from an individual who is manifesting clinical symptoms that are consistent with the existence of a disease or disorder characterized by abnormal MSC differentiation, or from an individual with no clinical symptoms but with a predisposition towards developing a disease or disorder characterized by abnormal MSC differentiation due to genetic or environmental factors. Samples may be obtained by extracting a small portion of bone tissue from an individual using, for example, a biopsy needle.

[0107] In some instances, genomic amplification of a sequence encoding a miRNA in a tissue may result in a higher level of expression of that miRNA relative to tissues in which the sequence encoding the miRNA has not undergone amplification. Thus, in another embodiment, the copy number of miR-489, miR-27a, and miR-148b is measured in a tissue which comprises MSCs. Methods suitable for determining the genomic copy number of a sequence encoding a miRNA include Southern blotting, fluorescence in situ hybridization, comparative genomic hybridization, and amplification based methods such as quantitative PCR (for example, using Taqman probes).

[0108] The methods of the disclosure can also be used to identify genes that play a role in enhancing osteogenesis and/or limit MSC differentiation into other cell types (e.g. adipocytes). The terms "miRNA target gene", "miRNA target", and "target gene" are used interchangeably herein to refer to genes that are directly modulated by specific miRNA (s). Extensive studies into the mechanism of miRNA action have identified characteristic features of miRNA target genes.

These include the presence of the 3' UTR target sites (e.g. seed complements), the number and positioning of seed complements within a 3' UTR, preferences for local AU-rich sequences and more (see, for instance, Grimson, A. et al 2007. Mol Cell 27:91-105). As such, miRNA target genes can be identified bioinformatically (e.g., see the miRNA target prediction site at http://www.russell.embl-heidelberg.de/miRNAs/; Targetscan, http://www.targetscan.org/mamm_31/), by microarray analysis (Huang et. al., 2007, Nature Methods 4:1045-9), and by biochemical methods (Karginov, F. V., 2007, PNAS 104:19291-6). Using the procedures described in Example 5, the inventors have determined target genes that are regulated by miRs-27a, 489, and 148b, including but not limited to the target genes disclosed in Tables 2-7. Thus, in another aspect, the disclosure provides a collection of target genes that are modulated by miRs-27a, 489, and 148b, including the genes in Tables 2-7. The nucleotide sequences of the genes in Tables 2-7 are well known in the art. For example, gene sequences may be obtained through http://www.ncbi.nlm.nih.gov/sites/entrez?db=gene using the gene names, target names, Transcript Id. Numbers and ReqSeq Accession Numbers provided in Tables 2-7. For each gene of Tables 2-7, the most recent version of the sequence associated with the recited accession number as of the filing date of this application is specifically incorporated herein by reference.

[0109] It will be recognized by one skilled in the art that knowledge of the target genes that are modulated by miRs-27a, 489, and 148b enables other methods for modulating mesenchymal stem cell differentiation both ex vivo (e.g. in vitro) and in vivo. In general, a decrease in the expression level of a gene from Tables 2-3 or Tables 4-5 (e.g. CHRD, GCA, and SLC22A2) will inhibit mesenchymal stem cell (MSC) differentiation towards the osteogenic cell fate, whereas an increase in the expression level of a gene from Tables 2-3 or Tables 4-5 will promote mesenchymal stem cell (MSC) differentiation towards the osteogenic cell fate. Similarly, a decrease in the expression level of a gene from Tables 6-7 (e.g. NOG) will promote mesenchymal stem cell (MSC) differentiation towards the osteogenic cell fate, whereas an increase in the expression level of a gene from Tables 6-7 will inhibit mesenchymal stem cell (MSC) differentiation towards the osteogenic cell fate.

[0110] In addition to using the miRNAs, miRNA mimics, and miRNA inhibitors disclosed above, modulation of the expression level of the target genes provided in Tables 2-7 can also be achieved using miRNA mimics that hybridize to a different site in the target gene than the site recognized by the endogenous miRs-27a, 489, and 148b.

[0111] Modulation of the expression level of the target genes provide in Tables 2-7 can also be achieved using siRNAs that can be designed using techniques well known in the art. Non-limiting examples demonstrating the siRNA-mediated modulation of the target genes of Tables 2-7 are provided in Example 5. For example, in one embodiment, the disclosure provides a method of promoting mesenchymal stem cell (MSC) differentiation towards the osteogenic cell fate, the method comprising introducing into a MSC at least one siRNA or miRNA mimic specific for at least one of the target genes of Tables 6-7 (e.g. a siRNA specific for NOG). In another embodiment, the disclosure provides a method of inhibiting mesenchymal stem cell (MSC) differentiation towards the osteogenic cell fate, the method comprising introducing into a MSC at least one siRNA or miRNA mimic specific for at least one of the target genes of Tables 2-5 (e.g. CHRD, GCA, and SLC22A2). In preferred embodiments, the expression level of one or more genes from Table 3, 5, and/or 7 (e.g. ARSE, COL2A1, FBN1, GHRHR, HOXA2, HOXA5, LECT1, NOG, OSTF1, PAPSS2, TFIP11, TRPS1, ADAMTS4, AHSG, ALPL, BMI1, CHRD, DLX5, HOXA13, MATN1, MINPP1, PEX7, PRKRA, THRA, AMELY, BMP7, CDH11, CHRD, CHRDL2, EN1, MAPK8, MGP, PAX1, POSTN, SPP1, SUFU, TRAPPC2, TWIST1, GCA, and SLC22A2) is modulated in an MSC in vivo or ex vivo (e.g. in vitro) using miRNAs, miRNA mimics, miRNA inhibitors, siRNA, and/or any other mediator of RNAi or transcriptional silencing known in the art.

[0112] It is expressly contemplated that combinations of two or more agents of the disclosure (miRNAs, miRNA mimics, miRNA inhibitors, and siRNAs) are used to modulate MSC differentiation in vivo or ex vivo.

[0113] The identification of the target genes of Tables 2-7 that are induced and/or suppressed by the miRNA mimics and inhibitors described herein can also lead to the identification of small molecules that can modulate this critical step in cellular differentiation. Small molecules can be identified, for example, using conventional High Throughput Screening (HTS) methodology.

[0114] All of the agents identified in the instant disclosure (miRNAs, miRNA mimics, miRNA inhibitors, and siRNAs) that modulate MSC differentiation have utility in the fields of tissue transplantation/grafting (e.g. bone formation, tissue mineralization, osteochondrial repair, fracture repair including non-union fracture repair), treatment of disease (e.g. osteogenesis imperfecta), bioprocessing, 3D culture, and biomarker development (see, for instance, Reiker, J. et al. (2005) *Expert Opin. Biol. Ther.* 5(12): 1572-1584). For example, using a differentiation promoting agent(s) of the disclosure (e.g., a miR-148b mimic, a miR-489 inhibitor, a miR-27a inhibitor, or siRNA or an miRNA mimic specific for a gene from Tables 6-7, such as NOG, or any combination of two or more of these agents such as two miR-489 inhibitors, or such as a miR-489 inhibitor plus a siRNA specific for NOG, or such as a miR-27a inhibitor plus a miRNA mimic for NOG etc), a MSC cultured ex vivo may be induced to differentiate towards the osteogenic cell fate and may then be transplanted into an individual in need of a bone graft along with an appropriate matrix or implant, if required. The MSC may be obtained from the same individual that receives the bone graft (autograft) or from a different individual (allograft).

[0115] Pharmaceutical compositions comprising the inhibitors, mimics, siRNAs, and small molecules of the disclosure, are also expressly contemplated and may be used for the treatment (e.g. therapy—ranging from alleviation of one or more symptoms to a complete cure—or prophylaxis) of any disease, condition, or disorder in which MSC differentiation (or lack thereof) is implicated (e.g. osteogenesis imperfecta) or where increased osteogenesis is desirable (e.g. osteoporosis or any other disease, condition, or disorder where increasing bone density and growth is desirable such as, without limitation, osteoarthritis, periodontal disease, bone fractures of any type or etiology, bone loss from surgery, reconstructive surgery, osteomylitis, and idiopathic bone loss) or where decreased osteogenesis is desirable (e.g. fibrodysplasia ossificans progressiva). For example, a pharmaceutical formulation comprising at least one siRNA or miRNA mimic specific for a gene from Tables 6-7 (e.g. NOG) can be used to treat an individual suffering from a disease character-

ized by a decreased degree of MSC differentiation relative to a normal individual, or to treat a disease or disorder in which increasing bone growth, mass, or density is desirable. Similarly, a pharmaceutical formulation comprising at least one siRNA or miRNA mimic specific for a gene from Tables 2-5 (e.g. CHRD, GCA, and SLC22A2) can be used to treat an individual suffering from a disease characterized by a increased degree of MSC differentiation relative to a normal individual. Preferably, the target gene whose expression level is modulated by a siRNA or miRNA mimic is a gene from Table 3, 5, or 7. By way of another example, a pharmaceutical formulation comprising at least one miR-148b mimic and/or at least one miR-489 inhibitor and/or at least one miR-27a inhibitor and/or at least one siRNA specific for a gene from Tables 6-7 can be used to treat an individual suffering from a disease characterized by a decreased degree of MSC differentiation relative to a normal individual. By way of another example, a pharmaceutical formulation comprising at least one miR-489 mimic and/or least one miR-27a mimic and/or at least one miR-148b inhibitor and/or at least one siRNA specific for a gene from Tables 2-5 can be used to treat an individual suffering from a disease characterized by a increased degree of MSC differentiation relative to a normal individual. In all cases, a pharmaceutically effective amount of the composition is administered to an individual in need thereof, such as a human patient i.e. an amount that is sufficient to induce a response in the individual that is clinically relevant and significant.

[0116] In addition to the siRNA(s), miRNA mimic(s), and miRNA inhibitor(s), the pharmaceutical formulations preferably also comprise one or more pharmaceutically acceptable carriers or excipients, and may be formulated for a variety of routes of administration, including systemic and topical or localized administration. Techniques and formulations generally may be found in Remmington's Pharmaceutical Sciences, Meade Publishing Co., Easton, Pa. For systemic administration, injection is preferred, including intramuscular, intravenous, intraperitoneal, and subcutaneous. For injection, the therapeutic compositions of the invention can be formulated in liquid solutions; preferably in physiologically compatible buffers such as Hank's solution or Ringer's solution. In addition, the therapeutic compositions may be formulated in solid form and redissolved or suspended immediately prior to use. Lyophilized forms are also included. Preparations for oral administration are also contemplated, and may be formulated in a conventional manner to give either immediate or controlled release.

[0117] The pharmaceutical compositions of the disclosure may also include an additional active ingredient(s) for the treatment of bone disease e.g. TAK-778 R2R,4S)-(−)-N-(4-diethoxyphosphorylmethylphenyl)-1,2,4,5-tetrahydro-4-methyl-7,8-methylenedioxy-5-oxo-3-benzothiepin-2-carboxyamide.

[0118] In another aspect, the level of expression of one or more of the target genes of Tables 2-7 is measured. The results of measurements can be used for disease detection, disease diagnosis, disease prognosis, and to determine or predict the efficacy of a therapeutic treatment. For example, individuals with a high level of expression of a gene from Tables 6-7 (e.g. NOG) may have a reduced degree of MSC differentiation compared to individuals with a relatively lower level of expression of the same gene(s). Conversely, individuals with a low level of expression of a gene from Tables 6-7 may have a higher degree of MSC differentiation compared to individuals with a relatively higher level of expression of the same genes. Similarly, individuals with a high level of expression of a gene from Tables 2-5 (e.g. CHRD, GCA, SLC22A2) may have a higher degree of MSC differentiation compared to individuals with a relatively lower level of expression of the same gene(s); individuals with a low level of expression of a gene from Tables 2-5 may have a reduced degree of MSC differentiation compared to individuals with a relatively higher level of expression of the same gene(s). Methods for the measurement of the expression level of the target genes of Table 2-7 are well-known in the art, and include Northern blotting and quantitative PCR-based methods and microarray analysis (see also the methods disclosed above for measuring miRNA levels which are generally applicable to the measurement of mRNA also). In other embodiments, the level of the protein encoded by a gene from Tables 2-7 is measured using, for example, western blots, antibody arrays, ELISA assays, or any other technique known in the art.

[0119] The assays can be performed on biological samples taken from the individual. In one embodiment, the method comprises the steps of 1) determining the expression level of one or more of the target genes of Tables 2-7 from an individual suspected of having a disease or disorder characterized by abnormal MSC differentiation (e.g., osteogenesis imperfecta) and 2) comparing the level of the one or more target genes with that observed in a normal individual known to not have the disease or disorder, whereby diagnostic or prognostic information may be obtained. Preferably, the target gene whose expression level is determined is a gene from Table 3, 5, or 7 (e.g. ARSE, COL2A1, FBN1, GHRHR, HOXA2, HOXA5, LECT1, NOG, OSTF1, PAPSS2, TFIP11, TRPS1, ADAMTS4, AHSG, ALPL, BMI1, CHRD, DLX5, HOXA13, MATN1, MINPP1, PEX7, PRKRA, THRA, AMELY, BMP7, CDH11, CHRD, CHRDL2, EN1, MAPK8, MGP, PAX1, POSTN, SPP1, SUFU, TRAPPC2, TWIST1, GCA, and SLC22A2). The targets genes of Tables 2-7 may be used as diagnostic or prognostic markers either individually or in combination with other molecular markers disclosed herein or identified in previous or future studies (e.g., other miRNAs, proteins, nucleotide polymorphisms).

[0120] In another embodiment, the miRNAs and target genes described herein can be used as molecular markers in drug screening assays during drug development. Typically, in the early stages of drug development, in vitro studies involving cultured cells that often mimic one or more aspects of diseased tissue are performed to identify molecules that induce desirable phenotypes. As up or down regulation of miRNAs or target genes described herein are indicative of e.g. osteogenic differentiation, they can be used as markers during drug development to identify agents that positively effect clinical outcomes. In one preferred example, one or more of the miRNAs described herein are used to screen a collection of small molecules to identify agents that modulate the expression of the target gene sequences listed in the enclosed tables. Agents that cause e.g., miRNA(s) expression levels to return to a level that is more normal would be considered potential therapeutic candidates.

[0121] In another example, one or more of the miRNAs described herein are used as prognostic indicators to judge the effectiveness of drug treatment regimes. For example, the levels of miRNAs of the disclosure can be assessed in osteogenesis imperfecta patients receiving a particular treatment to determine the effectiveness of the treatment in lessening one or more phenotypes of the disease.

[0122] In another aspect, an exogenous vector construct comprising at least part of the coding sequence of a gene from Tables 2-7 is expressed in cells ex vivo or in vivo in order to modulate MSC differentiation. For example, in one embodiment, MSC differentiation towards the osteogenic cell fate is promoted by expressing an expression construct comprising at least part of the coding sequence of a gene from Tables 2-5 (e.g. at least part of the coding sequence of CHRD, GCA, or SLC22A2) operationally linked to sequences that allow the expression of the coding sequence. In another embodiment, MSC differentiation towards the osteogenic cell fate is inhibited by expressing an expression construct comprising at least part of the coding sequence of a gene from Tables 6-7 (e.g. at least part of the coding sequence of NOG) operationally linked to sequences that allow the expression of the coding sequence. Methods for generating and expressing expression constructs, including methods for expressing such constructs in vivo in humans, are well known in the art.

[0123] The aforementioned treatment and diagnostic methods are preferably carried out using human subjects; however, one skilled in the art will recognize that the methods of the disclosure can also be carried out in other animal species which possess orthologs of the genes of the Table 2-7 and/or of miR-148b, miR-489, and miR-27a. Determining orthologs of the genes and miRs of the disclosure in other animal species is within the skill of the ordinary worker in the field.

[0124] Note that while the invention has been described with reference to the differentiation of MSCs, the inventors have also recognized that the methods and agents provided herein may be used to modulate the differentiation of any other cell type that has osteogenic potential. Thus, in another series of embodiments, the disclosure provides methods of promoting differentiation towards the osteogenic cell fate of a cell having osteogenic potential, the methods comprising introducing into the cell (in vivo or ex vivo) an effective amount of a composition comprising at least one differentiation promoting agent selected from the group consisting of inhibitors of miR-489, inhibitors of miR-27a, mimics of miR-148b, and siRNAs specific for genes from Tables 6-7. Similarly, in another series of embodiments, the disclosure provides methods of inhibiting differentiation towards the osteogenic cell fate of a cell having osteogenic potential, the methods comprising introducing into the cell (in vivo or ex vivo) an effective amount of a composition comprising at least one differentiation inhibitor selected from the group consisting of mimics of miR-489, mimics of miR-27a, siRNAs specific for genes from Tables 2-5, and inhibitors of miR-148b.

[0125] Given the general applicability of the methods and agents of the disclosure in modulating the differentiation of cells having osteogenic potential (not just MSCs), it will be clear that any disease or condition that is characterized by either inadequate or inappropriate osteogenesis (e.g. ectopic osteogenesis or increased osteogenesis) may be treated using the methods and agents of the disclosure i.e. the methods of the disclosure are not restricted to the treatment of diseases or conditions in which MSC differentiation (or lack thereof) plays a pathological role. Similarly, using the diagnostic methods disclosed herein, diagnostic and prognostic information may be obtained regarding any disease or condition characterized by either inadequate or inappropriate osteogenesis (e.g. ectopic osteogenesis or increased osteogenesis) i.e. the diagnostic methods of the disclosure are not restricted to the diagnosis of diseases or conditions in which MSC differentiation (or lack thereof) plays a pathological role.

[0126] By way of non-limiting example, it is known that certain vascular cells, namely vascular smooth muscle cells (VSMS), calcifying vascular cells (CVC), and pericytes have the ability to differentiate into osteoblasts (or osteoblast-type cell). With respect to VSMCs, it is known that these cells have the ability to differentiate into osteoblasts (or osteoblast-type cell) in response to several stimuli including oxidative stress, bone morphogenetic proteins, or changes in pyrophosphate levels. It has been suggested that the ability of VSMSs, CVCs, and/or pericytes to differentiate into osteoblasts may explain the development of vascular calcifications, such as atherosclerotic calcification, medial artery calcification, and cardiac valve calcification. Johnson et al., Circulation Research 99:1044-1059 (2006). Thus, the methods and agents of the disclosure may be used in the treatment or prevention of vascular calcification. In particular, the agents of the disclosure that inhibit the differentiation towards the osteogenic cell fate of cells having osteogenic differentiation potential (mimics of miR-489, mimics of miR-27a, siRNA specific for genes from Tables 2-5, and inhibitors of miR-148b) may be administered (e.g. in pharmaceutical compositions) to a patient to treat or prevent vascular calcification.

[0127] The following examples are non-limiting.

EXAMPLES

General Reagents and Techniques

[0128] Mesenchymal stem cells, propagation media, and differentiation media were obtained from Lonza, Inc (Basel, Switzerland). Total alkaline phosphatase was determined using an osteogenesis assay kit from Biomedical Research Service Center (SUNY, Buffalo, N.Y.). To detect alkaline phosphatase expression in individual cells, ELF kits were purchased from ATCC (Manassas, Va.). Cells were then analyzed for alkaline phosphatase activity using an ArrayScan VTi (Thermo Fisher).

[0129] In most assays, cells (2,500 cells per well, 96 well plate) were transfected with miRNA mimics and inhibitors (25 nM, DharmaFECT1 Lipid) and incubated for approximately six days before assessing the level of osteogenic differentiation.

Example 1

[0130] Primary Screen for microRNAs that Alter MSC Differentiation Using miRNA Inhibitors

[0131] To identify microRNAs that play an important role in MSC osteogenic differentiation, a screen using microRNA inhibitors targeting over 400 human miRNAs (miR database) was performed in adult human mesenchymal stem cells. To achieve this, MSC cells (Lonza, Inc) were plated in propagation media (Lonza, Inc) at a density of 2.5K cells per well in a 96-well plate (Nunc). At t=24 h, cells were transfected with miRNA inhibitors (miRIDIAN inhibitors, Thermo Fisher Scientific, 25 nM) and cultured for 6 days in differentiation media (Lonza, Inc). Subsequently, cells were lysed, the level of alkaline phosphatase (a classic osteogenic marker) was measured (osteogenesis assay kit, Biomedical Research Service Center, Cat # A-104) and normalized to total protein to determine the relative level of alkaline phosphatase expression in each culture. Untreated cells, cells treated with a negative control inhibitor (5' mAmGmCmUmCmUmCmAmUm CmCmAmUmGmGmAmUmCmUmAmCmUmCmUmUmUmCmUmAmGmGmAmGm GmUmUmGmUmGmAmUmGmGmUmAmCmCmUmAmCmUmCm UmCmGmA, fully 2'-O-methylated, inhibitor of *C. elegans* miR-67) (SEQ ID NO:1), and cells treated with siRNA targeting the RUNX2 transcription factor which has been identified as being important in MSC cell differentiation into osteocytes were used as controls in the primary screen.

Results were assessed using Excel software (Microsoft, Inc.) and standard statistical tools common to the art (e.g. z score).

[0132] Results of these experiments are presented in FIG. **1**. While the majority of inhibitors failed to significantly alter the level of osteogenic differentiation in the culture, a subset (including all of the miRNA inhibitors listed in Table 1) had significant effects on the expression levels of alkaline phosphatase. In particular, transfection of cells with inhibitors targeting hsa-miR-489 and hsa-miR-27a increased alkaline phosphatase levels by as much as 300% over control (non-targeting) miRNA inhibitors. In contrast, treating the cells with inhibitors to hsa-miR148b decreased alkaline phosphatase levels by approximately two-fold (as compared to inhibitor control molecules). These results were confirmed with a second inhibitor design that utilized hairpin flanking regions to enhance functionality of the molecule.

TABLE 1

Lists of miRNAs that when targeted with an inhibitor molecule, increase or decrease MSC osteogenic differentiation. The identity of the miRNA, as well as the sequence of the inhibitor and mimic used in the experiments described in this document are provided.

Molecule	Sequence: "m" = methylated, "p" = phosphorylated. All sequences reported as 5'→3'	SEQ ID NO:
hsa-miR-489 inhibitor	mAmGmCmUmCmUmGmAmAmAmAmG mAmGmCmUmGmCmUmGmCmCmGmUm AmUmAmUmGmUmGmAmUmGmUmCm AmCmUmUmCmGmAmGmAmUmUmCmG mUmCmUmCmGmA	2
hsa-miR-489 mimic sequence (AS strand)	pUCAGUGCAUCACAGAACUUUGU	3
hsa-miR-489 mimic sequence (S strand)	mUmGCCGUAUAUGUGAUGUCACU	4
hsa-miR-148b inhibitor	mAmGmCmUmCmUmCmAmUmCmCmAm UmGmGmAmGmAmCmAmAmAmGmUm UmCmUmGmUmGmAmUmGmCmAmCmU mGmAmCmUmUmGmUmAmCmCmUmA mCmUmCmUmCmGmA	5
hsa-miR-148b mimic (AS strand)	pUCAGUGCAUCACAGAACUUUGU	6
hsa-miR-148b mimic (S strand)	mAmAAGUUCUGUGAUGCACUGAUU	7
hsa-miR-27a inhibitor	mAmGmCmUmCmUmCmAmUmCmCmAm UmGmGmGmGmGmGmCmGmGmAmAm CmUmUmAmGmCmCznAmCmUmGmUmG mAmAmCznAmCmGmUmAmCmCmUmAm CmUmCmUmCmGmA	8
hsa-miR-27a mimic (AS strand)	pUUCACAGUGGCUAAGLTUCCGC	9
hsa-miR-27a mimic (S strand)	mGmGAACUUAGCCACUGUGAAUU	10
Control inhibitor	mAmGmCmUmCmUmCmAmUmCmCmAm UmGmGmAmUmCmUmAmCmUmCmUmU mUmCmUmAmGmGmAmGmGmUmUmG mUmGmAmUmGmGmUmAmCmCmUmA mCmUmCmUmCmGmA	11
Control mimic (AS strand)	pUCACAACCUCCUAGAAAGAGUAGA	12
Control mimic (S strand)	mUmACUCUUUCUAGGAGGUUGUGAUU	13

Example 2

[0133] Test of microRNA Mimics in MSC Differentiation

[0134] If an miRNA inhibitor increases differentiation, it was predicted that a miRNA mimic of the same microRNA would decrease differentiation. Conversely, if an miRNA inhibitor decreased differentiation, it was predicted that treatment of cells with the mimic for that miRNA would amplify differentiation. To that end, miRNA mimics that corresponded to the positive hits observed in the primary (inhibitor) screen were synthesized and transfected into MSCs (2.5K cells per well, 25 nM miRNA mimic, Thermo Fisher Scientific).

[0135] Only three of the miRNAs identified in the primary inhibitor screen exhibited the predicted effects in the mimic screen (see Table 1). While transfection of cells with inhibitors targeting hsa-miR-489 and hsa-miR-27a increased alkaline phosphatase levels, introduction of the corresponding mimics significantly decreased overall differentiation (see FIG. **2***a*). While treating the cells with inhibitors to hsa-miR148b decreased alkaline phosphatase levels, treatment with the corresponding mimic induced the opposite phenotype, elevating alkaline phosphatase expression by over 800%. Both inhibitor and mimic results were dose-dependent (see FIGS. **2**B-G). These results indicate that hsa-miR-489, hsa-miR-27a, and hsa-miR148b play a role in MSCs osteogenic differentiation and that mimics and inhibitors for these miRNAs can be used to modulate differentiation.

Example 3

[0136] Identification of Combinations of miRNA Inhibitors and/or Mimics that Provide Additive Effects.

[0137] Transfection of 1) hsa-miR-489 inhibitors, 2) hsa-miR-27a inhibitors, or 3) hsa-miR148b mimics enhanced expression of alkaline phosphatase and thus osteogenic differentiation by MSCs. To determine whether any combination of these reagents acted in an additive fashion, the action of individual inhibitor or mimic molecules (e.g. inhibitor 489, inhibitor 27a, or mimic 148b) was compared with various combinations including 1) i489+i27a, 2) i489+m148b, 3) i27a+m148b, and 4) i489+i27a+m148b in the differentiation assay. To achieve this, MCS cells were plated at standard cell densities (2.5K per well, standard propagation media) and either individual, pairs, or trios of inhibitors, or inhibitors and mimics were transfected. In this instance, alkaline phosphatase expression was assessed on a cell-by-cell basis using an ELF kit purchased from ATCC (Cat. # SCRR-3010). Briefly, following transfection, cells were incubated in propagation media for 6 days and then fixed in 4% paraformaldehyde. Subsequently, cultures were stained with ELF97 fluorogenic substrate to detect alkaline phosphatase, and counterstained with SYTO Green to label nuclei. Cells were then analyzed for alkaline phosphatase activity using an ArrayScan VTi (Thermo Fisher).

[0138] The results of these experiments along with the appropriate controls are presented in FIG. **3**A. Only two combinations (i489+m148b and i489+i27a+m148b) significantly enhanced the expression of alkaline phosphatase (and thus osteogenic differentiation.) in this assay. As a single pairing (i489+m148b) is common in both data sets, this indicates that the i489+m148b combination acts additively to enhance osteogenic differentiation by MSCs.

Example 4

[0139] miRNA Inhibitors and Mimics Induce Differentiation in Standard Propagation Media

[0140] Initial studies designed to identify miRNA inhibitors and mimics that enhanced osteogenic differentiation were performed in differentiation media. To determine whether the inhibitors and mimics identified in Examples 1 and 2 could induce their effects in propagation media, differentiation studies were performed in both differentiation media and standard propagation media (Lonzo Biologics, Inc).

[0141] The results of these experiments are presented in FIGS. **3**A and **3**B, which show that hsa-miR-489, and hsa-miR-27a inhibitors, as well as hsa-miR148b mimics induce alkaline phosphatase expression in both media conditions. This finding indicates that the inhibitors and mimics listed induce MSC osteogenic differentiation in the absence of other signals.

Example 5

[0142] Identifying Targets of miRs-27a, 489, and 148b.

[0143] To identify targets of the preferred miRNAs identified in previous examples, the sequence of each miRNA was entered into miRanda (http://www.microma.org/microrna/home.do) and a list of potential targets was generated based on the presence of 3' UTR seed complements and additional parameters (see, Lewis et al, (2005) Cell, 120:15-20). For miR-27a, 956 target genes were predicted, for miR-489, 888 target genes, and 327 target genes were predicted for miR-148b. See Tables 2, 4, and 6. Interestingly, roughly 80 of the bioinformatically identified targets were common to both miR-27a and miR-489, the two miRNAs that when introduced into MSCs, inhibited osteogenic differentiation. Additional in silico techniques were then employed to further narrow the list of targets provided by miRanda. Specifically, the genes identified by miRanda were analyzed using the gene ontology tool L2L (http://depts.washington.edu/l2l/database.html) to identify members that were associated with "skeletal development". From this study, 15 of the 956 target genes initially identified for miR-27a, 12 of the 888 target genes for miR-489, and 12 of the 827 target genes for miR-148b were identified (see Tables 3, 5, and 7).

[0144] In order to confirm the target genes identified herein are indeed functionally linked with the miRNAs identified, siRNAs were developed to a subset of the selected target genes to assess the involvement of the gene in osteogenic differentiation. We predicted that if these genes are truly targets of the respective miRNAs, then knockdown of those genes by siRNAs should mimic the effects of the respective miRNA. Four genes exemplified below represent this scenario; three that were predicted to be targeted by both miR-27a and miR-489 and one that was predicted to be targeted by miR-148b.

[0145] For these experiments, pools of siRNAs targeting NOG, CHRD, GCA, SLC22A2, RUNX2 (a positive control), or a non-targeting siRNA (a negative control, "control siRNA") were introduced into hMSCs. Cells were then transferred to differentiation media (48 hr after transfection) and assessed for the expression of AP 6 days after osteogenic induction.

[0146] The results of these studies are presented in FIG. **4** and demonstrate that knockdown of the respective targets mimics the phenotypes associated with the respective miRNAs. Specifically, in cultures treated with siRNA targeting CHRD, GCA and SLC22A2, expression of AP was similar to that observed in cultures where RUNX2 (a known modulator of osteogenic differentiation) was targeted (i.e. less than 50% of the controls). This phenotype is similar to that induced by miR-27a and miR-489 which are predicted to target the CHRD, GCA and SLC22A2 gene. In contrast, cultures treated with siRNA targeting NOG exhibited AP levels that were 2.5 times those observed in control (non-targeting siRNA) cultures. Again, this phenotype parallels that observed when cells were treated with miR148b, the miRNA that targets NOG. Together these studies validate 1) the function of miRs-27a, 489, and 148b in their role as regulators of osteogenic differentiation, and 2) the methods used to identify targets of the preferred miRNAs.

[0147] Tables 2, 4, and 6 represent miRNA target gene lists as determined by miRanda alone. Tables 3, 5, and 7 represent miRNA target gene lists as determined by miRanda followed by L2L bioinformatic procedures.

TABLE 2

All targets of miR-27a.

Transcript ID	RefSeq Accession Number	Target Name	Gene Name
ENST00000229384		15E2_HUMAN	
ENST00000382381	NM_001089	ABCA3	ATP-binding cassette, sub-family A (ABC1), member 3
ENST00000375538	NM_007168	ABCA8	ATP-binding cassette, sub-family A (ABC1), member 8
ENST00000382075	NM_178559	ABCB5	ATP-binding cassette, sub-family B (MDR/TAP), member 5
ENST00000339447		ABCB7	ATP-binding cassette, sub-family B (MDR/TAP), member 7
ENST00000347800	NM_004915 NM_016818.2 NM_207174 NM_207627.1 NM_207628.1 NM_207629	ABCG1	ATP-binding cassette, sub-family G (WHITE), member 1
ENST00000360937	NM_001091.2	ABP1	Amiloride binding protein 1 (amine oxidase (copper-containing))
ENST00000285093	NM_001080467.1	ACAA2	Acetyl-Coenzyme A acyltransferase 2 (mitochondrial 3-oxoacyl-Coenzyme A thiolase)
ENST00000373695	NM_052957	ACRC	Acidic repeat containing
ENST00000289416		ACSM3	Acyl-CoA synthetase medium-chain family member 3
ENST00000224784		ACTA2	Actin, alpha 2, smooth muscle, aorta
ENST00000188312	NM_022496	ACTR6	ARP6 actin-related protein 6 homolog (yeast)
ENST00000265708	NM_001464	ADAM2	ADAM metallopeptidase domain 2 (fertilin beta)
ENST00000367995	NM_005099	ADAMTS4	ADAM metallopeptidase with thrombospondin type 1 motif, 4
ENST00000381052	NM_197941	ADAMTS6	ADAM metallopeptidase with thrombospondin type 1 motif, 6
ENST00000383707	NM_182920	ADAMTS9	ADAM metallopeptidase with thrombospondin type 1 motif, 9
ENST00000358680		ADC	Arginine decarboxylase
ENST00000380823		ADCY3	Adenylate cyclase 3
ENST00000304222		ADORA2B	Adenosine A2b receptor
ENST00000380572	NM_000680 NM_033302 NM_033303 NM_033304	ADRA1A	Adrenergic, alpha-1A-, receptor
ENST00000269143	NM_006796	AFG3L2	AFG3 ATPase family gene 3-like 2 (yeast)
ENST00000375826		AGMAT	Agmatine ureohydrolase (agmatinase)
ENST00000264167	NM_003659	AGPS	Alkylglycerone phosphate synthase
ENST00000273784	NM_001622	AHSG	Alpha-2-HS-glycoprotein
ENST00000375341	NM_003748 NM_170726	ALDH4A1	Aldehyde dehydrogenase 4 family, member A1
ENST00000302708		ALKBH3	AlkB, alkylation repair homolog 3 (*E. coli*)
ENST00000374832	NM_000478	ALPL	Alkaline phosphatase, liver/bone/kidney

TABLE 2-continued

All targets of miR-27a.

Transcript ID	RefSeq Accession Number	Target Name	Gene Name
ENST00000330330		AMY2B	Amylase, alpha 2B (pancreatic)
ENST00000255667	NM_032290	ANKRD32	Ankyrin repeat domain 32
ENST00000265224		ANKRD7	
ENST00000375109		ANP32B	Acidic (leucine-rich) nuclear phosphoprotein 32 family, member B
ENST00000374368	NM_174890	ANUBL1	AN1, ubiquitin-like, homolog (*Xenopus laevis*)
ENST00000296511	NM_001154	ANXA5	Annexin A5
ENST00000258749	NM_001637	AOAH	Acyloxyacyl hydrolase (neutrophil)
ENST00000246149	NM_015013	AOF2	Amine oxidase (flavin containing) domain 2
ENST00000346661	NM_007247 NM_080550	AP1GBP1	AP1 gamma subunit binding protein 1
ENST00000359032	NM_014203.2 NM_130787.2	AP2A1	Adaptor-related protein complex 2, alpha 1 subunit
ENST00000316757		APBA3	Amyloid beta (A4) precursor protein-binding, family A, member 3 (X11-like 2)
ENST00000355285	NM_153000	APCDD1	Adenomatosis polyposis coli down-regulated 1
ENST00000257254		APJ_HUMAN	
ENST00000244669	NM_006789	APOBEC2	Apolipoprotein B mRNA editing enzyme, catalytic polypeptide-like 2
ENST00000313578	NM_173039	AQP11	Aquaporin 11
ENST00000320481	NM_020824	ARHGAP21	Rho GTPase activating protein 21
ENST00000374872	NM_015185	ARHGEF9	Cdc42 guanine nucleotide exchange factor (GEF) 9
ENST00000320767	NM_025047	ARL14	ADP-ribosylation factor-like 14
ENST00000379532		ARMC6_HUMAN	
ENST00000263634	NM_016115 NM_145863	ASB3	Ankyrin repeat and SOCS box-containing 3
ENST00000380920	NM_001671	ASGR1	Asialoglycoprotein receptor 1
ENST00000215906		ASPHD2	Aspartate beta-hydroxylase domain containing 2
ENST00000372393		ASS	
ENST00000378759		ATAD3A	ATPase family, AAA domain containing 3A
ENST00000378737		ATAD3B	ATPase family, AAA domain containing 3B
ENST00000373673	NM_145178	ATOH7	Atonal homolog 7 (*Drosophila*)
ENST00000218008	NM_012069	ATP1B4	ATPase, (Na+)/K+ transporting, beta 4 polypeptide
ENST00000284727	NM_001002258 NM_001689	ATP5G3	ATP synthase, H+ transporting, mitochondrial F0 complex, subunit C3 (subunit 9)
ENST00000369762	NM_001183	ATP6AP1	ATPase, H+ transporting, lysosomal accessory protein 1
ENST00000264649		ATP6V0A1	ATPase, H+ transporting, lysosomal V0 subunit a1
ENST00000374133		ATPBD1B	ATP binding domain 1 family, member B
ENST00000270637		ATPBD3	ATP binding domain 3
ENST00000378853		AURKAIP1	Aurora kinase A interacting protein 1
ENST00000358927	NM_000054	AVPR2	Arginine vasopressin receptor 2 (nephrogenic diabetes insipidus)
ENST00000320865		B3GNTL1	UDP-GlcNAc:betaGal beta-1,3-N-acetylglucosaminyltransferase-like 1
ENST00000367998		B4GALT3	UDP-Gal:betaGlcNAc beta 1,4-galactosyltransferase, polypeptide 3
ENST00000370693	NM_004282	BAG2	BCL2-associated athanogene 2
ENST00000286639	NM_006399	BATF	Basic leucine zipper transcription factor, ATF-like

TABLE 2-continued

All targets of miR-27a.

Transcript ID	RefSeq Accession Number	Target Name	Gene Name
ENST00000359924		BBC3_HUMAN	
ENST00000371608		BCAS4	Breast carcinoma amplified sequence 4
ENST00000310512		BCDIN3	
ENST00000164227	NM_005178	BCL3	B-cell CLL/lymphoma 3
ENST00000361907	NM_017745 NM_020926	BCOR	BCL6 co-repressor
ENST00000372677		BEX2	Brain expressed X-linked 2
ENST00000372645		BEX3_HUMAN	
ENST00000376719	NM_005180	BMI1	BMI1 polycomb ring finger oncogene
ENST00000368636		BNIP3	BCL2/adenovirus E1B 19 kDa interacting protein 3
ENST00000336049	NM_033030 NM_197970	BOLL	Bol, boule-like (*Drosophila*)
ENST00000382392	NM_001002760.1 NM_001002761.1 NM_004678.1	BPY2C	Basic charge, Y-linked, 2C
ENST00000324096		BPY2IP1	
ENST00000303498	NM_000060	BTD	Biotinidase
ENST00000290551	NM_006763	BTG2	BTG family, member 2
ENST00000368859		BUB3	BUB3 budding uninhibited by benzimidazoles 3 homolog (yeast)
ENST00000222969		BUD31	BUD31 homolog (*S. cerevisiae*)
ENST00000370654		BXDC5	Brix domain containing 5
ENST00000372996		BYSL	Bystin-like
ENST00000369286	NM_018017	C10orf118	Chromosome 10 open reading frame 118
ENST00000368815	NM_015608	C10orf137	Chromosome 10 open reading frame 137
ENST00000378605		C10orf30	Chromosome 10 open reading frame 30
ENST00000373279	NM_145306	C10orf35	Chromosome 10 open reading frame 35
ENST00000278064	NM_025145	C10orf79	Chromosome 10 open reading frame 79
ENST00000264020	NM_020153	C11orf60	Chromosome 11 open reading frame 60
ENST00000381047	NM_018169	C12orf35	Chromosome 12 open reading frame 35
ENST00000305457	NM_152335	C15orf27	Chromosome 15 open reading frame 27
ENST00000268138	NM_152259	C15orf42	Chromosome 15 open reading frame 42
ENST00000340827	NM_152448	C15orf43	Chromosome 15 open reading frame 43
ENST00000329410	NM_175900	C16orf54	Chromosome 16 open reading frame 54
ENST00000323355	NM_152728	C18orf20	Chromosome 18 open reading frame 20
ENST00000382462		C19orf24	Chromosome 19 open reading frame 24
ENST00000317292		C19orf30	Chromosome 19 open reading frame 30
ENST00000374526	NM_020362	C1orf128	Chromosome 1 open reading frame 128
ENST00000371007	NM_001013674	C1orf141	Chromosome 1 open reading frame 141
ENST00000366760		C1orf142	Chromosome 1 open reading frame 142
ENST00000370574	NM_017953	C1orf181	Chromosome 1 open reading frame 181
ENST00000367974		C1orf192	Chromosome 1 open reading frame 192
ENST00000368369	NM_006589 NM_198264	C1orf2	Chromosome 1 open reading frame 2
ENST00000369095	NM_018997 NM_031901 NM_144697	C1orf51	Chromosome 1 open reading frame 51

TABLE 2-continued

All targets of miR-27a.

Transcript ID	RefSeq Accession Number	Target Name	Gene Name
ENST00000366628		C1orf57	Chromosome 1 open reading frame 57
ENST00000367723	NM_014283 NM_016227.1	C1orf9	Chromosome 1 open reading frame 9
ENST00000251071		C1QDC1	
ENST00000304189		C20orf55	
ENST00000370351		C20orf59	Chromosome 20 open reading frame 59
ENST00000354932	NM_080574	C20orf70	Chromosome 20 open reading frame 70
ENST00000378239	NM_015701	C2orf30	Chromosome 2 open reading frame 30
ENST00000245907	NM_000064	C3	Complement component 3
ENST00000383793		C3orf20	Chromosome 3 open reading frame 20
ENST00000383805	NM_173472	C3orf24	Chromosome 3 open reading frame 24
ENST00000344697	NM_032806	C3orf39	Chromosome 3 open reading frame 39
ENST00000367070	NM_000715	C4BPA	Complement component 4 binding protein, alpha
ENST00000367659	NM_021243.2	C6orf115	Chromosome 6 open reading frame 115
ENST00000275228	NM_052831	C6orf192	Chromosome 6 open reading frame 192
ENST00000331399	NM_152738	C6orf218	Chromosome 6 open reading frame 218
ENST00000368475	NM_001100411.1 NM_024581.4	C6orf60	Chromosome 6 open reading frame 60
ENST00000368596		C6orf78	
ENST00000289989	NM_001013842	C8orf58	Chromosome 8 open reading frame 58
ENST00000378956	NM_148178 NM_148179	C9orf23	Chromosome 9 open reading frame 23
ENST00000338437	NM_001014435.1 NM_005182	CA7	Carbonic anhydrase VII
ENST00000378357	NM_001216	CA9	Carbonic anhydrase IX
ENST00000316803	NM_001033677 NM_004276 NM_031205	CABP1	Calcium binding protein 1
ENST00000360228	NM_000068.3 NM_023035.2	CACNA1A	Calcium channel, voltage-dependent, P/Q type, alpha 1A subunit
ENST00000288197	NM_018398.2	CACNA2D3	Calcium channel, voltage-dependent, alpha 2/delta 3 subunit
ENST00000252729	NM_031897 NM_145814 NM_145815	CACNG6	Calcium channel, voltage-dependent, gamma subunit 6
ENST00000296742		CAGE1	Cancer antigen 1
ENST00000339300	NM_138793	CANT1	Calcium activated nucleotidase 1
ENST00000270361		CAPN10	Calpain 10
ENST00000354537	NM_006615 NM_016452	CAPN9	Calpain 9
ENST00000380525	NM_001014437.1 NM_001014438.1 NM_001751 NM_139273.2	CARS	Cysteinyl-tRNA synthetase
ENST00000264645		CASC3	Cancer susceptibility candidate 3
ENST00000356473	NM_001080124.1 NM_001080125.1 NM_001228.4 NM_033355 NM_033356 NM_033358	CASP8	Caspase 8, apoptosis-related cysteine peptidase
ENST00000382436		CBWD1	COBW domain containing 1
ENST00000377349		CBWD3	
ENST00000303601	NM_145020	CCDC11	Coiled-coil domain containing 11
ENST00000370276	NM_206886.2	CCDC18	Coiled-coil domain containing 18
ENST00000373602		CCDC28B	Coiled-coil domain containing 28B

TABLE 2-continued

All targets of miR-27a.

Transcript ID	RefSeq Accession Number	Target Name	Gene Name
ENST00000284400	NM_001037325 NM_145036	CCDC46	Coiled-coil domain containing 46
ENST00000321895		CCDC71	Coiled-coil domain containing 71
ENST00000377638		CCDC88	
ENST00000219244	NM_002987	CCL17	Chemokine (C-C motif) ligand 17
ENST00000368261	NM_001008800 NM_001008883.1 NM_005998	CCT3	Chaperonin containing TCP1, subunit 3 (gamma)
ENST00000322008		CD151	CD151 molecule (Raph blood group)
ENST00000367063	NM_000574	CD55	CD55 molecule, decay accelerating factor for complement (Cromer blood group)
ENST00000381845	NM_017913	CDC37L1	Cell division cycle 37 homolog (*S. cerevisiae*)-like 1
ENST00000361246	NM_006035	CDC42BPB	CDC42 binding protein kinase beta (DMPK-like)
ENST00000341529	NM_001795	CDH5	Cadherin 5, type 2, VE-cadherin (vascular epithelium)
ENST00000268383	NM_001802	CDR2	Cerebellar degeneration-related protein 2, 62 kDa
ENST00000382279		CDY1_HUMAN	
ENST00000306882	NM_004680 NM_170723 NM_001003894 NM_001003895	CDY1B	Chromodomain protein, Y-linked, 1B
ENST00000372927		CENPI	Centromere protein I
ENST00000381884	NM_018451	CENPJ	Centromere protein J
ENST00000262127		CEP76	Centrosomal protein 76 kDa
ENST00000355558		CFLAR	CASP8 and FADD-like apoptosis regulator
ENST00000372833		CHCH1_HUMAN	
ENST00000290913		CHCHD6	Coiled-coil-helix-coiled-coil-helix domain containing 6
ENST00000342610		CHRD	Chordin
ENST00000289957	NM_000749	CHRNB3	Cholinergic receptor, nicotinic, beta 3
ENST00000308064	NM_003654	CHST1	Carbohydrate (keratan sulfate Gal-6) sulfotransferase 1
ENST00000358237		CI068_HUMAN	
ENST00000287159		CI070_HUMAN	
ENST00000269878	NM_054113	CIB3	Calcium and integrin binding family member 3
ENST00000323319		CLDN22	
ENST00000355690	NM_138337 NM_201623 NM_205852	CLEC12A	C-type lectin domain family 12, member A
ENST00000261340	NM_001004419 NM_013269	CLEC2D	C-type lectin domain family 2, member D
ENST00000316308		CLK4	CDC-like kinase 4
ENST00000245816		CLPP	ClpP caseinolytic peptidase, ATP-dependent, proteolytic subunit homolog (*E. coli*)
ENST00000281129		CN145_HUMAN	
ENST00000272602	NM_001079878.1 NM_001298	CNGA3	Cyclic nucleotide gated channel alpha 3
ENST00000356162	NM_001008225.1 NM_013316.2	CNOT4	CCR4-NOT transcription complex, subunit 4
ENST00000307431	NM_033401.3 NM_138994	CNTNAP4	Contactin associated protein-like 4
ENST00000307149		COG7	Component of oligomeric golgi complex 7
ENST00000373668	NM_001856.3	COL16A1	Collagen, type XVI, alpha 1
ENST00000370819	NM_030820.3	COL21A1	Collagen, type XXI, alpha 1
ENST00000328333	NM_000094	COL7A1	Collagen, type VII, alpha 1 (epidermolysis bullosa, dystrophic, dominant and recessive)

TABLE 2-continued

All targets of miR-27a.

Transcript ID	RefSeq Accession Number	Target Name	Gene Name
ENST00000261037		COL8A1	Collagen, type VIII, alpha 1
ENST00000333188		COPB2	Coatomer protein complex, subunit beta 2 (beta prime)
ENST00000253484	NM_001866	COX7B	Cytochrome c oxidase subunit VIIb
ENST00000314133	NM_004074	COX8A	Cytochrome c oxidase subunit 8A (ubiquitous)
ENST00000264193	NM_000097	CPOX	Coproporphyrinogen oxidase
ENST00000378951		CPSF3L	Cleavage and polyadenylation specific factor 3-like
ENST00000294997		CR1L	Complement component (3b/4b) receptor 1-like
ENST00000367401	NM_201253	CRB1	Crumbs homolog 1 (*Drosophila*)
ENST00000339139		CRISP2	Cysteine-rich secretory protein 2
ENST00000262982	NM_001316	CSE1L	CSE1 chromosome segregation 1-like (yeast)
ENST00000331769	NM_000759 NM_172219.1 NM_172220	CSF3	Colony stimulating factor 3 (granulocyte)
ENST00000383738	NM_006574	CSPG5	Chondroitin sulfate proteoglycan 5 (neuroglycan C)
ENST00000311083		CSRP2	Cysteine and glycine-rich protein 2
ENST00000201961		CT112_HUMAN	
ENST00000361944	NM_014633	CTR9	Ctr9, Paf1/RNA polymerase II complex component, homolog (*S. cerevisiae*)
ENST00000368980	NM_000396	CTSK	Cathepsin K
ENST00000217131	NM_001336	CTSZ	Cathepsin Z
ENST00000310126		CU058_HUMAN	
ENST00000372453	NM_173494	CXorf41	Chromosome X open reading frame 41
ENST00000285949		CYP26C1	Cytochrome P450, family 26, subfamily C, polypeptide 1
ENST00000371364	NM_016593	CYP39A1	Cytochrome P450, family 39, subfamily A, polypeptide 1
ENST00000336411	NM_017460	CYP3A4	Cytochrome P450, family 3, subfamily A, polypeptide 4
ENST00000379654	NM_022820 NM_057095 NM_057096	CYP3A43	Cytochrome P450, family 3, subfamily A, polypeptide 43
ENST00000368336	NM_004632 NM_033657	DAP3	Death associated protein 3
ENST00000250863	NM_001351.2	DAZL	Deleted in azoospermia-like
ENST00000355857		DBI	Diazepam binding inhibitor (GABA receptor modulator, acyl-Coenzyme A binding protein)
ENST00000339452	NM_017639	DCHS2	Dachsous 2 (*Drosophila*)
ENST00000378278	NM_001033855 NM_001033857 NM_001033858 NM_022487	DCLRE1C	DNA cross-link repair 1C (PSO2 homolog, *S. cerevisiae*)
ENST00000368419	NM_152494	DCST1	DC-STAMP domain containing 1
ENST00000378601		DDB2	Damage-specific DNA binding protein 2, 48 kDa
ENST00000378233		DDX3X_HUMAN	
ENST00000258772		DDX56	DEAD (Asp-Glu-Ala-Asp) box polypeptide 56
ENST00000381131	NM_018369	DEPDC1B	DEP domain containing 1B
ENST00000025429	NM_015954.2	DERA	2-deoxyribose-5-phosphate aldolase homolog (*C. elegans*)
ENST00000374057	NM_001083885.1 NM_015404	DFNB31	Deafness, autosomal recessive 31
ENST00000284688	NM_018180	DHX32	DEAH (Asp-Glu-Ala-His) box polypeptide 32
ENST00000266070	NM_022105 NM_033081 NM_080796 NM_080797	DIDO1	Death inducer-obliterator 1
ENST00000366636		DISC1	Disrupted in schizophrenia 1
ENST00000373347		DLGP3_HUMAN	
ENST00000222598		DLX5	Distal-less homeobox 5

TABLE 2-continued

All targets of miR-27a.

Transcript ID	RefSeq Accession Number	Target Name	Gene Name
ENST00000379075	NM_001035516.1 NM_033317	DMKN	Dermokine
ENST00000373718	NM_021800 NM_201262	DNAJC12	DnaJ (Hsp40) homolog, subfamily C, member 12
ENST00000382564	NM_145261	DNAJC19	DnaJ (Hsp40) homolog, subfamily C, member 19
ENST00000276570		DNAJC5B	DnaJ (Hsp40) homolog, subfamily C, member 5 beta
ENST00000367732	NM_015569.2	DNM3	Dynamin 3
ENST00000268793	NM_022357	DPEP3	Dipeptidase 3
ENST00000263084		DPH1	DPH1 homolog (*S. cerevisiae*)
ENST00000370107		DPH5_HUMAN	
ENST00000242158		DRC1A_HUMAN	
ENST00000305784		DTYMK	Deoxythymidylate kinase (thymidylate kinase)
ENST00000358896	NM_017803	DUS2L	Dihydrouridine synthase 2-like, SMM1 homolog (*S. cerevisiae*)
ENST00000380838	NM_004422	DVL2	Dishevelled, dsh homolog 2 (*Drosophila*)
ENST00000260605	NM_001012665.1 NM_016008	DYNC2LI1	Dynein, cytoplasmic 2, light intermediate chain 1
ENST00000367089	NM_006519	DYNLT1	Dynein, light chain, Tctex-type 1
ENST00000250024	NM_024680	E2F8	E2F transcription factor 8
ENST00000221847		EBI3	Epstein-Barr virus induced gene 3
ENST00000378284	NM_032565	EBPL	Emopamil binding protein-like
ENST00000264205	NM_001397	ECE1	Endothelin converting enzyme 1
ENST00000351385	NM_001037324 NM_001100120.1 NM_001100121.1 NM_014693 NM_032331	ECE2	Endothelin converting enzyme 2
ENST00000304546		ECEL1	Endothelin converting enzyme-like 1
ENST00000220959		EDD1	
ENST00000264263		EFG1_HUMAN	
ENST00000333845	NM_005155 NM_030652 NM_138717	EGFL8	EGF-like-domain, multiple 8
ENST00000253108		EIF3S4	
ENST00000381683		EIF3S6IP	
ENST00000228741	NM_005230	ELK3	ELK3, ETS-domain protein (SRF accessory protein 2)
ENST00000319359		ELL3	Elongation factor RNA polymerase II-like 3
ENST00000163344	NM_022821	ELOVL1	Elongation of very long chain fatty acids (FEN1/Elo2, SUR4/Elo3, yeast)-like 1
ENST00000334192	NM_001008707 NM_004434	EML1	Echinoderm microtubule associated protein like 1
ENST00000372642		ENDOG	Endonuclease G
ENST00000376666		ENTPD6	Ectonucleoside triphosphate diphosphohydrolase 6 (putative function)
ENST00000374311		ERGIC3	ERGIC and golgi 3
ENST00000355449		EVL	Enah/Vasp-like
ENST00000370902	NM_016046	EXOSC1	Exosome component 1
ENST00000320356		EZH2	Enhancer of zeste homolog 2 (*Drosophila*)
ENST00000375551	NM_000504	F10	Coagulation factor X
ENST00000355910	NM_001007524	F8A3	Coagulation factor VIII-associated (intronic transcript) 3
ENST00000301838	NM_003824	FADD	Fas (TNFRSF6)-associated via death domain
ENST00000338446	NM_001033030 NM_001033031 NM_001033032 NM_018147	FAIM	Fas apoptotic inhibitory molecule
ENST00000216214	NM_017911	FAM118A	Family with sequence similarity 118, member A
ENST00000336378		FAM21D	
ENST00000359512		FAM39A	

TABLE 2-continued

All targets of miR-27a.

Transcript ID	RefSeq Accession Number	Target Name	Gene Name
ENST00000357985		FAM3B	Family with sequence similarity 3, member B
ENST00000298575	NM_152421	FAM69B	Family with sequence similarity 69, member B
ENST00000373736		FAM77C	
ENST00000357809		FAM82A	Family with sequence similarity 82, member A
ENST00000300030		FAM96A	Family with sequence similarity 96, member A
ENST00000314606		FARSLA	
ENST00000367721	NM_000639	FASLG	Fas ligand (TNF superfamily, member 6)
ENST00000369956		FBX37_HUMAN	
ENST00000258200		FBXL8	
ENST00000382824	NM_012173 NM_183420 NM_183421	FBXO25	F-box protein 25
ENST00000368176		FCRL1	Fc receptor-like 1
ENST00000368181	NM_030764 NM_138738	FCRL2	Fc receptor-like 2
ENST00000339348	NM_001004310	FCRL6	Fc receptor-like 6
ENST00000371489	NM_013451.2 NM_133337.1	FER1L3	Fer-1-like 3, myoferlin (*C. elegans*)
ENST00000343958		FGD6_HUMAN	
ENST00000370603	NM_004114 NM_033642	FGF13	Fibroblast growth factor 13
ENST00000341420	NM_013281 NM_198391	FLRT3	Fibronectin leucine rich transmembrane protein 3
ENST00000357867	NM_002026 NM_054034.2 NM_212474 NM_212476.1 NM_212482.1	FN1	Fibronectin 1
ENST00000379745	NM_022823	FNDC4	Fibronectin type III domain containing 4
ENST00000370019	NM_173532	FNDC7	Fibronectin type III domain containing 7
ENST00000302177	NM_004497	FOXA3	Forkhead box A3
ENST00000354663	NM_005479	FRAT1	Frequently rearranged in advanced T-cell lymphomas
ENST00000373018	NM_006653	FRS3	Fibroblast growth factor receptor substrate 3
ENST00000166139	NM_005860	FSTL3	Follistatin-like 3 (secreted glycoprotein)
ENST00000250113	NM_004860.2	FXR2	Fragile X mental retardation, autosomal homolog 2
ENST00000342879		FXYD5	FXYD domain containing ion transport regulator 5
ENST00000367029		G0S2	G0/G1switch 2
ENST00000269097		G6PC3	Glucose 6 phosphatase, catalytic, 3
ENST00000259056		GALNT5	UDP-N-acetyl-alpha-D-galactosamine:polypeptide N-acetylgalactosaminyltransferase 5 (GalNAc-T5)
ENST00000227756		GALNTL4	UDP-N-acetyl-alpha-D-galactosamine:polypeptide N-acetylgalactosaminyltransferase-like 4
ENST00000373387		GARNL3	GTPase activating Rap/RanGAP domain-like 3
ENST00000265296	NM_002047.2	GARS	Glycyl-tRNA synthetase
ENST00000357389		GAS6	Growth arrest-specific 6
ENST00000341105		GATA2	GATA binding protein 2
ENST00000372043		GBGT1	Globoside alpha-1,3-N-acetylgalactosaminyltransferase 1
ENST00000233612	NM_012198	GCA	Grancalcin, EF-hand calcium binding protein
ENST00000379596	NM_001491 NM_145649 NM_145655	GCNT2	Glucosaminyl (N-acetyl) transferase 2, I-branching enzyme (I blood group)

TABLE 2-continued

All targets of miR-27a.

Transcript ID	RefSeq Accession Number	Target Name	Gene Name
ENST00000322348	NM_016591	GCNT4	Glucosaminyl (N-acetyl) transferase 4, core 2 (beta-1,6-N-acetylglucosaminyltransferase)
ENST00000378673	NM_005260	GDF9	Growth differentiation factor 9
ENST00000253778	NM_005110.2	GFPT2	Glutamine-fructose-6-phosphate transaminase 2
ENST00000313543		GIMAP7	GTPase, IMAP family member 7
ENST00000357424	NM_004123	GIP	Gastric inhibitory polypeptide
ENST00000241125	NM_021954	GJA3	Gap junction protein, alpha 3, 46 kDa
ENST00000331334		GLRX5	Glutaredoxin 5
ENST00000318348	NM_016433	GLTP	Glycolipid transfer protein
ENST00000303210		GNB2	Guanine nucleotide binding protein (G protein), beta polypeptide 2
ENST00000354540	NM_014366 NM_206825.1 NM_206826.1	GNL3	Guanine nucleotide binding protein-like 3 (nucleolar)
ENST00000225567	NM_004287.3 NM_054022	GOSR2	Golgi SNAP receptor complex member 2
ENST00000334304	NM_145290	GPR125	G protein-coupled receptor 125
ENST00000267015	NM_020370	GPR84	G protein-coupled receptor 84
ENST00000315614		GPS2	G protein pathway suppressor 2
ENST00000309731	NM_001012642	GRAMD2	GRAM domain containing 2
ENST00000347612		GRIN2C	Glutamate receptor, ionotropic, N-methyl D-aspartate 2C
ENST00000369106		GRK5	G protein-coupled receptor kinase 5
ENST00000296479		GRM2	Glutamate receptor, metabotropic 2
ENST00000319065	NM_000843	GRM6	Glutamate receptor, metabotropic 6
ENST00000256857	NM_001012512.1 NM_001012513.1 NM_002091	GRP	Gastrin-releasing peptide
ENST00000086933		GSCL	
ENST00000219627	NM_002094.2	GSPT1	G1 to S phase transition 1
ENST00000340438	NM_018094	GSPT2	G1 to S phase transition 2
ENST00000221130	NM_000637	GSR	Glutathione reductase
ENST00000267869	NM_004492	GTF2A2	General transcription factor IIA, 2, 12 kDa
ENST00000376329		GTF2H4	General transcription factor IIH, polypeptide 4, 52 kDa
ENST00000332377	NM_207118	GTF2H5	General transcription factor IIH, polypeptide 5
ENST00000372108	NM_012087	GTF3C5	General transcription factor IIIC, polypeptide 5, 63 kDa
ENST00000323798	NM_002103	GYS1	Glycogen synthase 1 (muscle)
ENST00000296417		H2AFZ	H2A histone family, member Z
ENST00000375852	NM_002110	HCK	Hemopoietic cell kinase
ENST00000314583		HCLS1	Hematopoietic cell-specific Lyn substrate 1
ENST00000373705		HCRTR1	Hypocretin (orexin) receptor 1
ENST00000262069	NM_014707.1 NM_058176.2 NM_058177.2 NM_178423.1 NM_178425.2	HDAC9	Histone deacetylase 9
ENST00000300605		HDHD2	Haloacid dehalogenase-like hydrolase domain containing 2
ENST00000374178	NM_031219	HDHD3	Haloacid dehalogenase-like hydrolase domain containing 3
ENST00000303775		HEMK2_HUMAN	
ENST00000329138		HGS	Hepatocyte growth factor-regulated tyrosine kinase substrate
ENST00000370940	NM_001031693 NM_001036645 NM_001036646 NM_007071	HHLA3	HERV-H LTR-associating 3

TABLE 2-continued

All targets of miR-27a.

Transcript ID	RefSeq Accession Number	Target Name	Gene Name
ENST00000229633	NM_138571	HINT3	Histidine triad nucleotide binding protein 3
ENST00000336926	NM_005338	HIP1	Huntingtin interacting protein 1
ENST00000360010		HKR1	GLI-Kruppel family member HKR1
ENST00000366903		HLX1	
ENST00000380749		HMGN1	High-mobility group nucleosome binding domain 1
ENST00000376263	NM_002140 NM_031262 NM_031263	HNRPK	Heterogeneous nuclear ribonucleoprotein K
ENST00000336726	NM_152510.2	HORMAD2	HORMA domain containing 2
ENST00000222753	NM_000522	HOXA13	Homeobox A13
ENST00000239144	NM_024016	HOXB8	Homeobox B8
ENST00000243108		HOXC6	
ENST00000306324	NM_014621	HOXD4	Homeobox D4
ENST00000299671		HSBP1	Heat shock factor binding protein 1
ENST00000225929	NM_000413	HSD17B1	Hydroxysteroid (17-beta) dehydrogenase 1
ENST00000373024		I5P2_HUMAN	
ENST00000235971		ID3	Inhibitor of DNA binding 3, dominant negative helix-loop-helix protein
ENST00000370747		IFI44	Interferon-induced protein 44
ENST00000276927	NM_024013	IFNA1	Interferon, alpha 1
ENST00000380205	NM_002170	IFNA8	Interferon, alpha 8
ENST00000229135	NM_000619	IFNG	Interferon, gamma
ENST00000296266	NM_018262 NM_052985 NM_052989 NM_052990	IFT122	Intraflagellar transport 122 homolog (Chlamydomonas)
ENST00000198587		IGSF9	Immunoglobulin superfamily, member 9
ENST00000367120	NM_014002	IKBKE	Inhibitor of kappa light polypeptide gene enhancer in B-cells, kinase epsilon
ENST00000290200		IL10RB	Interleukin 10 receptor, beta
ENST00000305579		IL12A	Interleukin 12A (natural killer cell stimulatory factor 1, cytotoxic lymphocyte maturation factor 1, p35)
ENST00000322153	NM_005535.1 NM_153701	IL12RB1	Interleukin 12 receptor, beta 1
ENST00000264260	NM_003853	IL18RAP	Interleukin 18 receptor accessory protein
ENST00000367095	NM_005449	IL24	Interleukin 24
ENST00000276110		IL2RG	Interleukin 2 receptor, gamma (severe combined immunodeficiency)
ENST00000368485	NM_000565 NM_181359	IL6R	Interleukin 6 receptor
ENST00000259239		IMP4	IMP4, U3 small nucleolar ribonucleoprotein, homolog (yeast)
ENST00000269159		IMPA2	Inositol(myo)-1(or 4)-monophosphatase 2
ENST00000322522	NM_002194	INPP1	Inositol polyphosphate-1-phosphatase
ENST00000265239		IQCG	IQ motif containing G
ENST00000356669	NM_016123	IRAK4	Interleukin-1 receptor-associated kinase 4
ENST00000258886	NM_004136	IREB2	Iron-responsive element binding protein 2
ENST00000303389		IRF2	Interferon regulatory factor 2
ENST00000268638	NM_002163	IRF8	Interferon regulatory factor 8
ENST00000379231		ISG20L1	Interferon stimulated exonuclease gene 20 kDa-like 1
ENST00000249842	NM_005545 NM_201526	ISLR	Immunoglobulin superfamily containing leucine-rich repeat
ENST00000268297	NM_005353	ITGAD	Integrin, alpha D

TABLE 2-continued

All targets of miR-27a.

Transcript ID	RefSeq Accession Number	Target Name	Gene Name
ENST00000335404	NM_198510	ITIH5L	Inter-alpha (globulin) inhibitor H5-like
ENST00000380883	NM_006277 NM_019595 NM_147152.1	ITSN2	Intersectin 2
ENST00000383816		JAGN1	Jagunal homolog 1 (*Drosophila*)
ENST00000327520		JHD2C_HUMAN	
ENST00000335080	NM_018039	JMJD2D	Jumonji domain containing 2D
ENST00000335647	NM_007044	KATNA1	Katanin p60 (ATPase-containing) subunit A 1
ENST00000328224	NM_002233.2	KCNA4	Potassium voltage-gated channel, shaker-related subfamily, member 4
ENST00000316071	NM_002241	KCNJ10	Potassium inwardly-rectifying channel, subfamily J, member 10
ENST00000233826	NM_002242	KCNJ13	Potassium inwardly-rectifying channel, subfamily J, member 13
ENST00000295101	NM_002239	KCNJ3	Potassium inwardly-rectifying channel, subfamily J, member 3
ENST00000366621		KCNK1	Potassium channel, subfamily K, member 1
ENST00000353172		KCTD14	
ENST00000379108	NM_198404	KCTD4	Potassium channel tetramerisation domain containing 4
ENST00000360029	NM_198353	KCTD8	Potassium channel tetramerisation domain containing 8
ENST00000297423	NM_001080394.1	KIAA0146	KIAA0146
ENST00000370992		KIAA0690	
ENST00000287546		KIAA0804	
ENST00000283351	NM_014939	KIAA1012	KIAA1012
ENST00000264501	NM_015312.2	KIAA1109	KIAA1109
ENST00000296121		KIAA1143	KIAA1143
ENST00000328839	NM_020958 NM_058237	KIAA1622	KIAA1622
ENST00000369271		KIAA1914	
ENST00000378843	NM_022113.3	KIF13A	Kinesin family member 13A
ENST00000353409	NM_015074 NM_183416	KIF1B	Kinesin family member 1B
ENST00000378746	NM_007054	KIF3A	Kinesin family member 3A
ENST00000332780	NM_173546	KLHDC8B	Kelch domain containing 8B
ENST00000378222	NM_002267	KPNA3	Karyopherin alpha 3 (importin alpha 4)
ENST00000329122	NM_181602	KRTAP6-1	Keratin associated protein 6-1
ENST00000251646		KRTHA3B	
ENST00000293670		KRTHB3	
ENST00000264170	NM_001032998 NM_003937	KYNU	Kynureninase (L-kynurenine hydrolase)
ENST00000373134		L3MBTL	
ENST00000381167		LAPTM4A	Lysosomal-associated protein transmembrane 4 alpha
ENST00000357788		LCN8	Lipocalin 8
ENST00000371103		LCOR_HUMAN	
ENST00000280706	NM_144972	LDHAL6A	Lactate dehydrogenase A-like 6A
ENST00000254301		LGALS3	Lectin, galactoside-binding, soluble, 3
ENST00000263726	NM_033343	LHX4	LIM homeobox 4
ENST00000261203		LIN7A	Lin-7 homolog A (*C. elegans*)
ENST00000267102		LMBR1L	Limb region 1 homolog (mouse)-like
ENST00000296603	NM_001007527	LMBRD2	LMBR1 domain containing 2
ENST00000368300	NM_005572 NM_170707 NM_170708	LMNA	Lamin A/C
ENST00000376633	NM_002335	LRP5	Low density lipoprotein receptor-related protein 5

TABLE 2-continued

All targets of miR-27a.

Transcript ID	RefSeq Accession Number	Target Name	Gene Name
ENST00000261349	NM_002336	LRP6	Low density lipoprotein receptor-related protein 6
ENST00000373324	NM_001005373 NM_001005374 NM_138361	LRSAM1	Leucine rich repeat and sterile alpha motif containing 1
ENST00000379953		LY86	Lymphocyte antigen 86
ENST00000244333		LYPD3	LY6/PLAUR domain containing 3
ENST00000374505	NM_007260 NR_001444.3	LYPLA2	Lysophospholipase II
ENST00000215739	NM_006767	LZTR1	Leucine-zipper-like transcription regulator 1
ENST00000372173	NM_001003690.1 NM_014628	MAD2L1BP	MAD2L1 binding protein
ENST00000285879	NM_005462	MAGEC1	Melanoma antigen family C, 1
ENST00000261483		MAN2A1	Mannosidase, alpha, class 2A, member 1
ENST00000366920	NM_005922 NM_006724	MAP3K4	Mitogen-activated protein kinase kinase kinase 4
ENST00000357955	NM_004635	MAPKAPK3	Mitogen-activated protein kinase-activated protein kinase 3
ENST00000294506		MATN1	Matrilin 1, cartilage matrix protein
ENST00000359787		MB	Myoglobin
ENST00000271648	NM_021960 NM_182763	MCL1	Myeloid cell leukemia sequence 1 (BCL2-related)
ENST00000230321	NM_005586	MDFI	MyoD family inhibitor
ENST00000267984	NM_022566	MESDC1	Mesoderm development candidate 1
ENST00000372811		MFSD2	Major facilitator superfamily domain containing 2
ENST00000312952	NM_004668.1	MGAM	Maltase-glucoamylase (alpha-glucosidase)
ENST00000371994	NM_004897	MINPP1	Multiple inositol polyphosphate histidine phosphatase, 1
ENST00000231790	NM_000249	MLH1	MutL homolog 1, colon cancer, nonpolyposis type 2 (*E. coli*)
ENST00000338530	NM_001042467.1 NM_024101	MLPH	Melanophilin
ENST00000182377	NM_018099	MLSTD1	Male sterility domain containing 1
ENST00000345114	NM_032951 NM_032952.2 NM_032953.2 NM_032954	MLXIPL	MLX interacting protein-like
ENST00000262065	NM_012329	MMD	Monocyte to macrophage differentiation-associated
ENST00000368141	NM_002432	MNDA	Myeloid cell nuclear differentiation antigen
ENST00000296473		MON1A	MON1 homolog A (yeast)
ENST00000333676		MRPL12	Mitochondrial ribosomal protein L12
ENST00000306185		MRPL13	Mitochondrial ribosomal protein L13
ENST00000379666		MRPL33	Mitochondrial ribosomal protein L33
ENST00000309352	NM_032478	MRPL38	Mitochondrial ribosomal protein L38
ENST00000370234	NM_032112 NM_176792 NM_176793 NM_176794	MRPL43	Mitochondrial ribosomal protein L43
ENST00000312513	NM_032351	MRPL45	Mitochondrial ribosomal protein L45
ENST00000372940	NM_016065	MRPS16	Mitochondrial ribosomal protein S16
ENST00000313608		MRPS23	Mitochondrial ribosomal protein S23
ENST00000276585		MRPS28	Mitochondrial ribosomal protein S28
ENST00000322684		MSI2	Musashi homolog 2 (*Drosophila*)
ENST00000314404	NM_017762.2	MTMR10	Myotubularin related protein 10
ENST00000323456	NM_004687	MTMR4	Myotubularin related protein 4

TABLE 2-continued

All targets of miR-27a.

Transcript ID	RefSeq Accession Number	Target Name	Gene Name
ENST00000374852	NM_017677	MTMR8	Myotubularin related protein 8
ENST00000381954		MUC20	Mucin 20, cell surface associated
ENST00000303270		MXD3	MAX dimerization protein 3
ENST00000252102		NDUFA2	NADH dehydrogenase (ubiquinone) 1 alpha subcomplex, 2, 8 kDa
ENST00000381417		NDUFS4	NADH dehydrogenase (ubiquinone) Fe—S protein 4, 18 kDa (NADH-coenzyme Q reductase)
ENST00000375569		NECAP2	NECAP endocytosis associated 2
ENST00000250495		NEDD8	Neural precursor cell expressed, developmentally down-regulated 8
ENST00000379072	NM_012224.1	NEK1	NIMA (never in mitosis gene a)-related kinase 1
ENST00000366999	NM_002497	NEK2	NIMA (never in mitosis gene a)-related kinase 2
ENST00000356175	NM_000267 NM_001042492.1	NF1	Neurofibromin 1 (neurofibromatosis, von Recklinghausen disease, Watson disease)
ENST00000355469	NM_145912	NFAM1	NFAT activating protein with ITAM motif 1
ENST00000361004	NM_006164.2	NFE2L2	Nuclear factor (erythroid-derived 2)-like 2
ENST00000375724	NM_005384	NFIL3	Nuclear factor, interleukin 3 regulated
ENST00000368009	NM_005600	NIT1	Nitrilase 1
ENST00000285279		NM_030796.3	
ENST00000360476	NM_021077 NM_205858.1	NMB	Neuromedin B
ENST00000255262	NM_020167	NMUR2	Neuromedin U receptor 2
ENST00000382421		NOL1	Nucleolar protein 1, 120 kDa
ENST00000328848	NM_018648	NOLA3	Nucleolar protein family A, member 3 (H/ACA small nucleolar RNPs)
ENST00000375043	NM_004557	NOTCH4	Notch homolog 4 (*Drosophila*)
ENST00000367158	NM_015718	NOX3	NADPH oxidase 3
ENST00000301284		NP_001001520.1	
ENST00000389349		NP_001001671.1	
ENST00000304823		NP_001004341.1	
ENST00000351071		NP_001005751.1	
ENST00000333305		NP_001007190.1	
ENST00000370732		NP_001007552.1	
ENST00000341942		NP_001008396.1	
ENST00000298943		NP_001010908.1	
ENST00000378704		NP_001012457.1	
ENST00000370494		NP_001013007.1	
ENST00000344380		NP_001013646.1	
ENST00000378909		NP_001017363.1	
ENST00000370743		NP_001017417.1	
ENST00000370737		NP_001017435.1	
ENST00000381461		NP_001017969.1	
ENST00000295220		NP_001025167.1	
ENST00000374412		NP_001034934.1	
ENST00000294916		NP_001035043.2	
ENST00000382142		NP_001035536.1	
ENST00000329687		NP_001111.2	
ENST00000355848		NP_006324.1	
ENST00000323199		NP_031375.3	
ENST00000357765		NP_054763.2	
ENST00000357899		NP_054874.3	
ENST00000377264		NP_055919.1	
ENST00000381237		NP_056174.1	
ENST00000296444		NP_057563.3	
ENST00000313565		NP_060000.1	
ENST00000321489		NP_060028.2	
ENST00000367501		NP_060143.3	
ENST00000265154		NP_060170.1	
ENST00000238788		NP_060197.3	

TABLE 2-continued

All targets of miR-27a.

Transcript ID	RefSeq Accession Number	Target Name	Gene Name
ENST00000357242		NP_060222.2	
ENST00000379207		NP_060463.1	
ENST00000358591		NP_060741.2	
ENST00000358867		NP_060950.2	
ENST00000329540		NP_061930.1	
ENST00000359236		NP_061959.2	
ENST00000270066		NP_061981.1	
ENST00000263657		NP_064528.1	
ENST00000336353		NP_064580.1	
ENST00000319688		NP_065789.1	
ENST00000368842		NP_071409.2	
ENST00000317623		NP_071940.3	
ENST00000295079		NP_078796.1	
ENST00000371410		NP_078804.1	
ENST00000358067		NP_078896.3	
ENST00000238936		NP_079065.2	
ENST00000278886		NP_079452.3	
ENST00000272521		NP_085054.1	
ENST00000369218		NP_110423.3	
ENST00000263776		NP_115981.1	
ENST00000367003		NP_116094.2	
ENST00000376396		NP_296375.1	
ENST00000300079		NP_542392.2	
ENST00000290894		NP_612365.1	
ENST00000341392		NP_620134.2	
ENST00000355682		NP_653178.1	
ENST00000301037		NP_653211.1	
ENST00000002125		NP_653337.1	
ENST00000335360		NP_689552.2	
ENST00000281961		NP_689603.1	
ENST00000282259		NP_689618.2	
ENST00000367136		NP_689704.3	
ENST00000370720		NP_689795.2	
ENST00000296468		NP_689991.1	
ENST00000292616		NP_690852.1	
ENST00000304584		NP_699196.1	
ENST00000296953		NP_705835.1	
ENST00000265453		NP_775795.2	
ENST00000329378		NP_775936.1	
ENST00000378660		NP_775966.1	
ENST00000335211		NP_840059.1	
ENST00000380814		NP_861450.1	
ENST00000334588		NP_872620.1	
ENST00000285718		NP_878908.1	
ENST00000383694		NP_878913.1	
ENST00000340369		NP_919269.2	
ENST00000343063		NP_919288.1	
ENST00000275053		NP_940870.1	
ENST00000306862		NP_940968.1	
ENST00000237186		NP_944602.1	
ENST00000317449		NP_981967.1	
ENST00000354805		NP_982273.1	
ENST00000377137		NP_997211.1	
ENST00000357485		NP_997646.1	
ENST00000339255	NM_020448	NPAL3	NIPA-like domain containing 3
ENST00000269228	NM_000271	NPC1	Niemann-Pick disease, type C1
ENST00000265634	NM_002523	NPTX2	Neuronal pentraxin II
ENST00000242152		NPY	Neuropeptide Y
ENST00000358384		NR_002822.1	
ENST00000332894		NR2F2	Nuclear receptor subfamily 2, group F, member 2
ENST00000291442	NM_005234	NR2F6	Nuclear receptor subfamily 2, group F, member 6
ENST00000314171	NM_030759	NRBF2	Nuclear receptor binding factor 2
ENST00000382740		NSG1_HUMAN	
ENST00000219066		NTHL1	Nth endonuclease III-like 1 (*E. coli*)
ENST00000231498		NU155_HUMAN	
ENST00000361681		NU6M_HUMAN	
ENST00000367157		NUAK2	NUAK family, SNF1-like kinase, 2
ENST00000262302		NUBP2	Nucleotide binding protein 2 (MinD homolog, *E. coli*)

TABLE 2-continued

All targets of miR-27a.

Transcript ID	RefSeq Accession Number	Target Name	Gene Name
ENST00000334513		NUD17_HUMAN	
ENST00000339154		NUDT6	Nudix (nucleoside diphosphate linked moiety X)-type motif 6
ENST00000366680	NM_018230	NUP133	Nucleoporin 133 kDa
ENST00000294172		NXF1	Nuclear RNA export factor 1
ENST00000372107	NM_018698	NXT2	Nuclear transport factor 2-like export factor 2
ENST00000324607		OACT1	
ENST00000366706		OBSCN	Obscurin, cytoskeletal calmodulin and titin-interacting RhoGEF
ENST00000334011	NM_152635	OIT3	Oncoprotein induced transcript 3
ENST00000371797	NM_006334 NM_014279	OLFM1	Olfactomedin 1
ENST00000333973	NM_001004738	OR5L1	Olfactory receptor, family 5, subfamily L, member 1
ENST00000297431	NM_002553 NM_181747.1	ORC5L	Origin recognition complex, subunit 5-like (yeast)
ENST00000313733	NM_014835 NM_144498	OSBPL2	Oxysterol binding protein-like 2
ENST00000263650	NM_020896 NM_145638	OSBPL5	Oxysterol binding protein-like 5
ENST00000378500	NM_000531	OTC	Ornithine carbamoyltransferase
ENST00000339475	NM_021728 NM_172337.1	OTX2	Orthodenticle homeobox 2
ENST00000378434	NM_005767	P2RY5	Purinergic receptor P2Y, G-protein coupled, 5
ENST00000360935		P54762-4	
ENST00000318607	NM_002568	PABPC1	Poly(A) binding protein, cytoplasmic 1
ENST00000381859	NM_030979	PABPC3	Poly(A) binding protein, cytoplasmic 3
ENST00000374284	NM_000437	PAFAH2	Platelet-activating factor acetylhydrolase 2, 40 kDa
ENST00000265192		PAIP2	Poly(A) binding protein interacting protein 2
ENST00000378466	NM_018216	PANK4	Pantothenate kinase 4
ENST00000045065	NM_001003931.1 NM_001003935.1 NM_005485.3	PARP3	Poly (ADP-ribose) polymerase family, member 3
ENST00000368465	NM_020524	PBXIP1	Pre-B-cell leukemia homeobox interacting protein 1
ENST00000376286		PCCA	Propionyl Coenzyme A carboxylase, alpha polypeptide
ENST00000377922	NM_001040429	PCDH17	Protocadherin 17
ENST00000297529	NM_006197.3	PCM1	Pericentriolar material 1
ENST00000282096		PDE3B	Phosphodiesterase 3B, cGMP-inhibited
ENST00000227868		PDHX	Pyruvate dehydrogenase complex, component X
ENST00000219406	NM_006849.2	PDIA2	Protein disulfide isomerase family A, member 2
ENST00000005178	NM_002612	PDK4	Pyruvate dehydrogenase kinase, isozyme 4
ENST00000340532	NM_003687	PDLIM4	PDZ and LIM domain 4
ENST00000261313		PEBP1	Phosphatidylethanolamine binding protein 1
ENST00000367756	NM_000288	PEX7	Peroxisomal biogenesis factor 7
ENST00000296029	NM_002619	PF4	Platelet factor 4 (chemokine (C-X-C motif) ligand 4)
ENST00000226524	NM_002620	PF4V1	Platelet factor 4 variant 1
ENST00000340802		PFKM	Phosphofructokinase, muscle
ENST00000321327	NM_024554	PGBD5	PiggyBac transposable element derived 5
ENST00000300408		PHB	Prohibitin
ENST00000361895		PHF15_HUMAN	
ENST00000327906		PHF7	PHD finger protein 7
ENST00000369409	NM_006623	PHGDH	Phosphoglycerate dehydrogenase
ENST00000328273		PHKG2	Phosphorylase kinase, gamma 2 (testis)

TABLE 2-continued

All targets of miR-27a.

Transcript ID	RefSeq Accession Number	Target Name	Gene Name
ENST00000369604		PHTF1	Putative homeodomain transcription factor 1
ENST00000331075	NM_001002837.1 NM_014422.2	PIB5PA	Phosphatidylinositol (4,5) bisphosphate 5-phosphatase, A
ENST00000026218		PIGQ	Phosphatidylinositol glycan anchor biosynthesis, class Q
ENST00000291009	NM_002652	PIP	Prolactin-induced protein
ENST00000230643	NM_014386.2	PKD2L2	Polycystic kidney disease 2-like 2
ENST00000368452		PKIB	Protein kinase (cAMP-dependent, catalytic) inhibitor beta
ENST00000372764	NM_002658	PLAU	Plasminogen activator, urokinase
ENST00000325234	NM_000932	PLCB3	Phospholipase C, beta 3 (phosphatidylinositol-specific)
ENST00000326631		PLEKHJ1	Pleckstrin homology domain containing, family J member 1
ENST00000381170	NM_006622	PLK2	Polo-like kinase 2 (*Drosophila*)
ENST00000380965		PM14_HUMAN	
ENST00000368276		PMF1	Polyamine-modulated factor 1
ENST00000369216		PNLIPRP1	Pancreatic lipase-related protein 1
ENST00000254508		PO210_HUMAN	
ENST00000265465	NM_002689	POLA2	Polymerase (DNA directed), alpha 2 (70 kD subunit)
ENST00000222572		PON2	Paraoxonase 2
ENST00000264231		POPDC2	Popeye domain containing 2
ENST00000229003		PP11_HUMAN	
ENST00000373232		PPA1	Pyrophosphatase (inorganic) 1
ENST00000269812		PPAP2C	Phosphatidic acid phosphatase type 2C
ENST00000309576	NM_005037 NM_015869 NM_138711 NM_138712	PPARG	Peroxisome proliferator-activated receptor gamma
ENST00000225174	NM_005729	PPIF	Peptidylprolyl isomerase F (cyclophilin F)
ENST00000367437	NM_139126	PPIL4	Peptidylprolyl isomerase (cyclophilin)-like 4
ENST00000295908		PPM1K	Protein phosphatase 1K (PP2C domain containing)
ENST00000328257		PPME1_HUMAN	
ENST00000376745		PPP1CA	Protein phosphatase 1, catalytic subunit, alpha isoform
ENST00000279387		PPP4C	Protein phosphatase 4 (formerly X), catalytic subunit
ENST00000229430	NM_002726	PREP	Prolyl endopeptidase
ENST00000296800	NM_006251 NM_206907	PRKAA1	Protein kinase, AMP-activated, alpha 1 catalytic subunit
ENST00000378567	NM_001033581.1 NM_001033582.1 NM_002744	PRKCZ	Protein kinase C, zeta
ENST00000325748		PRKRA	Protein kinase, interferon-inducible double stranded RNA dependent activator
ENST00000361340	NM_001536.3 NM_198318.2 NM_198319	PRMT1	Protein arginine methyltransferase 1
ENST00000374477		PROCR	Protein C receptor, endothelial (EPCR)
ENST00000375547	NM_003891	PROZ	Protein Z, vitamin K-dependent plasma glycoprotein
ENST00000227524	NM_014502	PRPF19	PRP19/PSO4 pre-mRNA processing factor 19 homolog (*S. cerevisiae*)
ENST00000360614		PRSS15	
ENST00000376376	NM_020200	PRTFDC1	Phosphoribosyl transferase domain containing 1
ENST00000291752	NM_002784	PSG9	Pregnancy specific beta-1-glycoprotein 9
ENST00000322215		PSMA1	Proteasome (prosome, macropain) subunit, alpha type, 1

TABLE 2-continued

All targets of miR-27a.

Transcript ID	RefSeq Accession Number	Target Name	Gene Name
ENST00000261303		PSMC1	Proteasome (prosome, macropain) 26S subunit, ATPase, 1
ENST00000219313		PSMD7	Proteasome (prosome, macropain) 26S subunit, non-ATPase, 7
ENST00000215071	NM_002812	PSMD8	Proteasome (prosome, macropain) 26S subunit, non-ATPase, 8
ENST00000338910		PSPC1	Paraspeckle component 1
ENST00000375275		PTCH	
ENST00000261266		PTPRB	Protein tyrosine phosphatase, receptor type, B
ENST00000354705	NM_002840 NM_130440	PTPRF	Protein tyrosine phosphatase, receptor type, F
ENST00000281171	NM_002848 NM_030667 NM_030668.1 NM_030669.1 NM_030670.1 NM_030671.1	PTPRO	Protein tyrosine phosphatase, receptor type, O
ENST00000335223		PTRH1	Peptidyl-tRNA hydrolase 1 homolog (*S. cerevisiae*)
ENST00000329875	NM_006907 NM_153824	PYCR1	Pyrroline-5-carboxylate reductase 1
ENST00000382759		Q15379_HUMAN	
ENST00000300167		Q15885_HUMAN	
ENST00000389664		Q3B8N5_HUMAN	
ENST00000377441		Q4V339_HUMAN	
ENST00000284630		Q5H9U9_HUMAN	
ENST00000371125		Q5JQE8_HUMAN	
ENST00000358745		Q5JTY0_HUMAN	
ENST00000377380		Q5RIA9_HUMAN	
ENST00000355876		Q5SNT8_HUMAN	
ENST00000376284		Q5STD0_HUMAN	
ENST00000369586		Q5T5W8_HUMAN	
ENST00000377523		Q5T7N8_HUMAN	
ENST00000382086		Q5TI84_HUMAN	
ENST00000374801		Q5VW05_HUMAN	
ENST00000357846		Q6DRA6_HUMAN	
ENST00000357858		Q6IPT3_HUMAN	
ENST00000330280		Q6P1K8_HUMAN	
ENST00000376153		Q6P6C6_HUMAN	
ENST00000258884		Q6PCB6_HUMAN	
ENST00000293695		Q6PIF2_HUMAN	
ENST00000310694		Q6UTX4_HUMAN	
ENST00000371751		Q6ZP22_HUMAN	
ENST00000329807		Q6ZQP9_HUMAN	
ENST00000373364		Q6ZRV4_HUMAN	
ENST00000381934		Q6ZSM7_HUMAN	
ENST00000342355		Q6ZU04_HUMAN	
ENST00000377696		Q6ZUF0_HUMAN	
ENST00000375548		Q6ZUP0_HUMAN	
ENST00000370590		Q6ZUQ1_HUMAN	
ENST00000371863		Q6ZVB9_HUMAN	
ENST00000382314		Q86SG3-2	
ENST00000334298		Q86TT0_HUMAN	
ENST00000307823		Q8N467_HUMAN	
ENST00000322053		Q8N675_HUMAN	
ENST00000356176		Q8N7L3_HUMAN	
ENST00000313294		Q8NA31_HUMAN	
ENST00000380816		Q8NA85_HUMAN	
ENST00000327685		Q8NBD7_HUMAN	
ENST00000277491		Q8NDA2_HUMAN	
ENST00000313807		Q8TAS2_HUMAN	
ENST00000358148		Q8TEB0_HUMAN	
ENST00000268314		Q96C12_HUMAN	
ENST00000339359		Q9BVY2_HUMAN	
ENST00000253461		Q9H693_HUMAN	
ENST00000261651		Q9H7M0_HUMAN	
ENST00000321536		Q9P188_HUMAN	

TABLE 2-continued

All targets of miR-27a.

Transcript ID	RefSeq Accession Number	Target Name	Gene Name
ENST00000267328	NM_017817	RAB20	RAB20, member RAS oncogene family
ENST00000344445	NM_016277 NM_183227	RAB23	RAB23, member RAS oncogene family
ENST00000375836		RAB3GAP1	RAB3 GTPase activating protein subunit 1 (catalytic)
ENST00000373826		RAB42	RAB42, member RAS oncogene family
ENST00000373538	NM_005833	RABEPK	Rab9 effector protein with kelch motifs
ENST00000337432		RAD51C	RAD51 homolog C (*S. cerevisiae*)
ENST00000368404		RAG1AP1	Recombination activating gene 1 activating protein 1
ENST00000372062		RALGDS	Ral guanine nucleotide dissociation stimulator
ENST00000374757	NM_002885	RAP1GAP	RAP1 GTPase activating protein
ENST00000319149	NM_000964 NM_001024809.2 NM_001033603	RARA	Retinoic acid receptor, alpha
ENST00000231572	NM_002887	RARS	Arginyl-tRNA synthetase
ENST00000220062	NM_016563	RASL12	RAS-like, family 12
ENST00000319715	NM_006910 NM_018703	RBBP6	Retinoblastoma binding protein 6
ENST00000369784	NM_022768	RBM15	RNA binding motif protein 15
ENST00000367006		RCOR3	REST corepressor 3
ENST00000367664		REPS1	RALBP1 associated Eps domain containing 1
ENST00000355710	NM_020630.4 NM_020975	RET	Ret proto-oncogene
ENST00000380071		RFC3	Replication factor C (activator 1) 3, 38 kDa
ENST00000374596		RGL2	Ral guanine nucleotide dissociation stimulator-like 2
ENST00000367459	NM_002922	RGS1	Regulator of G-protein signaling 1
ENST00000206262	NM_012419	RGS17	Regulator of G-protein signaling 17
ENST00000343854	NM_004296	RGS6	Regulator of G-protein signaling 6
ENST00000268125	NM_000326	RLBP1	Retinaldehyde binding protein 1
ENST00000340900		RNASE1	Ribonuclease, RNase A family, 1 (pancreatic)
ENST00000344624		RNASEN	Ribonuclease III, nuclear
ENST00000375734	NM_005168	RND3	Rho family GTPase 3
ENST00000311269		RNF190	
ENST00000358395	NM_007219	RNF24	Ring finger protein 24
ENST00000339626	NM_005977 NM_183043 NM_183044 NM_183045	RNF6	Ring finger protein (C3H2C3 type) 6
ENST00000369485		RNGTT	RNA guanylyltransferase and 5'-phosphatase
ENST00000296255	NM_002950	RPN1	Ribophorin I
ENST00000341844		RPS12	Ribosomal protein S12
ENST00000372360		RPS24	Ribosomal protein S24
ENST00000334205	NM_001006944.1 NM_003942	RPS6KA4	Ribosomal protein S6 kinase, 90 kDa, polypeptide 4
ENST00000261991		RPS6KA5	Ribosomal protein S6 kinase, 90 kDa, polypeptide 5
ENST00000312629		RPS6KB2	Ribosomal protein S6 kinase, 70 kDa, polypeptide 2
ENST00000358328	NM_031464	RPS6KL1	Ribosomal protein S6 kinase-like 1
ENST00000246792		RRAS	Related RAS viral (r-ras) oncogene homolog
ENST00000258955	NM_018346	RSAD1	Radical S-adenosyl methionine domain containing 1
ENST00000276659	NM_178565	RSPO2	R-spondin 2 homolog (*Xenopus laevis*)
ENST00000368317	NM_032784	RSPO3	R-spondin 3 homolog (*Xenopus laevis*)
ENST00000369724		RWDD2	
ENST00000367891	NM_001009598 NM_006917	RXRG	Retinoid X receptor, gamma

TABLE 2-continued

All targets of miR-27a.

Transcript ID	RefSeq Accession Number	Target Name	Gene Name
ENST00000367469	NM_015278	SASH1	SAM and SH3 domain containing 1
ENST00000368363	NM_005698 NM_052837	SCAMP3	Secretory carrier membrane protein 3
ENST00000019103	NM_002980	SCTR	Secretin receptor
ENST00000247020		SDF2	Stromal cell-derived factor 2
ENST00000360001		SDF4	Stromal cell derived factor 4
ENST00000215812		SEC14L3	SEC14-like 3 (*S. cerevisiae*)
ENST00000264454		SEC22C	SEC22 vesicle trafficking protein homolog C (*S. cerevisiae*)
ENST00000379041		SEC61A2	Sec61 alpha 2 subunit (*S. cerevisiae*)
ENST00000368868	NM_003944	SELENBP1	Selenium binding protein 1
ENST00000355853		SEMA4G	Sema domain, immunoglobulin domain (Ig), transmembrane domain (TM) and short cytoplasmic domain, (semaphorin) 4G
ENST00000357599	NM_001031702	SEMA5B	Sema domain, seven thrombospondin repeats (type 1 and type 1-like), transmembrane domain (TM) and short cytoplasmic domain, (semaphorin) 5B
ENST00000367516		SEN15_HUMAN	
ENST00000004980		SENP1_HUMAN	
ENST00000367104		SERAC1	Serine active site containing 1
ENST00000372563	NM_000354	SERPINA7	Serpin peptidase inhibitor, clade A (alpha-1 antiproteinase, antitrypsin), member 7
ENST00000221455	NM_007056	SFRS16	Splicing factor, arginine/serine-rich 16
ENST00000229390		SFRS9	Splicing factor, arginine/serine-rich 9
ENST00000355697		SFXN4_HUMAN	
ENST00000373277	NM_005489 NM_170600	SH2D3C	SH2 domain containing 3C
ENST00000350336	NM_016009	SH3GLB1	SH3-domain GRB2-like endophilin B1
ENST00000359782		SIRT5	Sirtuin (silent mating type information regulation 2 homolog) 5 (*S. cerevisiae*)
ENST00000354161		SLC12A9	Solute carrier family 12 (potassium/chloride transporters), member 9
ENST00000318989		SLC16A10	Solute carrier family 16, member 10 (aromatic amino acid transporter)
ENST00000308453	NM_001098486.1 NM_006632	SLC17A3	Solute carrier family 17 (sodium phosphate), member 3
ENST00000273173		SLC22A14	Solute carrier family 22 (organic cation transporter), member 14
ENST00000345033	NM_003058	SLC22A2	Solute carrier family 22 (organic cation transporter), member 2
ENST00000317881		SLC25A5	Solute carrier family 25 (mitochondrial carrier; adenine nucleotide translocator), member 5
ENST00000361193	NM_173626	SLC26A11	Solute carrier family 26, member 11
ENST00000356119	NM_052961 NM_138718	SLC26A8	Solute carrier family 26, member 8
ENST00000306873		SLC30A1	Solute carrier family 30 (zinc transporter), member 1
ENST00000379343		SLC30A6	Solute carrier family 30 (zinc transporter), member 6
ENST00000217420	NM_080552	SLC32A1	Solute carrier family 32 (GABA vesicular transporter), member 1
ENST00000298681	NM_014579	SLC39A2	Solute carrier family 39 (zinc transporter), member 2
ENST00000380059	NM_032034	SLC4A11	Solute carrier family 4, sodium borate transporter, member 11

TABLE 2-continued

All targets of miR-27a.

Transcript ID	RefSeq Accession Number	Target Name	Gene Name
ENST00000260126		SLCO5A1	Solute carrier organic anion transporter family, member 5A1
ENST00000359345	NM_144990	SLFNL1	Schlafen-like 1
ENST00000332281		SNAI3	Snail homolog 3 (*Drosophila*)
ENST00000348795	NM_003087	SNCG	Synuclein, gamma (breast cancer-specific protein 1)
ENST00000354725		SND1_HUMAN	
ENST00000290330		SNF8	SNF8, ESCRT-II complex subunit, homolog (*S. cerevisiae*)
ENST00000374015		SNRPC	Small nuclear ribonucleoprotein polypeptide C
ENST00000244227		SNUT3_HUMAN	
ENST00000379516	NM_003100	SNX2	Sorting nexin 2
ENST00000344780		SNX21_HUMAN	
ENST00000251847		SNX23_HUMAN	
ENST00000264694	NM_031953	SNX25	Sorting nexin 25
ENST00000306121	NM_015976 NM_152238	SNX7	Sorting nexin 7
ENST00000302056	NM_004232	SOCS6	Suppressor of cytokine signaling 6
ENST00000373645	NM_001005176 NM_007237.3	SP140	SP140 nuclear body protein
ENST00000282470	NM_004684	SPARCL1	SPARC-like 1 (mast9, hevin)
ENST00000351008	NM_031955	SPATA16	Spermatogenesis associated 16
ENST00000289431	NM_006038	SPATA2	Spermatogenesis associated 2
ENST00000282074		SPBC25	
ENST00000377104		SPRY2	Sprouty homolog 2 (*Drosophila*)
ENST00000372739	NM_003127	SPTAN1	Spectrin, alpha, non-erythrocytic 1 (alpha-fodrin)
ENST00000379648		SRP19	Signal recognition particle 19 kDa
ENST00000343379	NM_015558 NM_198935	SS18L1	Synovial sarcoma translocation gene on chromosome 18-like 1
ENST00000278742	NM_021978	ST14	Suppression of tumorigenicity 14 (colon carcinoma)
ENST00000382009	NM_020860	STIM2	Stromal interaction molecule 2
ENST00000368625		STK32C	Serine/threonine kinase 32C
ENST00000220876		STMN2	Stathmin-like 2
ENST00000378577		STOML2	Stomatin (EPB72)-like 2
ENST00000298596	NM_152709.3	STOX1	Storkhead box 1
ENST00000374263	NM_022486	SUSD1	Sushi domain containing 1
ENST00000342784		SYDE1	Synapse defective 1, Rho GTPase, homolog 1 (*C. elegans*)
ENST00000360448		SYTL3	Synaptotagmin-like 3
ENST00000369958		TAF13	TAF13 RNA polymerase II, TATA box binding protein (TBP)-associated factor, 18 kDa
ENST00000380818	NM_001015892 NM_003187	TAF9	TAF9 RNA polymerase II, TATA box binding protein (TBP)-associated factor, 32 kDa
ENST00000374895	NM_000544.3 NM_018833	TAP2	Transporter 2, ATP-binding cassette, sub-family B (MDR/TAP)
ENST00000040877	NM_005646	TARBP1	TAR (HIV-1) RNA binding protein 1
ENST00000375371	NM_152232	TAS1R2	Taste receptor, type 1, member 2
ENST00000331710	NM_013254	TBK1	TANK-binding kinase 1
ENST00000230354	NM_003194	TBP	TATA box binding protein
ENST00000247219	NM_199047	TBPL2	TATA box binding protein like 2
ENST00000369431	NM_152380	TBX15	T-box 15
ENST00000309889	NM_003673	TCAP	Titin-cap (telethonin)
ENST00000282111	NM_031283	TCF7L1	Transcription factor 7-like 1 (T-cell specific, HMG-box)
ENST00000373977	NM_001093728.1 NM_018679	TCP11	T-complex 11 (mouse)
ENST00000335725	NM_001008744 NM_018319	TDP1	Tyrosyl-DNA phosphodiesterase 1
ENST00000372578	NM_031274.3	TEX13A	Testis expressed 13A
ENST00000274400		TF2H2_HUMAN	
ENST00000222543	NM_006528	TFPI2	Tissue factor pathway inhibitor 2
ENST00000261600		THOC1	THO complex 1

TABLE 2-continued

All targets of miR-27a.

Transcript ID	RefSeq Accession Number	Target Name	Gene Name
ENST00000264637		THRA	Thyroid hormone receptor, alpha (erythroblastic leukemia viral (v-erb-a) oncogene homolog, avian)
ENST00000297347		THRAP6	
ENST00000288014		THTPA	Thiamine triphosphatase
ENST00000287814	NM_003256	TIMP4	TIMP metallopeptidase inhibitor 4
ENST00000296802		TIP1_HUMAN	
ENST00000311912	NM_016610 NM_138636	TLR8	Toll-like receptor 8
ENST00000370196		TLX1_HUMAN	
ENST00000294613	NM_032027.2	TM2D1	TM2 domain containing 1
ENST00000299705		TMED3	Transmembrane emp24 protein transport domain containing 3
ENST00000206380		TMEM101	Transmembrane protein 101
ENST00000216080		TMEM153	
ENST00000292246	NM_018075	TMEM16K	Transmembrane protein 16K
ENST00000336702	NM_014807	TMEM24	Transmembrane protein 24
ENST00000297459	NM_153015	TMEM74	Transmembrane protein 74
ENST00000307216	NM_015497	TMEM87A	Transmembrane protein 87A
ENST00000300433	NM_153229	TMEM92	Transmembrane protein 92
ENST00000335572	NM_182559.2	TMPRSS12	Transmembrane protease, serine 12
ENST00000233143	NM_021103	TMSB10	Thymosin, beta 10
ENST00000297533		TMUB1	Transmembrane and ubiquitin-like domain containing 1
ENST00000264331	NM_001068.2	TOP2B	Topoisomerase (DNA) II beta 180 kDa
ENST00000373284	NM_001085347.1 NM_130459	TOR2A	Torsin family 2, member A
ENST00000301057		TP53I13	Tumor protein p53 inducible protein 13
ENST00000308422	NM_000547 NM_175719 NM_175720 NM_175721 NM_175722	TPO	Thyroid peroxidase
ENST00000367478	NM_003292.2	TPR	Translocated promoter region (to activated MET oncogene)
ENST00000340513	NM_012112	TPX2	TPX2, microtubule-associated, homolog (*Xenopus laevis*)
ENST00000373887	NM_005658	TRAF1	TNF receptor-associated factor 1
ENST00000367023		TRAF3IP3	TRAF3 interacting protein 3
ENST00000297221		TRERF1	Transcriptional regulating factor 1
ENST00000357105		TREX1	Three prime repair exonuclease 1
ENST00000311762	NM_003301	TRHR	Thyrotropin-releasing hormone receptor
ENST00000274327	NM_001656 NM_033227.2 NM_033228	TRIM23	Tripartite motif-containing 23
ENST00000357530	NM_024114	TRIM48	Tripartite motif-containing 48
ENST00000380027		TRIM5	Tripartite motif-containing 5
ENST00000333149	NM_178125	TRIM50	Tripartite motif-containing 50
ENST00000360177		TRIM59	Tripartite motif-containing 59
ENST00000379705	NM_016179	TRPC4	Transient receptor potential cation channel, subfamily C, member 4
ENST00000277065	NM_001007470.1 NM_001007471.2 NM_020952.4 NM_024971 NM_206945.3 NM_206946 NM_206947 NM_206948	TRPM3	Transient receptor potential cation channel, subfamily M, member 3
ENST00000333213	NM_207346	TSEN54	TRNA splicing endonuclease 54 homolog (*S. cerevisiae*)

TABLE 2-continued

All targets of miR-27a.

Transcript ID	RefSeq Accession Number	Target Name	Gene Name
ENST00000307180	NM_145003	TSNARE1	T-SNARE domain containing 1
ENST00000372003	NM_005727	TSPAN1	Tetraspanin 1
ENST00000375442		TSPYL2	TSPY-like 2
ENST00000382110		TTC15	Tetratricopeptide repeat domain 15
ENST00000334974		TUBGCP2	Tubulin, gamma complex associated protein 2
ENST00000216185		TXN2	Thioredoxin 2
ENST00000371626	NM_015913	TXNDC12	Thioredoxin domain containing 12 (endoplasmic reticulum)
ENST00000369317	NM_006472	TXNIP	Thioredoxin interacting protein
ENST00000301944		TXNL6	
ENST00000367926	NM_003115	UAP1	UDP-N-acteylglucosamine pyrophosphorylase 1
ENST00000340573	NM_004223 NM_198183	UBE2L6	Ubiquitin-conjugating enzyme E2L 6
ENST00000371076	NM_152489	UBE2U	Ubiquitin-conjugating enzyme E2U (putative)
ENST00000381764		UCHL1	Ubiquitin carboxyl-terminal esterase L1 (ubiquitin thiolesterase)
ENST00000337130		UGP2	UDP-glucose pyrophosphorylase 2
ENST00000268159	NM_001039675.1 NM_018671	UNC45A	Unc-45 homolog A (*C. elegans*)
ENST00000340926	NM_025154.3	UNC84A	Unc-84 homolog A (*C. elegans*)
ENST00000366829	NM_018974	UNC93A	Unc-93 homolog A (*C. elegans*)
ENST00000262946	NM_006830	UQCR	Ubiquinol-cytochrome c reductase, 6.4 kDa subunit
ENST00000335373	NM_006677.1	USP19	Ubiquitin specific peptidase 19
ENST00000304076	NM_005428	VAV1	Vav 1 guanine nucleotide exchange factor
ENST00000313132		VDAC2	Voltage-dependent anion channel 2
ENST00000309422		VEGFB	Vascular endothelial growth factor B
ENST00000280193	NM_005429.2	VEGFC	Vascular endothelial growth factor C
ENST00000249330	NM_003378	VGF	VGF nerve growth factor inducible
ENST00000367244	NM_003381 NM_194435	VIP	Vasoactive intestinal peptide
ENST00000301774		VMD2	
ENST00000331471		VMDL3_HUMAN	
ENST00000355155		VP13B_HUMAN	
ENST00000220509	NM_020857	VPS18	Vacuolar protein sorting 18 homolog (*S. cerevisiae*)
ENST00000324849		VPS37A	Vacuolar protein sorting 37 homolog A (*S. cerevisiae*)
ENST00000369456	NM_024626	VTCN1	V-set domain containing T cell activation inhibitor 1
ENST00000233615		WBP1	WW domain binding protein 1
ENST00000381329	NM_014023	WDR37	WD repeat domain 37
ENST00000330317		WDR4	WD repeat domain 4
ENST00000378322		WDR8	WD repeat domain 8
ENST00000368664		WISP3	WNT1 inducible signaling pathway protein 3
ENST00000366753	NM_033131	WNT3A	Wingless-type MMTV integration site family, member 3A
ENST00000380713		WRB	Tryptophan rich basic protein
ENST00000313620		XP_292836.3	
ENST00000372288		XP_931110.1	
ENST00000383005		XP_932040.1	
ENST00000309582		XP_935270.1	
ENST00000255845		XP_937394.1	
ENST00000388939		XP_937526.1	
ENST00000378263		XP_942691.1	
ENST00000378260		XP_942710.1	
ENST00000323562		XP_943634.1	

TABLE 2-continued

All targets of miR-27a.

Transcript ID	RefSeq Accession Number	Target Name	Gene Name
ENST00000331993		XP_944689.1	
ENST00000303979		XP_944836.1	
ENST00000367014		XR_000991.1	
ENST00000380885		XR_001064.1	
ENST00000282268	NM_003401 NM_022406 NM_022550	XRCC4	X-ray repair complementing defective repair in Chinese hamster cells 4
ENST00000300145	NM_033276.2	XRCC6BP1	XRCC6 binding protein 1
ENST00000339413	NM_001039671.1 NM_001039672 NM_001039673.1 NM_033557	YIF1B	Yip1 interacting factor homolog B (*S. cerevisiae*)
ENST00000204279		YPEL3	Yippee-like 3 (*Drosophila*)
ENST00000317012	NM_024508	ZBED2	Zinc finger, BED-type containing 2
ENST00000291374		ZBTB8_HUMAN	
ENST00000218506	NM_144969	ZDHHC15	Zinc finger, DHHC-type containing 15
ENST00000216602		ZFYVE21	Zinc finger, FYVE domain containing 21
ENST00000339296		ZN621_HUMAN	
ENST00000358296	NM_173531.2	ZNF100	Zinc finger protein 100
ENST00000360371		ZNF124	Zinc finger protein 124
ENST00000343499		ZNF177	Zinc finger protein 177
ENST00000300823	NM_001032372.1 NM_001032373.1 NM_001032374.1 NM_001032375.1 NM_015919.3	ZNF226	Zinc finger protein 226
ENST00000377255		ZNF306	
ENST00000361328		ZNF31	
ENST00000372167		ZNF334	Zinc finger protein 334
ENST00000243644	NM_021632	ZNF350	Zinc finger protein 350
ENST00000361807	NM_145312	ZNF485	Zinc finger protein 485
ENST00000361113	NM_145295.2	ZNF627	Zinc finger protein 627
ENST00000358785	NM_024804	ZNF669	Zinc finger protein 669
ENST00000341976	NM_021916	ZNF70	Zinc finger protein 70
ENST00000293068		ZNFN1A3	
ENST00000233331		ZNHIT4	Zinc finger, HIT type 4

TABLE 3

miR-27a targets identified by miRanda and L2L.

Target Gene	Accession No:	Gene Name
ADAMTS4	NM_005099.4 GI: 157427674	ADAM metallopeptidase with thrombospondin type 1 motif, 4
AHSG	NM_001622.2 GI: 156523969	alpha-2-HS-glycoprotein
ALPL	NM_000478.3 GI: 116734716	alkaline phosphatase, liver/bone/kidney
BMI1	NM_005180.5 GI: 39725706	BMI1 polycomb ring finger oncogene
CHRD	NM_003741.2 GI: 30089979	chordin
DLX5	NM_005221.5 GI: 84043959	distal-less homeobox 5
HOXA13	NM_000522.3 GI: 84452162	homeobox A13
MATN1	NM_002379.2 GI: 13518035	matrilin 1, cartilage matrix protein

TABLE 3-continued

miR-27a targets identified by miRanda and L2L.

Target Gene	Accession No:	Gene Name
MINPP1	NM_004897.2 GI: 19923760	multiple inositol polyphosphate histidine phosphatase, 1
PEX7	NM_000288.1 GI: 4505730	peroxisomal biogenesis factor 7
PRKRA	NM_003690.3 GI: 32261293	protein kinase, interferon-inducible double stranded RNA dependent activator
THRA	NM_199334.2 GI: 46255056	thyroid hormone receptor, alpha (erythroblastic leukemia viral (v-erb-a) oncogene homolog, avian)
THRA	NM_003250.4 GI: 40806158	thyroid hormone receptor, alpha (erythroblastic leukemia viral (v-erb-a) oncogene homolog, avian)

TABLE 4

All targets of miR-489.

Transcript ID	RefSeq Accession Number	Target Name	Gene Name
ENST00000263100	NM_130786	A1BG	Alpha-1-B glycoprotein
ENST00000389663	NM_015657 NM_173076	ABCA12	ATP-binding cassette, sub-family A (ABC1), member 12
ENST00000382055	NM_178559	ABCB5	ATP-binding cassette, sub-family B (MDR/TAP), member 5
ENST00000339718	NM_033226	ABCC12	ATP-binding cassette, sub-family C (CFTR/MRP), member 12
ENST00000334444	NM_001023587 NM_005688.2	ABCC5	ATP-binding cassette, sub-family C (CFTR/MRP), member 5
ENST00000295962		ABHD6	Abhydrolase domain containing 6
ENST00000308982		ACAD9	Acyl-Coenzyme A dehydrogenase family, member 9
ENST00000231909	NM_022899	ACTR8	ARP8 actin-related protein 8 homolog (yeast)
ENST00000303536		ACYP2	Acylphosphatase 2, muscle type
ENST00000256389	NM_003814	ADAM20	ADAM metallopeptidase domain 20
ENST00000335595	NM_003817	ADAM7	ADAM metallopeptidase domain 7
ENST00000352040	NM_030955	ADAMTS12	ADAM metallopeptidase with thrombospondin type 1 motif, 12
ENST00000299164	NM_139055	ADAMTS15	ADAM metallopeptidase with thrombospondin type 1 motif, 15
ENST00000380559	NM_001040272.4 NM_052866 NM_139238 NM_139264	ADAMTSL1	ADAMTS-like 1
ENST00000238561		ADCK1	AarF domain containing kinase 1
ENST00000349243		AGTR1	Angiotensin II receptor, type 1
ENST00000273784	NM_001622	AHSG	Alpha-2-HS-glycoprotein
ENST00000367601	NM_016108	AIG1	Androgen-induced 1
ENST00000373176	NM_000476	AK1	Adenylate kinase 1
ENST00000267584	NM_152327	AK7	Adenylate kinase 7
ENST00000228850	NM_006422	AKAP3	A kinase (PRKA) anchor protein 3
ENST00000358526	NM_003886 NM_139289	AKAP4	A kinase (PRKA) anchor protein 4
ENST00000285930		AKR1B1	Aldo-keto reductase family 1, member B1 (aldose reductase)
ENST00000339618	NM_000382 NM_001031806	ALDH3A2	Aldehyde dehydrogenase 3 family, member A2
ENST00000007633	NM_000694.2 NM_001030010.1	ALDH3B1	Aldehyde dehydrogenase 3 family, member B1
ENST00000338110		ALDOA_HUMAN	
ENST00000374978	NM_033087	ALG2	Asparagine-linked glycosylation 2 homolog (*S. cerevisiae*, alpha-1,3-mannosyltransferase)
ENST00000239891		ALG5	Asparagine-linked glycosylation 5 homolog (*S. cerevisiae*, dolichyl-phosphate beta-glucosyltransferase)
ENST00000216489	NM_006020	ALKBH1	AlkB, alkylation repair homolog 1 (*E. coli*)
ENST00000378840		ALKBH3	AlkB, alkylation repair homolog 3 (*E. coli*)
ENST00000380490		ALOX5AP	Arachidonate 5-lipoxygenase-activating protein
ENST00000383037	NM_001143	AMELY	Amelogenin, Y-linked
ENST00000338852		AMY2B	Amylase, alpha 2B (pancreatic)
ENST00000354910	NM_015391	ANAPC13	Anaphase promoting complex subunit 13
ENST00000304704	NM_002937 NM_194430 NM_194431	ANG	Angiogenin, ribonuclease, RNase A family, 5
ENST00000367629	NM_004673	ANGPTL1	Angiopoietin-like 1
ENST00000373815	NM_001149 NM_020987	ANK3	Ankyrin 3, node of Ranvier (ankyrin G)
ENST00000357927		ANKRD18A	Ankyrin repeat domain 18A
ENST00000322980	NM_173505	ANKRD29	Ankyrin repeat domain 29
ENST00000296511	NM_001154	ANXA5	Annexin A5

TABLE 4-continued

All targets of miR-489.

Transcript ID	RefSeq Accession Number	Target Name	Gene Name
ENST00000291439		AP1M1	Adaptor-related protein complex 1, mu 1 subunit
ENST00000250244	NM_005498.3	AP1M2	Adaptor-related protein complex 1, mu 2 subunit
ENST00000337619	NM_001283.3 NM_057089.2	AP1S1	Adaptor-related protein complex 1, sigma 1 subunit
ENST00000334271	NM_001039569.1	AP1S3	Adaptor-related protein complex 1, sigma 3 subunit
ENST00000263270		AP2S1	Adaptor-related protein complex 2, sigma 1 subunit
ENST00000278359		APIP	APAF1 interacting protein
ENST00000375918	NM_019101	APOM	Apolipoprotein M
ENST00000315596		APRIN	
ENST00000368087		ARG1	Arginase, liver
ENST00000300901		ARHGAP23	Rho GTPase activating protein 23
ENST00000273258	NM_006407	ARL6IP5	ADP-ribosylation-like factor 6 interacting protein 5
ENST00000305242	NM_018076	ARMC4	Armadillo repeat containing 4
ENST00000349321		ART3	ADP-ribosyltransferase 3
ENST00000389601	NM_130387	ASB14	Ankyrin repeat and SOCS box-containing 14
ENST00000263634	NM_016115 NM_145863	ASB3	Ankyrin repeat and SOCS box-containing 3
ENST00000266744		ASCL1	Achaete-scute complex homolog 1 (*Drosophila*)
ENST00000375689	NM_015338	ASXL1	Additional sex combs like 1 (*Drosophila*)
ENST00000264110		ATF2	Activating transcription factor 2
ENST00000317868	NM_032852 NM_178221	ATG4C	ATG4 autophagy related 4 homolog C (*S. cerevisiae*)
ENST00000309469	NM_032885	ATG4D	ATG4 autophagy related 4 homolog D (*S. cerevisiae*)
ENST00000286371		ATP1B3	ATPase, Na+/K+ transporting, beta 3 polypeptide
ENST00000349466	NM_001001344 NM_021949	ATP2B3	ATPase, Ca++ transporting, plasma membrane 3
ENST00000284727	NM_001002258 NM_001689	ATP5G3	ATP synthase, H+ transporting, mitochondrial F0 complex, subunit C3 (subunit 9)
ENST00000330342	NM_012463	ATP6V0A2	ATPase, H+ transporting, lysosomal V0 subunit a2
ENST00000290949		ATP6V0D1	ATPase, H+ transporting, lysosomal 38 kDa, V0 subunit d1
ENST00000335514		ATPIF1	ATPase inhibitory factor 1
ENST00000377526		AUP1	Ancient ubiquitous protein 1
ENST00000382956		AXIN1	Axin 1
ENST00000367998		B4GALT3	UDP-Gal:betaGlcNAc beta 1,4-galactosyltransferase, polypeptide 3
ENST00000375372		BARX1	BARX homeobox 1
ENST00000375842		BAT5	HLA-B associated transcript 5
ENST00000378455	NM_017745 NM_020926	BCOR	BCL6 co-repressor
ENST00000296424	NM_020139	BDH2	3-hydroxybutyrate dehydrogenase, type 2
ENST00000372677		BEX2	Brain expressed X-linked 2
ENST00000372645		BEX3_HUMAN	
ENST00000227758	NM_001166	BIRC2	Baculoviral IAP repeat-containing 2
ENST00000367807	NM_003666	BLZF1	Basic leucine zipper nuclear factor 1 (JEM-1)
ENST00000265624		BMP7	Bone morphogenetic protein 7 (osteogenic protein 1)
ENST00000349552	NM_174897	BPIL3	Bactericidal/permeability-increasing protein-like 3
ENST00000354807	NM_006085.4	BPNT1	3'(2'), 5'-bisphosphate nucleotidase 1

TABLE 4-continued

All targets of miR-489.

Transcript ID	RefSeq Accession Number	Target Name	Gene Name
ENST00000220659		BRF2	BRF2, subunit of RNA polymerase III transcription initiation factor, BRF1-like
ENST00000339775	NM_006806	BTG3	BTG family, member 3
ENST00000289361		BTN3A1	Butyrophilin, subfamily 3, member A1
ENST00000244519		BTN3A3	Butyrophilin, subfamily 3, member A3
ENST00000230340		BYSL	Bystin-like
ENST00000337623	NM_015608	C10orf137	Chromosome 10 open reading frame 137
ENST00000331772	NM_001031709 NM_018363	C10orf59	Chromosome 10 open reading frame 59
ENST00000374157		C10orf73	Chromosome 10 open reading frame 73
ENST00000368887		C10orf89	
ENST00000333254	NM_198515	C10orf96	Chromosome 10 open reading frame 96
ENST00000378615		C11orf49	Chromosome 11 open reading frame 49
ENST00000261191	NM_018164	C12orf11	Chromosome 12 open reading frame 11
ENST00000261700		C14orf166	Chromosome 14 open reading frame 166
ENST00000256545		C15orf24	Chromosome 15 open reading frame 24
ENST00000311880		C17orf66	Chromosome 17 open reading frame 66
ENST00000389005	NM_018553	C17orf85	Chromosome 17 open reading frame 85
ENST00000333234	NM_031446	C18orf21	Chromosome 18 open reading frame 21
ENST00000300227	NM_198995	C18orf34	Chromosome 18 open reading frame 34
ENST00000367910	NM_178550.4	C1orf110	Chromosome 1 open reading frame 110
ENST00000371760		C1orf185	Chromosome 1 open reading frame 185
ENST00000371980	NM_001013615	C1orf190	Chromosome 1 open reading frame 190
ENST00000368790		C1orf42	
ENST00000331283		C21orf119	Chromosome 21 open reading frame 119
ENST00000266155	NM_031444	C22orf13	Chromosome 22 open reading frame 13
ENST00000295049		C2orf11	
ENST00000273037		C3orf31	Chromosome 3 open reading frame 31
ENST00000318887	NM_173824	C3orf38	Chromosome 3 open reading frame 38
ENST00000344697	NM_032806	C3orf39	Chromosome 3 open reading frame 39
ENST00000341199		C5orf25	Chromosome 5 open reading frame 25
ENST00000244558		C6orf130	Chromosome 6 open reading frame 130
ENST00000369552	NM_001031743 NM_178823	C6orf165	Chromosome 6 open reading frame 165
ENST00000316149		C6orf66	Chromosome 6 open reading frame 66
ENST00000368596		C6orf78	
ENST00000234643	NM_000066	C8B	Complement component 8, beta polypeptide
ENST00000375117		C9orf156	Chromosome 9 open reading frame 156
ENST00000256925		CABL1_HUMAN	
ENST00000325656	NM_145200	CABP4	Calcium binding protein 4
ENST00000350061	NM_000720	CACNA1D	Calcium channel, voltage-dependent, L type, alpha 1D subunit

TABLE 4-continued

All targets of miR-489.

Transcript ID	RefSeq Accession Number	Target Name	Gene Name
ENST00000263942	NM_000069	CACNA1S	Calcium channel, voltage-dependent, L type, alpha 1S subunit
ENST00000329008	NM_001017440 NM_031468	CALN1	Calneuron 1
ENST00000359414		CAPN13	Calpain 13
ENST00000251973	NM_014550	CARD10	Caspase recruitment domain family, member 10
ENST00000309710		CARD14	Caspase recruitment domain family, member 14
ENST00000296777		CART_HUMAN	
ENST00000247026		CCDC55	Coiled-coil domain containing 55
ENST00000320516	NM_033124	CCDC65	Coiled-coil domain containing 65
ENST00000321945	NM_139076	CCDC98	Coiled-coil domain containing 98
ENST00000358813	NM_004591	CCL20	Chemokine (C-C motif) ligand 20
ENST00000250151		CCL4	Chemokine (C-C motif) ligand 4
ENST00000378569		CCL7	Chemokine (C-C motif) ligand 7
ENST00000225840		CCL8	Chemokine (C-C motif) ligand 8
ENST00000376042	NM_033031 NM_033670	CCNB3	Cyclin B3
ENST00000360054	NM_001039577 NM_030937	CCNL2	Cyclin L2
ENST00000299300	NM_006431	CCT2	Chaperonin containing TCP1, subunit 2 (beta)
ENST00000258091	NM_001009570.1 NM_006429.2	CCT7	Chaperonin containing TCP1, subunit 7 (eta)
ENST00000368169	NM_001765	CD1C	CD1c molecule
ENST00000354397	NM_021155	CD209	CD209 molecule
ENST00000368034	NM_016382	CD244	CD244 molecule, natural killer cell receptor 2B4
ENST00000262262	NM_001082618.1 NM_001772	CD33	CD33 molecule
ENST00000226279		CD38	CD38 molecule
ENST00000381180		CD99	CD99 molecule
ENST00000229265		CDCA3	Cell division cycle associated 3
ENST00000336219		CDCA4_HUMAN	
ENST00000268794	NM_004360	CDH1	Cadherin 1, type 1, E-cadherin (epithelial)
ENST00000382239	NM_006727	CDH10	Cadherin 10, type 2 (T2-cadherin)
ENST00000268603	NM_001797	CDH11	Cadherin 11, type 2, OB-cadherin (osteoblast)
ENST00000219789	NM_006319	CDIPT	CDP-diacylglycerol--inositol 3-phosphatidyltransferase (phosphatidylinositol synthase)
ENST00000361279		CDKN2A	Cyclin-dependent kinase inhibitor 2A (melanoma, p16, inhibits CDK4)
ENST00000262662		CDKN2C	Cyclin-dependent kinase inhibitor 2C (p18, inhibits CDK4)
ENST00000006724	NM_006890	CEACAM7	Carcinoembryonic antigen-related cell adhesion molecule 7
ENST00000331437	NM_031890	CECR6	Cat eye syndrome chromosome region, candidate 6
ENST00000379037	NM_030649	CENTB5	Centaurin, beta 5
ENST00000373855	NM_007018	CEP110	Centrosomal protein 110 kDa
ENST00000375002		CF010_HUMAN	
ENST00000370318		CF150_HUMAN	
ENST00000355693		CHCHD8	Coiled-coil-helix-coiled-coil-helix domain containing 8
ENST00000361293	NM_004284	CHD1L	Chromodomain helicase DNA binding protein 1-like
ENST00000309818	NM_001042572.2 NM_001271	CHD2	Chromodomain helicase DNA binding protein 2
ENST00000266880		CHFR	Checkpoint with forkhead and ring finger domains

TABLE 4-continued

All targets of miR-489.

Transcript ID	RefSeq Accession Number	Target Name	Gene Name
ENST00000035307		CHGUT_HUMAN	
ENST00000342610		CHRD	Chordin
ENST00000263671	NM_015424	CHRDL2	Chordin-like 2
ENST00000276410	NM_004198	CHRNA6	Cholinergic receptor, nicotinic, alpha 6
ENST00000370397		CHUK	Conserved helix-loop-helix ubiquitous kinase
ENST00000381895		CI068_HUMAN	
ENST00000377773		CI105_HUMAN	
ENST00000317358		CJ055_HUMAN	
ENST00000342366	NM_000084	CLCN5	Chloride channel 5 (nephrolithiasis 2, X-linked, Dent disease)
ENST00000328796	NM_021195	CLDN6	Claudin 6
ENST00000300107		CLPX	ClpX caseinolytic peptidase X homolog (*E. coli*)
ENST00000360535		CLR59_HUMAN	
ENST00000263200	NM_007098.2	CLTCL1	Clathrin, heavy chain-like 1
ENST00000380446	NM_001831 NM_203339.1	CLU	Clusterin
ENST00000338387	NM_014410.4 NM_199167.1	CLUL1	Clusterin-like 1 (retinal)
ENST00000229329		CMAS	Cytidine monophosphate N-acetylneuraminic acid synthetase
ENST00000306954		CN142_HUMAN	
ENST00000303904		COPS6	COP9 constitutive photomorphogenic homolog subunit 6 (*Arabidopsis*)
ENST00000229251	NM_016319	COPS7A	COP9 constitutive photomorphogenic homolog subunit 7A (*Arabidopsis*)
ENST00000300452		COQ4	Coenzyme Q4 homolog (*S. cerevisiae*)
ENST00000314133	NM_004074	COX8A	Cytochrome c oxidase subunit 8A (ubiquitous)
ENST00000264613	NM_000096	CP	Ceruloplasmin (ferroxidase)
ENST00000296046	NM_001870	CPA3	Carboxypeptidase A3 (mast cell)
ENST00000359703		CPE	Carboxypeptidase E
ENST00000266679	NM_007007	CPSF6	Cleavage and polyadenylation specific factor 6, 68 kDa
ENST00000299529		CRABP1	Cellular retinoic acid binding protein 1
ENST00000354577		CRSP3	
ENST00000353151	NM_001891	CSN2	Casein beta
ENST00000361804		CSPG6	
ENST00000370938	NM_001902 NM_153742	CTH	Cystathionase (cystathionine gamma-lyase)
ENST00000330295	NM_138455	CTHRC1	Collagen triple helix repeat containing 1
ENST00000375943		CTRC	Chymotrypsin C (caldecrin)
ENST00000217131	NM_001336	CTSZ	Cathepsin Z
ENST00000346329	NM_005231.2 NM_138565	CTTN	Cortactin
ENST00000382705		CU063_HUMAN	
ENST00000310513		CUGBP1	CUG triplet repeat, RNA binding protein 1
ENST00000310806		CV106_HUMAN	
ENST00000371594	NM_022101	CXorf56	Chromosome X open reading frame 56
ENST00000302517	NM_016463.6	CXXC5	CXXC finger 5
ENST00000371904	NM_000778	CYP4A11	Cytochrome P450, family 4, subfamily A, polypeptide 11
ENST00000250498	NM_001344	DAD1	Defender against cell death 1
ENST00000264161	NM_001349	DARS	Aspartyl-tRNA synthetase
ENST00000369563	NM_022836	DCLRE1B	DNA cross-link repair 1B (PSO2 homolog, *S. cerevisiae*)
ENST00000263576	NM_013264.2	DDX25	DEAD (Asp-Glu-Ala-Asp) box polypeptide 25
ENST00000382697	NM_001925	DEFA4	Defensin, alpha 4, corticostatin

TABLE 4-continued

All targets of miR-489.

Transcript ID	RefSeq Accession Number	Target Name	Gene Name
ENST00000362033	NM_004401 NM_213566	DFFA	DNA fragmentation factor, 45 kDa, alpha polypeptide
ENST00000264057	NM_003648.2 NM_152879	DGKD	Diacylglycerol kinase, delta 130 kDa
ENST00000346603		DHRS7B	Dehydrogenase/reductase (SDR family) member 7B
ENST00000358290		DHRS8	
ENST00000199320		DIMH_HUMAN	
ENST00000366636		DISC1	Disrupted in schizophrenia 1
ENST00000346964	NM_001098424.1 NM_004087	DLG1	Discs, large homolog 1 (*Drosophila*)
ENST00000190165	NM_021240	DMRT3	Doublesex and mab-3 related transcription factor 3
ENST00000082259	NM_020877	DNAH2	Dynein, axonemal, heavy chain 2
ENST00000376795		DNAJC3	DnaJ (Hsp40) homolog, subfamily C, member 3
ENST00000359526	NM_001379	DNMT1	DNA (cytosine-5-)-methyltransferase 1
ENST00000382345		DOCK8_HUMAN	
ENST00000371403	NM_018431	DOK5	Docking protein 5
ENST00000382713		DOK6_HUMAN	
ENST00000268795		DPEP2	Dipeptidase 2
ENST00000360534	NM_001935	DPP4	Dipeptidyl-peptidase 4 (CD26, adenosine deaminase complexing protein 2)
ENST00000342856	NM_181787	DPY19L4	Dpy-19-like 4 (*C. elegans*)
ENST00000370192	NM_000110	DPYD	Dihydropyrimidine dehydrogenase
ENST00000338492	NM_006426	DPYSL4	Dihydropyrimidinase-like 4
ENST00000382465	NM_000798	DRD5	Dopamine receptor D5
ENST00000374395		DSCR1L2	
ENST00000377846		DSTN	Destrin (actin depolymerizing factor)
ENST00000267837		DUOX2	Dual oxidase 2
ENST00000288943	NM_004418	DUSP2	Dual specificity phosphatase 2
ENST00000372199	NM_032372	DYDC2	DPY30 domain containing 2
ENST00000375735	NM_001080463.1	DYNC2H1	Dynein, cytoplasmic 2, heavy chain 1
ENST00000240343		DYNLL2	Dynein, light chain, LC8-type 2
ENST00000372497		EBNA1BP2	EBNA1 binding protein 2
ENST00000372979	NM_007265	ECD	Ecdysoneless homolog (*Drosophila*)
ENST00000253392	NM_021783	EDA2R	Ectodysplasin A2 receptor
ENST00000309311	NM_001961	EEF2	Eukaryotic translation elongation factor 2
ENST00000337611	NM_001039348 NM_001039349 NM_004105	EFEMP1	EGF-containing fibulin-like extracellular matrix protein 1
ENST00000382374		EFHA1	EF-hand domain family, member A1
ENST00000344838	NM_144715	EFHB	EF-hand domain family, member B
ENST00000250457	NM_022073	EGLN3	Egl nine homolog 3 (*C. elegans*)
ENST00000253039	NM_001415	EIF2S3	Eukaryotic translation initiation factor 2, subunit 3 gamma, 52 kDa
ENST00000380512		EIF4A1	Eukaryotic translation initiation factor 4A, isoform 1
ENST00000269466	NM_018696	ELAC1	ElaC homolog 1 (*E. coli*)
ENST00000379498		ELF1	E74-like factor 1 (ets domain transcription factor)
ENST00000163344	NM_022821	ELOVL1	Elongation of very long chain fatty acids (FEN1/Elo2, SUR4/Elo3, yeast)-like 1
ENST00000295206	NM_001426	EN1	Engrailed homeobox 1
ENST00000361674		ENK13_HUMAN	
ENST00000254928		ERAL1	Era G-protein-like 1 (*E. coli*)
ENST00000376107		ERCC3	Excision repair cross-complementing rodent repair deficiency, complementation

TABLE 4-continued

All targets of miR-489.

Transcript ID	RefSeq Accession Number	Target Name	Gene Name
			group 3 (xeroderma pigmentosum group B complementing)
ENST00000314992	NM_152596	EXDL1	Exonuclease 3'-5' domain-like 1
ENST00000381295	NM_001024924 NM_018261 NM_178237	EXOC1	Exocyst complex component 1
ENST00000300005	NM_080663	EXOD1	Exonuclease domain containing 1
ENST00000370880	NM_016046	EXOSC1	Exosome component 1
ENST00000319211	NM_001992	F2R	Coagulation factor II (thrombin) receptor
ENST00000371780	NM_007051	FAF1	Fas (TNFRSF6) associated factor 1
ENST00000306378		FALZ_HUMAN	
ENST00000373084		FAM102A	Family with sequence similarity 102, member A
ENST00000361723	NM_022074 NM_198847	FAM111A	Family with sequence similarity 111, member A
ENST00000264344		FAM13A1	Family with sequence similarity 13, member A1
ENST00000359943	NM_001040020 NM_014888	FAM3C	Family with sequence similarity 3, member C
ENST00000369796		FAM40A	Family with sequence similarity 40, member A
ENST00000380274	NM_012135	FAM50B	Family with sequence similarity 50, member B
ENST00000372570	NM_173642	FAM80A	Family with sequence similarity 80, member A
ENST00000297530		FASTK	Fas-activated serine/threonine kinase
ENST00000368178	NM_030764 NM_138738	FCRL2	Fc receptor-like 2
ENST00000359263	NM_013451.2 NM_133337.1	FER1L3	Fer-1-like 3, myoferlin (*C. elegans*)
ENST00000373535	NM_173558	FGD2	FYVE, RhoGEF and PH domain containing 2
ENST00000228837	NM_020996	FGF6	Fibroblast growth factor 6
ENST00000382333	NM_005130	FGFBP1	Fibroblast growth factor binding protein 1
ENST00000344213		FHL2	Four and a half LIM domains 2
ENST00000325888	NM_001458.3	FLNC	Filamin C, gamma (actin binding protein 280)
ENST00000008553	NM_001002294 NM_006894	FMO3	Flavin containing monooxygenase 3
ENST00000343844	NM_001014986 NM_004476	FOLH1	Folate hydrolase (prostate-specific membrane antigen) 1
ENST00000263578		FOXRED1	FAD-dependent oxidoreductase domain containing 1
ENST00000305531	NM_001017929 NM_001018071 NM_152428	FRMPD2	FERM and PDZ domain containing 2
ENST00000287474	NM_001013660	FRRS1	Ferric-chelate reductase 1
ENST00000265825		FSCN3	Fascin homolog 3, actin-bundling protein, testicular (*Strongylocentrotus purpuratus*)
ENST00000304421	NM_000145 NM_181446	FSHR	Follicle stimulating hormone receptor
ENST00000379164	NM_020116	FSTL5	Follistatin-like 5
ENST00000367586	NM_032020	FUCA2	Fucosidase, alpha-L-2, plasma
ENST00000254108		FUS	Fusion (involved in t(12; 16) in malignant liposarcoma)
ENST00000303225	NM_000149 NM_001097639.1 NM_001097640.1 NM_001097641.1	FUT3	Fucosyltransferase 3 (galactoside 3(4)-L-fucosyltransferase, Lewis blood group)
ENST00000286955	NM_000150 NM_001040701.1	FUT6	Fucosyltransferase 6 (alpha (1,3) fucosyltransferase)
ENST00000326575	NM_002035	FVT1	Follicular lymphoma variant translocation 1

TABLE 4-continued

All targets of miR-489.

Transcript ID	RefSeq Accession Number	Target Name	Gene Name
ENST00000259271		GAD2	Glutamate decarboxylase 2 (pancreatic islets and brain, 65 kDa)
ENST00000376665	NM_002049	GATA1	GATA binding protein 1 (globin transcription factor 1)
ENST00000370545		GATA5	GATA binding protein 5
ENST00000233612	NM_012198	GCA	Grancalcin, EF-hand calcium binding protein
ENST00000255945	NM_018326	GIMAP4	GTPase, IMAP family member 4
ENST00000342280	NM_002060	GJA4	Gap junction protein, alpha 4, 37 kDa
ENST00000377938		GKN1	Gastrokine 1
ENST00000306497		GLPK3_HUMAN	
ENST00000278400	NM_005838 NM_201648	GLYAT	Glycine-N-acyltransferase
ENST00000380251	NM_002069	GNAI1	Guanine nucleotide binding protein (G protein), alpha inhibiting activity polypeptide 1
ENST00000378609	NM_002074	GNB1	Guanine nucleotide binding protein (G protein), beta polypeptide 1
ENST00000261837	NM_006578.3 NM_016194	GNB5	Guanine nucleotide binding protein (G protein), beta 5
ENST00000335281	NM_053064	GNG2	Guanine nucleotide binding protein (G protein), gamma 2
ENST00000373062		GNL2	Guanine nucleotide binding protein-like 2 (nucleolar)
ENST00000359187		GOG8A_HUMAN	
ENST00000381436	NM_005288	GPR12	G protein-coupled receptor 12
ENST00000367838		GPR161	G protein-coupled receptor 161
ENST00000335866	NM_001001549.1 NM_001001550.1 NM_001001555.1 NM_005311.3	GRB10	Growth factor receptor-bound protein 10
ENST00000381001	NM_001098477.1 NM_002092.3	GRSF1	G-rich RNA sequence binding factor 1
ENST00000341272		GSN	Gelsolin (amyloidosis, Finnish type)
ENST00000219627	NM_002094.2	GSPT1	G1 to S phase transition 1
ENST00000375981	NM_018094	GSPT2	G1 to S phase transition 2
ENST00000369831		GSTM2	Glutathione S-transferase M2 (muscle)
ENST00000261195	NM_021957	GYS2	Glycogen synthase 2 (liver)
ENST00000378789	NM_017545	HAO1	Hydroxyacid oxidase (glycolate oxidase) 1
ENST00000336133		HCC1_HUMAN	
ENST00000376800	NM_005844	HCG9	HLA complex group 9
ENST00000368632	NM_001527.2	HDAC2	Histone deacetylase 2
ENST00000264173		HEAT1_HUMAN	
ENST00000058691		HEBP2	Heme binding protein 2
ENST00000261609	NM_004667	HERC2	Hect domain and RLD 2
ENST00000296575	NM_022475	HHIP	Hedgehog interacting protein
ENST00000274787		HIGD2A	HIG1 domain family, member 2A
ENST00000377781	NM_021063 NM_138720	HIST1H2BD	Histone cluster 1, H2bd
ENST00000289352		HIST1H4D	Histone cluster 1, H4d
ENST00000361427	NM_005517	HMGN2	High-mobility group nucleosomal binding domain 2
ENST00000377575	NM_006353	HMGN4	High mobility group nucleosomal binding domain 4
ENST00000313093	NM_012292	HMHA1	Histocompatibility (minor) HA-1
ENST00000358715	NM_012484 NM_012485	HMMR	Hyaluronan-mediated motility receptor (RHAMM)
ENST00000313173		HOXD8	Homeobox D8
ENST00000375000	NM_016287	HP1BP3	Heterochromatin protein 1, binding protein 3
ENST00000370027	NM_024747	HPS6	Hermansky-Pudlak syndrome 6
ENST00000381418		HR	Hairless homolog (mouse)

TABLE 4-continued

All targets of miR-489.

Transcript ID	RefSeq Accession Number	Target Name	Gene Name
ENST00000369413		HSD3B1	Hydroxy-delta-5-steroid dehydrogenase, 3 beta- and steroid delta-isomerase 1
ENST00000369416		HSD3B2	Hydroxy-delta-5-steroid dehydrogenase, 3 beta- and steroid delta-isomerase 2
ENST00000375650		HSPA1A	Heat shock 70 kDa protein 1A
ENST00000375653		HSPA1L	Heat shock 70 kDa protein 1-like
ENST00000304298	NM_080659	HSPB2	Heat shock 27 kDa protein 2
ENST00000258400	NM_000867	HTR2B	5-hydroxytryptamine (serotonin) receptor 2B
ENST00000223026	NM_012269	HYAL4	Hyaluronoglucosaminidase 4
ENST00000240652	NM_000415	IAPP	Islet amyloid polypeptide
ENST00000371580	NM_004969	IDE	Insulin-degrading enzyme
ENST00000368132	NM_005531	IFI16	Interferon, gamma-inducible protein 16
ENST00000380206	NM_000605	IFNA2	Interferon, alpha 2
ENST00000229135	NM_000619	IFNG	Interferon, gamma
ENST00000357896		IFT20	Intraflagellar transport 20 homolog (*Chlamydomonas*)
ENST00000270800	NM_021258	IL22RA1	Interleukin 22 receptor, alpha 1
ENST00000254636		IMMT	Inner membrane protein, mitochondrial (mitofilin)
ENST00000193391	NM_016247	IMPG2	Interphotoreceptor matrix proteoglycan 2
ENST00000338450	NM_005537 NM_198217 NM_198218 NM_198219	ING1	Inhibitor of growth family, member 1
ENST00000372343	NM_014652	IPO13	Importin 13
ENST00000360635		ITBP1_HUMAN	
ENST00000320640	NM_030790	ITFG1	Integrin alpha FG-GAP repeat containing 1
ENST00000339307	NM_000885.4	ITGA4	Integrin, alpha 4 (antigen CD49D, alpha 4 subunit of VLA-4 receptor)
ENST00000222573	NM_002214	ITGB8	Integrin, beta 8
ENST00000295321	NM_017969	IWS1	IWS1 homolog (*S. cerevisiae*)
ENST00000327520		JHD2C_HUMAN	
ENST00000240874	NM_001024660.2 NM_003947 NM_007064	KALRN	Kalirin, RhoGEF kinase
ENST00000377843		KC1A_HUMAN	
ENST00000290310	NM_172201	KCNE2	Potassium voltage-gated channel, Isk-related family, member 2
ENST00000381593	NM_002236	KCNF1	Potassium voltage-gated channel, subfamily F, member 1
ENST00000366621		KCNK1	Potassium channel, subfamily K, member 1
ENST00000303015		KCNK9	Potassium channel, subfamily K, member 9
ENST00000372443	NM_001014797.1 NM_002247	KCNMA1	Potassium large conductance calcium-activated channel, subfamily M, alpha member 1
ENST00000359963		KCNMB3L	
ENST00000264773	NM_021614 NM_170775.1	KCNN2	Potassium intermediate/small conductance calcium-activated channel, subfamily N, member 2
ENST00000382267		KDELR2	KDEL (Lys-Asp-Glu-Leu) endoplasmic reticulum protein retention receptor 2
ENST00000335817	NM_014656	KIAA0040	KIAA0040
ENST00000264214	NM_015047	KIAA0090	KIAA0090
ENST00000297423	NM_001080394.1	KIAA0146	KIAA0146
ENST00000318709		KIAA0241	KIAA0241
ENST00000372442	NM_031207	KIAA0467	KIAA0467
ENST00000322335	NM_015229.3	KIAA0664	KIAA0664
ENST00000236980		KIAA0971	
ENST00000242315	NM_015297.1	KIAA1045	KIAA1045

TABLE 4-continued

All targets of miR-489.

Transcript ID	RefSeq Accession Number	Target Name	Gene Name
ENST00000297222	NM_152748	KIAA1324L	KIAA1324-like
ENST00000329923	NM_138346	KIAA2013	KIAA2013
ENST00000335044	NM_022342 NM_182902 NM_182903	KIF9	Kinesin family member 9
ENST00000367769 ENST00000381763	NM_014970	KIFAP3 KKCC1_HUMAN	Kinesin-associated protein 3
ENST00000359358	NM_020805	KLHL14	Kelch-like 14 (*Drosophila*)
ENST00000265023	NM_000893 NM_001102416.1	KNG1	Kininogen 1
ENST00000375773	NM_001032998 NM_003937	KYNU	Kynureninase (L-kynurenine hydrolase)
ENST00000381167		LAPTM4A	Lysosomal-associated protein transmembrane 4 alpha
ENST00000368787	NM_032563	LCE3D	Late cornified envelope 3D
ENST00000368789	NM_178435	LCE3E	Late cornified envelope 3E
ENST00000368791	NM_178438	LCE5A	Late cornified envelope 5A
ENST00000371748	NM_014564 NM_178138	LHX3	LIM homeobox 3
ENST00000316300	NM_005577.2	LPA	Lipoprotein, Lp(a)
ENST00000306688	NM_144999	LRRC45	Leucine rich repeat containing 45
ENST00000269025		LRRC46	Leucine rich repeat containing 46
ENST00000260382	NM_017691	LRRC49	Leucine rich repeat containing 49
ENST00000343742		LRRK2_HUMAN	
ENST00000228740		LTA4H	Leukotriene A4 hydrolase
ENST00000264265	NM_020169	LXN	Latexin
ENST00000219345		LYPLA3	Lysophospholipase 3 (lysosomal phospholipase A2)
ENST00000285879	NM_005462	MAGEC1	Melanoma antigen family C, 1
ENST00000347546	NM_014599 NM_177433 NM_201222	MAGED2	Melanoma antigen family D, 2
ENST00000354489	NM_005906	MAK	Male germ cell-associated kinase
ENST00000369293	NM_024641	MANEA	Mannosidase, endo-alpha
ENST00000373045	NM_001031740.1 NM_152496	MANEAL	Mannosidase, endo-alpha-like
ENST00000307102	NM_002755	MAP2K1	Mitogen-activated protein kinase kinase 1
ENST00000354570	NM_003980	MAP7	Microtubule-associated protein 7
ENST00000374189		MAPK8	Mitogen-activated protein kinase 8
ENST00000347470	NM_002752 NM_139068.1 NM_139069.1 NM_139070	MAPK9	Mitogen-activated protein kinase 9
ENST00000329421		MARCKSL1	MARCKS-like 1
ENST00000376973	NM_006610 NM_139208	MASP2	Mannan-binding lectin serine peptidase 2
ENST00000359787		MB	Myoglobin
ENST00000370578	NM_001099855.1 NM_005369	MCF2	MCF.2 cell line derived transforming sequence
ENST00000265056	NM_004526	MCM2	Minichromosome maintenance complex component 2
ENST00000233114		MDH1	Malate dehydrogenase 1, NAD (soluble)
ENST00000359803		MDK	Midkine (neurite growth-promoting factor 2)
ENST00000346108	NM_005587.1	MEF2A	Myocyte enhancer factor 2A
ENST00000298048	NM_014791	MELK	Maternal embryonic leucine zipper kinase
ENST00000381290	NM_005926	MFAP1	Microfibrillar-associated protein 1
ENST00000228938	NM_000900	MGP	Matrix Gla protein
ENST00000379614		MICAL2	Microtubule associated monoxygenase, calponin and LIM domain containing 2

TABLE 4-continued

All targets of miR-489.

Transcript ID	RefSeq Accession Number	Target Name	Gene Name
ENST00000317552	NM_000381 NM_001098624.1 NM_033290	MID1	Midline 1 (Opitz/BBB syndrome)
ENST00000296597		MIMIT_HUMAN	
ENST00000388758		MKLN1	Muskelin 1, intracellular mediator containing kelch motifs
ENST00000377052		MLLT10	Myeloid/lymphoid or mixed-lineage leukemia (trithorax homolog, *Drosophila*); translocated to, 10
ENST00000374259		MLLT7	
ENST00000264605	NM_001042467.1 NM_024101	MLPH	Melanophilin
ENST00000182377	NM_018099	MLSTD1	Male sterility domain containing 1
ENST00000246912		MLX	MAX-like protein X
ENST00000260227		MMP7	Matrix metallopeptidase 7 (matrilysin, uterine)
ENST00000370782		MMS19L	
ENST00000340556	NM_194270	MORN2	MORN repeat containing 2
ENST00000370778	NM_019556	MOSPD1	Motile sperm domain containing 1
ENST00000245959		MPIP2_HUMAN	
ENST00000332314		MRGPRG	MAS-related GPR, member G
ENST00000371785		MRPS2	Mitochondrial ribosomal protein S2
ENST00000310776		MRPS22	Mitochondrial ribosomal protein S22
ENST00000313608		MRPS23	Mitochondrial ribosomal protein S23
ENST00000272418		MRPS5	Mitochondrial ribosomal protein S5
ENST00000016913	NM_017716	MS4A12	Membrane-spanning 4-domains, subfamily A, member 12
ENST00000281047		MSGN1	Mesogenin 1
ENST00000360270	NM_002444	MSN	Moesin
ENST00000249442	NM_001006635.1 NM_006554	MTX2	Metaxin 2
ENST00000308110		MUS81	MUS81 endonuclease homolog (*S. cerevisiae*)
ENST00000274813		MUT	Methylmalonyl Coenzyme A mutase
ENST00000301415	NM_001077186.1 NM_024729.3	MYH14	Myosin, heavy chain 14
ENST00000349606	NM_013262	MYLIP	Myosin regulatory light chain interacting protein
ENST00000358212	NM_000259.2	MYO5A	Myosin VA (heavy chain 12, myoxin)
ENST00000259021	NM_007067	MYST2	MYST histone acetyltransferase 2
ENST00000360149	NM_018257	MYT1	Myelin transcription factor 1
ENST00000202831		NCKX6_HUMAN	
ENST00000359003	NM_014071	NCOA6	Nuclear receptor coactivator 6
ENST00000274137		NDUFS6	NADH dehydrogenase (ubiquinone) Fe—S protein 6, 13 kDa (NADH-coenzyme Q reductase)
ENST00000318388		NDUFV2	NADH dehydrogenase (ubiquinone) flavoprotein 2, 24 kDa
ENST00000373599		NEK6	NIMA (never in mitosis gene a)-related kinase 6
ENST00000297142		NEUROD6	Neurogenic differentiation 6
ENST00000375724	NM_005384	NFIL3	Nuclear factor, interleukin 3 regulated
ENST00000329043	NM_152995	NFXL1	Nuclear transcription factor, X-box binding-like 1
ENST00000265259		NIT2	Nitrilase family, member 2
ENST00000295886		NKX6-1	NK6 homeobox 1
ENST00000298087	NM_007363	NONO	Non-POU domain containing, octamer-binding
ENST00000367158	NM_015718	NOX3	NADPH oxidase 3

TABLE 4-continued

All targets of miR-489.

Transcript ID	RefSeq Accession Number	Target Name	Gene Name
ENST00000361505		NP	Nucleoside phosphorylase
ENST00000378115		NP_001003702.1	
ENST00000279907		NP_001006948.1	
ENST00000370640		NP_001009997.1	
ENST00000340967		NP_001010887.2	
ENST00000335160		NP_001012735.1	
ENST00000374884		NP_001012986.2	
ENST00000344380		NP_001013646.1	
ENST00000388936		NP_001013712.1	
ENST00000378877		NP_001013726.1	
ENST00000377957		NP_001019851.1	
ENST00000374251		NP_001020436.1	
ENST00000360388		NP_001025029.1	
ENST00000021776		NP_001025037.1	
ENST00000334306		NP_001025041.1	
ENST00000343217		NP_001028747.1	
ENST00000315313		NP_001028831.1	
ENST00000332968		NP_001030177.1	
ENST00000381078		NP_001034981.1	
ENST00000382142		NP_001035536.1	
ENST00000262498		NP_037374.1	
ENST00000361462		NP_055906.2	
ENST00000381240		NP_056174.1	
ENST00000358677		NP_056350.1	
ENST00000367220		NP_056368.1	
ENST00000226105		NP_057576.2	
ENST00000344442		NP_057732.1	
ENST00000288168		NP_060028.2	
ENST00000310452		NP_060222.2	
ENST00000354544		NP_060325.3	
ENST00000264434		NP_060350.1	
ENST00000372543		NP_060485.3	
ENST00000252100		NP_060972.3	
ENST00000285871		NP_065930.2	
ENST00000297788		NP_073579.2	
ENST00000292199		NP_078894.2	
ENST00000306049		NP_078959.2	
ENST00000281924		NP_112185.1	
ENST00000317568		NP_114110.1	
ENST00000325106		NP_114162.1	
ENST00000329713		NP_115622.2	
ENST00000367003		NP_116094.2	
ENST00000375706		NP_443121.1	
ENST00000319194		NP_588616.1	
ENST00000295488		NP_598375.1	
ENST00000370922		NP_659404.2	
ENST00000280571		NP_659495.1	
ENST00000357613		NP_660297.1	
ENST00000309733		NP_689613.1	
ENST00000329620		NP_689826.1	
ENST00000323352		NP_694553.1	
ENST00000257034		NP_710163.1	
ENST00000321510		NP_775908.1	
ENST00000295723		NP_775919.2	
ENST00000383671		NP_776160.1	
ENST00000357872		NP_776161.2	
ENST00000374900		NP_777572.1	
ENST00000333598		NP_777578.1	
ENST00000354310		NP_778223.1	
ENST00000379190		NP_787068.2	
ENST00000318586		NP_848650.2	
ENST00000307201		NP_937790.1	
ENST00000331738		NP_937992.1	
ENST00000338588		NP_995327.1	
ENST00000320866		NP_997283.1	
ENST00000367553		NPL	N-acetylneuraminate pyruvate lyase (dihydrodipicolinate synthase)
ENST00000296930		NPM1	Nucleophosmin (nucleolar phosphoprotein B23, numatrin)

TABLE 4-continued

All targets of miR-489.

Transcript ID	RefSeq Accession Number	Target Name	Gene Name
ENST00000342694	NM_003995	NPR2	Natriuretic peptide receptor B/guanylate cyclase B (atrionatriuretic peptide receptor B)
ENST00000338566	NM_006174	NPY5R	Neuropeptide Y receptor Y5
ENST00000290426		NPY6R	Neuropeptide Y receptor Y6 (pseudogene)
ENST00000374570		NR_003086.1	
ENST00000374816	NM_001024628 NM_001024629 NM_003873	NRP1	Neuropilin 1
ENST00000355783	NM_022455 NM_172349	NSD1	Nuclear receptor binding SET domain protein 1
ENST00000293973	NM_006181	NTN2L	Netrin 2-like (chicken)
ENST00000361681		NU6M_HUMAN	
ENST00000309188	NM_024815.3	NUDT18	Nudix (nucleoside diphosphate linked moiety X)-type motif 18
ENST00000354226		NUP214	Nucleoporin 214 kDa
ENST00000295119		NUP35	Nucleoporin 35 kDa
ENST00000372788	NM_032946 NM_033152 NM_033153 NM_033154 NM_033155	NXF5	Nuclear RNA export factor 5
ENST00000357403	NM_022463	NXN	Nucleoredoxin
ENST00000368845		OAT	Ornithine aminotransferase (gyrate atrophy)
ENST00000371226		OMA1	OMA1 homolog, zinc metallopeptidase (*S. cerevisiae*)
ENST00000304646	NM_012360	OR1F1	Olfactory receptor, family 1, subfamily F, member 1
ENST00000259357	NM_001004451	OR1J1	Olfactory receptor, family 1, subfamily J, member 1
ENST00000359776	NM_001005479	OR5H6	Olfactory receptor, family 5, subfamily H, member 6
ENST00000368144	NM_001005184	OR6K6	Olfactory receptor, family 6, subfamily K, member 6
ENST00000339258	NM_001005278	OR6N2	Olfactory receptor, family 6, subfamily N, member 2
ENST00000319481		OSBPL1A	Oxysterol binding protein-like 1A
ENST00000372858		PABPC4	Poly(A) binding protein, cytoplasmic 4 (inducible form)
ENST00000366889	NM_001080378.1 NM_001080379.1 NM_152410	PACRG	PARK2 co-regulated
ENST00000375481	NM_007365	PADI2	Peptidyl arginine deiminase, type II
ENST00000290507	NM_012387	PADI4	Peptidyl arginine deiminase, type IV
ENST00000221265	NM_019088	PAF1	Paf1, RNA polymerase II associated factor, homolog (*S. cerevisiae*)
ENST00000376141	NM_007003	PAGE4	P antigen family, member 4 (prostate associated)
ENST00000381543	NM_006451 NM_182789.2 NM_183323	PAIP1	Poly(A) binding protein interacting protein 1
ENST00000379568	NM_017906	PAK1IP1	PAK1 interacting protein 1
ENST00000370180		PALMD	Palmdelphin
ENST00000358107	NM_018109	PAPD1	PAP associated domain containing 1
ENST00000338639		PARK7	Parkinson disease (autosomal recessive, early onset) 7
ENST00000310366		PARP15	Poly (ADP-ribose) polymerase family, member 15
ENST00000377123	NM_006192	PAX1	Paired box 1
ENST00000368465	NM_020524	PBXIP1	Pre-B-cell leukemia homeobox interacting protein 1
ENST00000231173	NM_018935	PCDHB15	Protocadherin beta 15
ENST00000194155	NM_018936	PCDHB2	Protocadherin beta 2

TABLE 4-continued

All targets of miR-489.

Transcript ID	RefSeq Accession Number	Target Name	Gene Name
ENST00000297529	NM_006197.3	PCM1	Pericentriolar material 1
ENST00000367384	NM_005389	PCMT1	Protein-L-isoaspartate (D-aspartate) O-methyltransferase
ENST00000295992	NM_013363	PCOLCE2	Procollagen C-endopeptidase enhancer 2
ENST00000359062	NM_000921	PDE3A	Phosphodiesterase 3A, cGMP-inhibited
ENST00000358923		PDE4D	Phosphodiesterase 4D, cAMP-specific (phosphodiesterase E3 dunce homolog, *Drosophila*)
ENST00000266395		PDE6H	Phosphodiesterase 6H, cGMP-specific, cone, gamma
ENST00000354513		PDGFA	Platelet-derived growth factor alpha polypeptide
ENST00000329399		PDLIM1	PDZ and LIM domain 1 (elfin)
ENST00000308354	NM_021630 NM_176871 NM_198042	PDLIM2	PDZ and LIM domain 2 (mystique)
ENST00000369032	NM_020381	PDSS2	Prenyl (decaprenyl) diphosphate synthase, subunit 2
ENST00000344770	NM_002614	PDZK1	PDZ domain containing 1
ENST00000261313		PEBP1	Phosphatidylethanolamine binding protein 1
ENST00000263985		PET112L	PET112-like (yeast)
ENST00000225873	NM_000286	PEX12	Peroxisomal biogenesis factor 12
ENST00000367756	NM_000288	PEX7	Peroxisomal biogenesis factor 7
ENST00000374516		PHF1	PHD finger protein 1
ENST00000370800	NM_001015877 NM_032335 NM_032458	PHF6	PHD finger protein 6
ENST00000378659	NM_001037537.1 NM_006214	PHYH	Phytanoyl-CoA 2-hydroxylase
ENST00000367728	NM_002642 NM_153747	PIGC	Phosphatidylinositol glycan anchor biosynthesis, class C
ENST00000372689	NM_015937	PIGT	Phosphatidylinositol glycan anchor biosynthesis, class T
ENST00000374147	NM_017837	PIGV	Phosphatidylinositol glycan anchor biosynthesis, class V
ENST00000262039		PIK3C3	Phosphoinositide-3-kinase, class 3
ENST00000380994		PITRM1	Pitrilysin metallopeptidase 1
ENST00000361478	NM_001032396 NM_022368 NM_145119	PJA1	Praja 1
ENST00000262304	NM_000296.2 NM_001009944	PKD1	Polycystic kidney disease 1 (autosomal dominant)
ENST00000372675	NM_013355	PKN3	Protein kinase N3
ENST00000367324	NM_000299 NM_001005337	PKP1	Plakophilin 1 (ectodermal dysplasia/skin fragility syndrome)
ENST00000367466	NM_024420	PLA2G4A	Phospholipase A2, group IVA (cytosolic, calcium-dependent)
ENST00000216446		PLEK2	Pleckstrin 2
ENST00000341590	NM_006832	PLEKHC1	Pleckstrin homology domain containing, family C (with FERM domain) member 1
ENST00000361349	NM_001042663.1 NM_001042664.1 NM_001042665.1 NM_020631 NM_198681.2	PLEKHG5	Pleckstrin homology domain containing, family G (with RhoGef domain) member 5
ENST00000223127	NM_001084	PLOD3	Procollagen-lysine, 2-oxoglutarate 5-dioxygenase 3
ENST00000252590	NM_031310	PLVAP	Plasmalemma vesicle associated protein
ENST00000277585	NM_032812	PLXDC2	Plexin domain containing 2
ENST00000368276		PMF1	Polyamine-modulated factor 1
ENST00000342075		PMS1	PMS1 postmeiotic segregation increased 1 (*S. cerevisiae*)

TABLE 4-continued

All targets of miR-489.

Transcript ID	RefSeq Accession Number	Target Name	Gene Name
ENST00000388753		PO210_HUMAN	
ENST00000382229		POK9_HUMAN	
ENST00000215960		POLR2F	Polymerase (RNA) II (DNA directed) polypeptide F
ENST00000275569		POMZP3	POM (POM121 homolog, rat) and ZP3 fusion
ENST00000379747	NM_006475	POSTN	Periostin, osteoblast specific factor
ENST00000344265	NM_000306	POU1F1	POU class 1 homeobox 1
ENST00000373232		PPA1	Pyrophosphatase (inorganic) 1
ENST00000372561	NM_001080850	PPCS	Phosphopantothenoylcysteine synthetase
ENST00000319610	NM_006240 NM_152226.1	PPEF1	Protein phosphatase, EF-hand calcium binding domain 1
ENST00000372341	NM_005729	PPIF	Peptidylprolyl isomerase F (cyclophilin F)
ENST00000253329	NM_139126	PPIL4	Peptidylprolyl isomerase (cyclophilin)-like 4
ENST00000357726		PRA12_HUMAN	
ENST00000389488		PRIM2A	
ENST00000287878		PRKAG2	Protein kinase, AMP-activated, gamma 2 non-catalytic subunit
ENST00000379066		PRKD3	Protein kinase D3
ENST00000234071	NM_000312	PROC	Protein C (inactivator of coagulation factors Va and VIIIa)
ENST00000257860	NM_006262	PRPH	Peripherin
ENST00000161006	NM_022119	PRSS22	Protease, serine, 22
ENST00000284885	NM_002772	PRSS7	Protease, serine, 7 (enterokinase)
ENST00000376588	NM_021154 NM_058179	PSAT1	Phosphoserine aminotransferase 1
ENST00000342601		PSIP1	PC4 and SFRS1 interacting protein 1
ENST00000261479		PSMA6	Proteasome (prosome, macropain) subunit, alpha type, 6
ENST00000275605		PSPH	Phosphoserine phosphatase
ENST00000331920		PTCH	
ENST00000372192	NM_003738	PTCH2	Patched homolog 2 (*Drosophila*)
ENST00000370758	NM_000959 NM_001039585	PTGFR	Prostaglandin F receptor (FP)
ENST00000263708		PTPN4	Protein tyrosine phosphatase, non-receptor type 4 (megakaryocyte)
ENST00000367364	NM_002838 NM_080921 NM_080922 NM_080923.2	PTPRC	Protein tyrosine phosphatase, receptor type, C
ENST00000295927	NM_002852	PTX3	Pentraxin-related gene, rapidly induced by IL-1 beta
ENST00000373742	NM_001020658.1 NM_014676	PUM1	Pumilio homolog 1 (*Drosophila*)
ENST00000216200	NM_002854	PVALB	Parvalbumin
ENST00000376902		Q16653-5	
ENST00000371277		Q4TT42_HUMAN	
ENST00000377439		Q4V339_HUMAN	
ENST00000316733		Q5SWJ0_HUMAN	
ENST00000331562		Q5T6X4_HUMAN	
ENST00000371932		Q5VXJ0_HUMAN	
ENST00000320930		Q68DA7_HUMAN	
ENST00000359049		Q6AI40_HUMAN	
ENST00000340357		Q6NXN4_HUMAN	
ENST00000359425		Q6ZNB4_HUMAN	
ENST00000327804		Q6ZSN3_HUMAN	
ENST00000376812		Q6ZSR2_HUMAN	
ENST00000377722		Q6ZVM9_HUMAN	
ENST00000359074		Q7Z4R2_HUMAN	
ENST00000333898		Q86TS2_HUMAN	
ENST00000335624		Q86VR7_HUMAN	
ENST00000280876		Q8IXV1_HUMAN	

TABLE 4-continued

All targets of miR-489.

Transcript ID	RefSeq Accession Number	Target Name	Gene Name
ENST00000341249		Q8N712_HUMAN	
ENST00000327979		Q8NF41_HUMAN	
ENST00000328798		Q8NI66_HUMAN	
ENST00000358148		Q8TEB0_HUMAN	
ENST00000254579		Q8TEE6_HUMAN	
ENST00000329244		Q96S36_HUMAN	
ENST00000272845		Q96SS0_HUMAN	
ENST00000343811		Q9H579-2	
ENST00000382764		Q9H606_HUMAN	
ENST00000314272		Q9NT86_HUMAN	
ENST00000356397		Q9P1D0_HUMAN	
ENST00000380195		Q9Y6V0-3	
ENST00000382282		QDPR	Quinoid dihydropteridine reductase
ENST00000367495		RAB32	RAB32, member RAS oncogene family
ENST00000264158		RAB3GAP1	RAB3 GTPase activating protein subunit 1 (catalytic)
ENST00000337311	NM_001024647.2 NM_022456 NM_175623 NM_175624 NM_175625.2	RAB3IP	RAB3A interacting protein (rabin3)
ENST00000251507		RABGAP1L	RAB GTPase activating protein 1-like
ENST00000251849	NM_002880	RAF1	V-raf-1 murine leukemia viral oncogene homolog 1
ENST00000389591	NM_002271	RANBP5	RAN binding protein 5
ENST00000383772		RARB_HUMAN	
ENST00000369523		RARSL	
ENST00000222145	NM_017805	RASIP1	Ras interacting protein 1
ENST00000319715	NM_006910 NM_018703	RBBP6	Retinoblastoma binding protein 6
ENST00000315658		RBED1	RNA binding motif and ELMO/CED-12 domain 1
ENST00000254105	NM_005105	RBM8A	RNA binding motif protein 8A
ENST00000378415	NM_001268	RCBTB2	Regulator of chromosome condensation (RCC1) and BTB (POZ) domain containing protein 2
ENST00000265881		REXO2	REX2, RNA exonuclease 2 homolog (*S. cerevisiae*)
ENST00000367669	NM_001001740.2 NM_022457	RFWD2	Ring finger and WD repeat domain 2
ENST00000372092		RGR	Retinal G protein coupled receptor
ENST00000367460	NM_130782	RGS18	Regulator of G-protein signaling 18
ENST00000371175	NM_000324	RHAG	Rh-associated glycoprotein
ENST00000378013		RHG26_HUMAN	
ENST00000303700		RHOH	Ras homolog gene family, member H
ENST00000257700	NM_021930	RINT1	RAD50 interactor 1
ENST00000296277		RL39L_HUMAN	
ENST00000311413	NM_032015	RNF26	Ring finger protein 26
ENST00000263808	NM_002944	ROS1	V-ros UR2 sarcoma virus oncogene homolog 1 (avian)
ENST00000381209		RPAIN	RPA interacting protein
ENST00000359429	NM_006916.1 NM_199229	RPE	Ribulose-5-phosphate-3-epimerase
ENST00000361575	NM_001000	RPL39	Ribosomal protein L39
ENST00000315741		RPL5	Ribosomal protein L5
ENST00000378203	NM_001097590.1 NM_006414 NM_183005	RPP38	Ribonuclease P/MRP 38 kDa subunit
ENST00000341844		RPS12	Ribosomal protein S12
ENST00000359364		RPS4X	Ribosomal protein S4, X-linked

TABLE 4-continued

All targets of miR-489.

Transcript ID	RefSeq Accession Number	Target Name	Gene Name
ENST00000358328	NM_031464	RPS6KL1	Ribosomal protein S6 kinase-like 1
ENST00000246792		RRAS	Related RAS viral (r-ras) oncogene homolog
ENST00000260563		RTCD1	RNA terminal phosphate cyclase domain 1
ENST00000312295	NM_153708	RTP1	Receptor (chemosensory) transporter protein 1
ENST00000369724		RWDD2	
ENST00000368738	NM_002965	S100A9	S100 calcium binding protein A9
ENST00000296370		S100P	S100 calcium binding protein P
ENST00000359674		S6A12_HUMAN	
ENST00000335556	NM_182610	SAMD7	Sterile alpha motif domain containing 7
ENST00000367469	NM_015278	SASH1	SAM and SH3 domain containing 1
ENST00000379253		SAT	
ENST00000341787		SBSN	Suprabasin
ENST00000255390	NM_004589	SCO1	SCO cytochrome oxidase deficient homolog 1 (yeast)
ENST00000371514	NM_001007098.1 NM_001007099.1 NM_001007100.1 NM_001007250 NM_002979	SCP2	Sterol carrier protein 2
ENST00000327872		SDHA	Succinate dehydrogenase complex, subunit A, flavoprotein (Fp)
ENST00000236147	NM_000655.3	SELL	Selectin L (lymphocyte adhesion molecule 1)
ENST00000379122	NM_020210.3 NM_198925.2	SEMA4B	Sema domain, immunoglobulin domain (Ig), transmembrane domain (TM) and short cytoplasmic domain, (semaphorin) 4B
ENST00000357877	NM_004263	SEMA4F	Sema domain, immunoglobulin domain (Ig), transmembrane domain (TM) and short cytoplasmic domain, (semaphorin) 4F
ENST00000340912	NM_145204	SENP8	SUMO/sentrin specific peptidase family member 8
ENST00000341584		SERPINA6	Serpin peptidase inhibitor, clade A (alpha-1 antiproteinase, antitrypsin), member 6
ENST00000258405		SERPINE2	Serpin peptidase inhibitor, clade E (nexin, plasminogen activator inhibitor type 1), member 2
ENST00000295777	NM_005025	SERPINI1	Serpin peptidase inhibitor, clade I (neuroserpin), member 1
ENST00000264677	NM_006217	SERPINI2	Serpin peptidase inhibitor, clade I (pancpin), member 2
ENST00000335508	NM_001005526.1 NM_012433	SF3B1	Splicing factor 3b, subunit 1, 155 kDa
ENST00000330854		SFR14_HUMAN	
ENST00000376280		SFRS1	Splicing factor, arginine/serine-rich 1 (splicing factor 2, alternate splicing factor)
ENST00000334121	NM_001077199.1 NM_139168	SFRS12	Splicing factor, arginine/serine-rich 12
ENST00000370201		SFXN3	Sideroflexin 3
ENST00000263753	NM_001012409.1 NM_001012410 NM_001012413.1 NM_138484	SGOL1	Shugoshin-like 1 (*S. pombe*)
ENST00000379698	NM_001024666 NM_031892	SH3KBP1	SH3-domain kinase binding protein 1
ENST00000316341	NM_005072	SLC12A4	Solute carrier family 12 (potassium/chloride transporters), member 4

TABLE 4-continued

All targets of miR-489.

Transcript ID	RefSeq Accession Number	Target Name	Gene Name
ENST00000321925		SLC14A1	Solute carrier family 14 (urea transporter), member 1 (Kidd blood group)
ENST00000376494	NM_005073	SLC15A1	Solute carrier family 15 (oligopeptide transporter), member 1
ENST00000345033	NM_003058	SLC22A2	Solute carrier family 22 (organic cation transporter), member 2
ENST00000263255		SLC25A17	Solute carrier family 25 (mitochondrial carrier; peroxisomal membrane protein, 34 kDa), member 17
ENST00000338602	NM_004213 NM_201651	SLC28A1	Solute carrier family 28 (sodium-coupled nucleoside transporter), member 1
ENST00000335244	NM_181776	SLC36A2	Solute carrier family 36 (proton/amino acid symporter), member 2
ENST00000367714		SLC9A11	Solute carrier family 9, member 11
ENST00000350148	NM_005905	SMAD9	SMAD family member 9
ENST00000358026	NM_003072	SMARCA4	SWI/SNF related, matrix associated, actin dependent regulator of chromatin, subfamily a, member 4
ENST00000283131	NM_003601	SMARCA5	SWI/SNF related, matrix associated, actin dependent regulator of chromatin, subfamily a, member 5
ENST00000374785		SMC2L1	
ENST00000379494		SMPX	Small muscle protein, X-linked
ENST00000308624	NM_018968.2	SNTG2	Syntrophin, gamma 2
ENST00000368982		SNX3	Sorting nexin 3
ENST00000371227		SORBS1	Sorbin and SH3 domain containing 1
ENST00000340356	NM_018419	SOX18	SRY (sex determining region Y)-box 18
ENST00000227135		SPA17	Sperm autoantigenic protein 17
ENST00000357804	NM_003971	SPAG9	Sperm associated antigen 9
ENST00000280191		SPATA4	Spermatogenesis associated 4
ENST00000372659	NM_020398 NM_080827 NM_181502	SPINLW1	Serine peptidase inhibitor-like, with Kunitz and WAP domains 1 (eppin)
ENST00000371258	NM_012444 NM_198265	SPO11	SPO11 meiotic protein covalently bound to DSB homolog (*S. cerevisiae*)
ENST00000237623		SPP1	Secreted phosphoprotein 1 (osteopontin, bone sialoprotein I, early T-lymphocyte activation 1)
ENST00000307122	NM_005987	SPRR1A	Small proline-rich protein 1A
ENST00000244891	NM_032681	SPRYD5	SPRY domain containing 5
ENST00000372739	NM_003127	SPTAN1	Spectrin, alpha, non-erythrocytic 1 (alpha-fodrin)
ENST00000262554		SPTLC1	Serine palmitoyltransferase, long chain base subunit 1
ENST00000382562	NM_001047	SRD5A1	Steroid-5-alpha-reductase, alpha polypeptide 1 (3-oxo-5 alpha-steroid delta 4-dehydrogenase alpha 1)
ENST00000336613	NM_182691 NM_182692	SRPK2	SFRS protein kinase 2
ENST00000371320	NM_001009955 NM_018070 NM_145716	SSBP3	Single stranded DNA binding protein 3
ENST00000320370		SSFA2	Sperm specific antigen 2
ENST00000278412	NM_003146	SSRP1	Structure specific recognition protein 1
ENST00000337768		ST65G_HUMAN	

TABLE 4-continued

All targets of miR-489.

Transcript ID	RefSeq Accession Number	Target Name	Gene Name
ENST00000225276		ST6GALNAC2	ST6 (alpha-N-acetyl-neuraminyl-2,3-beta-galactosyl-1,3)-N-acetylgalactosaminide alpha-2,6-sialyltransferase 2
ENST00000388888	NM_017564	STAB2	Stabilin 2
ENST00000380854	NM_003155	STC1	Stanniocalcin 1
ENST00000375333	NM_004197 NM_032454	STK19	Serine/threonine kinase 19
ENST00000376541	NM_001032296 NM_003576	STK24	Serine/threonine kinase 24 (STE20 homolog, yeast)
ENST00000378577		STOML2	Stomatin (EPB72)-like 2
ENST00000267540		STON2	Stonin 2
ENST00000222812	NM_004603	STX1A	Syntaxin 1A (brain)
ENST00000273666	NM_014980.1	STXBP5L	Syntaxin binding protein 5-like
ENST00000378631	NM_003850	SUCLA2	Succinate-CoA ligase, ADP-forming, beta subunit
ENST00000369899	NM_016169	SUFU	Suppressor of fused homolog (*Drosophila*)
ENST00000377973		SUGT1	SGT1, suppressor of G2 allele of SKP1 (*S. cerevisiae*)
ENST00000371001	NM_014258	SYCP2	Synaptonemal complex protein 2
ENST00000376303		SYPH_HUMAN	
ENST00000334568	NM_001077503.1 NM_001077504.1 NM_001077505.1 NM_001077506.1 NM_170685.2	TAC4	Tachykinin 4 (hemokinin)
ENST00000357300		TAF12	TAF12 RNA polymerase II, TATA box binding protein (TBP)-associated factor, 20 kDa
ENST00000337256	NM_005681 NM_139352	TAF1A	TATA box binding protein (TBP)-associated factor, RNA polymerase I, A, 48 kDa
ENST00000344095	NM_005641 NM_139122.1 NM_139123.1 NM_139315	TAF6	TAF6 RNA polymerase II, TATA box binding protein (TBP)-associated factor, 80 kDa
ENST00000374699		TAL2	T-cell acute lymphocytic leukemia 2
ENST00000259075		TANK_HUMAN	
ENST00000355975	NM_017714	TASP1	Taspase, threonine aspartase, 1
ENST00000265393	NM_001079864.1 NM_006024	TAX1BP1	Tax1 (human T-cell leukemia virus type I) binding protein 1
ENST00000380377		TBCA	Tubulin folding cofactor A
ENST00000373296	NM_016954	TBX22	T-box 22
ENST00000372680		TCAL5_HUMAN	
ENST00000372671		TCEAL7	Transcription elongation factor A (SII)-like 7
ENST00000369397		TCF7L2	Transcription factor 7-like 2 (T-cell specific, HMG-box)
ENST00000286956	NM_153046	TDRD9	Tudor domain containing 9
ENST00000265993		TECT3_HUMAN	
ENST00000239462		TENN_HUMAN	
ENST00000374896	NM_001032281 NM_006287	TFPI	Tissue factor pathway inhibitor (lipoprotein-associated coagulation inhibitor)
ENST00000305126		TGFBI	Transforming growth factor, beta-induced, 68 kDa
ENST00000212355	NM_003243	TGFBR3	Transforming growth factor, beta receptor III
ENST00000296736	NM_030953	TIGD6	Tigger transposable element derived 6
ENST00000296802		TIP1_HUMAN	
ENST00000279992		TIRAP_HUMAN	
ENST00000265284		TLE4_HUMAN	
ENST00000389469		TLN2	Talin 2
ENST00000260010		TLR2	Toll-like receptor 2
ENST00000370196		TLX1_HUMAN	
ENST00000261789	NM_001014842.1 NM_006405	TM9SF1	Transmembrane 9 superfamily member 1

TABLE 4-continued

All targets of miR-489.

Transcript ID	RefSeq Accession Number	Target Name	Gene Name
ENST00000245361	NM_004800	TM9SF2	Transmembrane 9 superfamily member 2
ENST00000288025	NM_144676	TMED6	Transmembrane emp24 protein transport domain containing 6
ENST00000368671		TMEM12	
ENST00000379828	NM_198507	TMEM157	Transmembrane protein 157
ENST00000292246	NM_018075	TMEM16K	Transmembrane protein 16K
ENST00000353948		TMEM20	Transmembrane protein 20
ENST00000383743		TMEM42	Transmembrane protein 42
ENST00000381964	NM_006134	TMEM50B	Transmembrane protein 50B
ENST00000310991	NM_178545	TMEM52	Transmembrane protein 52
ENST00000356838	NM_144649	TMEM71	Transmembrane protein 71
ENST00000264331	NM_001068.2	TOP2B	Topoisomerase (DNA) II beta 180 kDa
ENST00000329305		TPM2	Tropomyosin 2 (beta)
ENST00000367471	NM_003292.2	TPR	Translocated promoter region (to activated MET oncogene)
ENST00000357819	NM_001011658.1 NM_014563.3	TRAPPC2	Trafficking protein particle complex 2
ENST00000373162		TRAPPC3	Trafficking protein particle complex 3
ENST00000297221		TRERF1	Transcriptional regulating factor 1
ENST00000336708		TRIM16	Tripartite motif-containing 16
ENST00000225583		TRIM16L	Tripartite motif-containing 16-like
ENST00000376674	NM_003449	TRIM26	Tripartite motif-containing 26
ENST00000272395	NM_138800	TRIM43	Tripartite motif-containing 43
ENST00000353317	NM_033058 NM_184085 NM_184086 NM_184087	TRIM55	Tripartite motif-containing 55
ENST00000251607	NM_182916	TRNT1	TRNA nucleotidyl transferase, CCA-adding, 1
ENST00000375041	NM_001039705.1 NM_016157.2 NM_177556.1	TRO	Trophinin
ENST00000379645	NM_003305	TRPC3	Transient receptor potential cation channel, subfamily C, member 3
ENST00000312449	NM_017662	TRPM6	Transient receptor potential cation channel, subfamily M, member 6
ENST00000339687		TRYA1_HUMAN	
ENST00000361875	NM_014779	TSC22D2	TSC22 domain family, member 2
ENST00000355053	NM_025244 NM_182911	TSGA10	Testis specific, 10
ENST00000322038	NM_005786	TSHZ1	Teashirt zinc finger homeobox 1
ENST00000381121		TSN32_HUMAN	
ENST00000377711	NM_145003	TSNARE1	T-SNARE domain containing 1
ENST00000315170		TSP50_HUMAN	
ENST00000372003	NM_005727	TSPAN1	Tetraspanin 1
ENST00000360913	NM_032037	TSSK6	Testis-specific serine kinase 6
ENST00000382320	NM_001007795	TTC6	Tetratricopeptide repeat domain 6
ENST00000369798	NM_003318	TTK	TTK protein kinase
ENST00000242261	NM_000474	TWIST1	Twist homolog 1 (acrocephalosyndactyly 3; Saethre-Chotzen syndrome) (*Drosophila*)
ENST00000380122		TXLNG_HUMAN	
ENST00000217515		TXNL1	Thioredoxin-like 1
ENST00000271469	NM_003115	UAP1	UDP-N-acteylglucosamine pyrophosphorylase 1
ENST00000222402		UBE2D4	Ubiquitin-conjugating enzyme E2D 4 (putative)
ENST00000272930		UBE2F	
ENST00000371077	NM_152489	UBE2U	Ubiquitin-conjugating enzyme E2U (putative)

TABLE 4-continued

All targets of miR-489.

Transcript ID	RefSeq Accession Number	Target Name	Gene Name
ENST00000232165	NM_000462.2 NM_130838 NM_130839.1	UBE3A	Ubiquitin protein ligase E3A (human papilloma virus E6-associated protein, Angelman syndrome)
ENST00000252108	NM_004788	UBE4A	Ubiquitination factor E4A (UFD2 homolog, yeast)
ENST00000343638	NM_001076683.1 NM_001076684.1 NM_014233	UBTF	Upstream binding transcription factor, RNA polymerase I
ENST00000265616	NM_005671.2	UBXD6	UBX domain containing 6
ENST00000337130		UGP2	UDP-glucose pyrophosphorylase 2
ENST00000305107	NM_021139.2	UGT2B4	UDP glucuronosyltransferase 2 family, polypeptide B4
ENST00000282507	NM_174914	UGT3A2	UDP glycosyltransferase 3 family, polypeptide A2
ENST00000257548	NM_032663	USP30	Ubiquitin specific peptidase 30
ENST00000258499	NM_001042403.1 NM_032147	USP44	Ubiquitin specific peptidase 44
ENST00000286428	NM_003372	VBP1	Von Hippel-Lindau binding protein 1
ENST00000251127		VGCNL1	
ENST00000372207		VMD2L2	
ENST00000355155		VP13B_HUMAN	
ENST00000300793	NM_021729.4	VPS11	Vacuolar protein sorting 11 homolog (*S. cerevisiae*)
ENST00000354367	NM_018668	VPS33B	Vacuolar protein sorting 33 homolog B (yeast)
ENST00000381313	NM_003385	VSNL1	Visinin-like 1
ENST00000369277	NM_198496	VWA2	Von Willebrand factor A domain containing 2
ENST00000368938	NM_001024934 NM_001024935 NM_001024936 NM_003931	WASF1	WAS protein family, member 1
ENST00000299764	NM_153210.3	WDR16	WD repeat domain 16
ENST00000369965	NM_014969	WDR47	WD repeat domain 47
ENST00000262144	NM_030581	WDR59	WD repeat domain 59
ENST00000287380	NM_145647	WDR67	WD repeat domain 67
ENST00000278856		WDR74	WD repeat domain 74
ENST00000289953	NM_130896 NM_181510	WFDC8	WAP four-disulfide core domain 8
ENST00000265293	NM_015238	WWC1	WW and C2 domain containing 1
ENST00000297303	NM_173683	XKR6	XK, Kell blood group complex subunit-related family, member 6
ENST00000340777		XP_498354.2	
ENST00000351427		XP_931530.1	
ENST00000274299		XP_932027.1	
ENST00000342036		XP_932444.1	
ENST00000361410		XP_942995.1	
ENST00000306716		XP_944511.1	
ENST00000375128		XPA	Xeroderma pigmentosum, complementation group A
ENST00000311755		XR_000659.1	
ENST00000262887		XRCC1	X-ray repair complementing defective repair in Chinese hamster cells 1
ENST00000325680		YLPM1_HUMAN	
ENST00000261749		ZA20D3	
ENST00000373515		ZBTB8_HUMAN	
ENST00000375947		ZCCHC6	Zinc finger, CCHC domain containing 6
ENST00000359775		ZDH14_HUMAN	
ENST00000341191		ZF36_HUMAN	
ENST00000370609	NM_003413	ZIC3	Zic family member 3 heterotaxy 1 (odd-paired homolog, *Drosophila*)
ENST00000381591	NM_006624 NM_212479	ZMYND11	Zinc finger, MYND domain containing 11

TABLE 4-continued

All targets of miR-489.

Transcript ID	RefSeq Accession Number	Target Name	Gene Name
ENST00000298585	NM_138462	ZMYND19	Zinc finger, MYND-type containing 19
ENST00000355114		ZN565_HUMAN	
ENST00000299871		ZNF211	Zinc finger protein 211
ENST00000263095	NM_003417	ZNF264	Zinc finger protein 264
ENST00000262990	NM_014487	ZNF330	Zinc finger protein 330
ENST00000335815	NM_005649	ZNF354A	Zinc finger protein 354A
ENST00000221315	NM_014650 NM_025040	ZNF432	Zinc finger protein 432
ENST00000372524	NM_032772	ZNF503	Zinc finger protein 503
ENST00000291598	NM_152478	ZNF583	Zinc finger protein 583
ENST00000248125		ZNF598	Zinc finger protein 598
ENST00000379365	NM_152577	ZNF645	Zinc finger protein 645
ENST00000357130	NM_024733.3	ZNF665	Zinc finger protein 665
ENST00000372503		ZNF691	Zinc finger protein 691
ENST00000295131	NM_182521	ZSWIM2	Zinc finger, SWIM-type containing 2

TABLE 5

miR-489 targets identified by miRanda and L2L

Target Gene	Accession No:	Gene Name
AHSG	NM_001622.2 GI: 156523969	alpha-2-HS-glycoprotein
AMELY	NM_001143.1 GI: 4502072	amelogenin, Y-linked
BMP7	NM_001719.1 GI: 4502426	bone morphogenetic protein 7 (osteogenic protein 1)
CDH11	NM_001797.2 GI: 16306531	cadherin 11, type 2, OB-cadherin (osteoblast)
CHRD	NM_003741.2 GI: 30089979	chordin
CHRDL2	NM_015424.3 GI: 40353768	chordin-like 2
EN1	NM_001426.3 GI: 126090908	engrailed homeobox 1
MAPK8	NM_002750.2 GI: 20986493	mitogen-activated protein kinase 8
MAPK8	NM_139046.1 GI: 20986518	mitogen-activated protein kinase 8
MAPK8	NM_139047.1 GI: 20986520	mitogen-activated protein kinase 8
MAPK8	NM_139049.1 GI: 20986522	mitogen-activated protein kinase 8
MGP	NM_000900.2 GI: 49574513	matrix Gla protein

TABLE 5-continued

miR-489 targets identified by miRanda and L2L

Target Gene	Accession No:	Gene Name
PAX1	NM_006192.3 GI: 153791841	paired box gene 1
PEX7	NM_000288.1 GI: 4505730	peroxisomal biogenesis factor 7
POSTN	NM_006475.1 GI: 5453833	periostin, osteoblast specific factor
SPP1	NM_001040058.1 GI: 91206461	secreted phosphoprotein 1 (osteopontin, bone sialoprotein I, early T-lymphocyte activation 1)
SPP1	NM_000582.2 GI: 38146097	secreted phosphoprotein 1 (osteopontin, bone sialoprotein I, early T-lymphocyte activation 1)
SPP1	NM_001040060.1 GI: 91598938	secreted phosphoprotein 1 (osteopontin, bone sialoprotein I, early T-lymphocyte activation 1)
SUFU	NM_016169.2 GI: 19923478	suppressor of fused homolog (*Drosophila*)
TRAPPC2	NM_001011658.1 GI: 58533178	trafficking protein particle complex 2
TRAPPC2	NM_014563.3 GI: 58533177	trafficking protein particle complex 2
TWIST1	NM_000474.3 GI: 68160957	twist homolog 1 (acrocephalosyndactyly 3; Saethre-Chotzen syndrome) (*Drosophila*)

TABLE 6

All Targets of miR-148b

Transcript ID.	RefSeq Accession No.	Target Name	Gene
ENSG00000008311	NM_005763	AASS	Aminoadipate-semialdehyde synthase
		ABCB7	ATP-binding cassette, sub-family B (MDR/TAP), member 7
ENSG00000108846	NM_003786	ABCC3	ATP-binding cassette, sub-family C (CFTR/MRP), member 3

TABLE 6-continued

All Targets of miR-148b

Transcript ID.	RefSeq Accession No.	Target Name	Gene
ENSG00000117528	NM_002858	ABCD3	ATP-binding cassette, sub-family D (ALD), member 3
ENSG00000100997	NM_001042472.1 NM_015600	ABHD12	Abhydrolase domain containing 12
ENSG00000112077 ENSG00000136754	NM_000324 NM_001012750 NM_001012751 NM_001012752 NM_005470	ABI1	Abl-interactor 1
ENSG00000108798	NM_016428	ABI3	ABI gene family, member 3
ENSG00000167315	NM_006111	ACAA2	Acetyl-Coenzyme A acyltransferase 2 (mitochondrial 3-oxoacyl-Coenzyme A thiolase)
ENSG00000135847	NM_032360	ACBD6	Acyl-Coenzyme A binding domain containing 6
ENSG00000101473	NM_005469 NM_183385 NM_183386	ACOT8	Acyl-CoA thioesterase 8
ENSG00000102575	NM_001611	ACP5	Acid phosphatase 5, tartrate resistant
ENSG00000187003	NM_006687	ACTL7A	Actin-like 7A
ENSG00000163485	NM_000674 NM_001048230.1	ADORA1	Adenosine A1 receptor
ENSG00000150594	NM_000681	ADRA2A	Adrenergic, alpha-2A-, receptor
ENSG00000106688 ENSG00000141385	NM_004170 NM_006796	AFG3L2	AFG3 ATPase family gene 3-like 2 (yeast)
ENSG00000166748	NM_152336.2	AGBL1	ATP/GTP binding protein-like 1
ENSG00000165923	NM_024783	AGBL2	ATP/GTP binding protein-like 2
ENSG00000144891	NM_000685 NM_004835 NM_009585 NM_031850 NM_032049	AGTR1	Angiotensin II receptor, type 1
ENSG00000134817	NM_005161	AGTRL1	Angiotensin II receptor-like 1
ENSG00000004455	NM_001625 NM_013411	AK2 AK3L2	Adenylate kinase 2
ENSG00000121057 ENSG00000204689 ENSG00000206519	NM_003488	AKAP1	A kinase (PRKA) anchor protein 1
ENSG00000117020	NM_005465 NM_181690	AKT3	V-akt murine thymoma viral oncogene homolog 3 (protein kinase B, gamma)
ENSG00000155749	NM_139163	ALS2CR12	Amyotrophic lateral sclerosis 2 (juvenile) chromosome region, candidate 12
ENSG00000082146	NM_018571	ALS2CR2 AMZ2_HUMAN	Amyotrophic lateral sclerosis 2 (juvenile) chromosome region, candidate 2
ENSG00000176248	NM_013366	ANAPC2	Anaphase promoting complex subunit 2
ENSG00000091879	NM_001147	ANGPT2 ANKRD10	Angiopoietin 2 Ankyrin repeat domain 10
ENSG00000133302	NM_032290	ANKRD32	Ankyrin repeat domain 32
ENSG00000168096	NM_133450	ANKS3	Ankyrin repeat and sterile alpha motif domain containing 3
ENSG00000163516	NM_001042410.1 NM_018089.2	ANKZF1	Ankyrin repeat and zinc finger domain containing 1
ENSG00000213983	NM_003917 NM_080545	AP1G2	Adaptor-related protein complex 1, gamma 2 subunit
ENSG00000157823	NM_005829	AP3S2	Adaptor-related protein complex 3, sigma 2 subunit
ENSG00000204305 ENSG00000206253 ENSG00000206320	NM_001136 NM_172197	APBA1	Amyloid beta (A4) precursor protein-binding, family A, member 1 (X11)

TABLE 6-continued

All Targets of miR-148b

Transcript ID.	RefSeq Accession No.	Target Name	Gene
ENSG00000166313	NM_001164.2 NM_145689	APBB1	Amyloid beta (A4) precursor protein-binding, family B, member 1 (Fe65)
ENSG00000110244	NM_000482	APOA4	Apolipoprotein A-IV
ENSG00000111701	NM_001644	APOBEC1	Apolipoprotein B mRNA editing enzyme, catalytic polypeptide 1
ENSG00000204444 ENSG00000206304 ENSG00000206409	NM_019101	APOM	Apolipoprotein M
ENSG00000178301	NM_173039	AQP11	Aquaporin 11
ENSG00000165269	NM_001170	AQP7	Aquaporin 7
ENSG00000105127 ENSG00000168374	NM_005858 NM_001660	ARF4	ADP-ribosylation factor 4
ENSG00000066777	NM_006421	ARFGEF1	ADP-ribosylation factor guanine nucleotide-exchange factor 1(brefeldin A-inhibited)
ENSG00000170540	NM_015161	ARL6IP1	ADP-ribosylation factor-like 6 interacting protein 1
ENSG00000140691	NM_024742.1	ARMC5	Armadillo repeat containing 5
ENSG00000133794 ENSG00000159423	NM_001030272 NM_001030273.1 NM_001178 NM_003748 NM_170726	ARNTL	Aryl hydrocarbon receptor nuclear translocator-like
		ARPC4	Actin related protein 2/3 complex, subunit 4, 20 kDa
ENSG00000136950	NM_030978	ARPC5L	Actin related protein 2/3 complex, subunit 5-like
ENSG00000157399	NM_000047	ARSE	Arylsulfatase E (chondrodysplasia punctata 1)
ENSG00000141337	NM_014960	ARSG	Arylsulfatase G
ENSG00000156219	NM_001179	ART3	ADP-ribosyltransferase 3
ENSG00000119778	NM_017552.1	ATAD2B	ATPase family, AAA domain containing 2B
ENSG00000107669 ENSG00000153147	NM_001001976 NM_007041 NM_003601	ATE1	Arginyltransferase 1
ENSG00000125703	NM_032852 NM_178221	ATG4C	ATG4 autophagy related 4 homolog C (*S. cerevisiae*)
ENSG00000130734	NM_032885	ATG4D	ATG4 autophagy related 4 homolog D (*S. cerevisiae*)
ENSG00000198925	NM_001077198.1 NM_024085.3	ATG9A	ATG9 autophagy related 9 homolog A (*S. cerevisiae*)
ENSG00000101280 ENSG00000196296	NM_015985 NM_004320.3 NM_173201	ATP2A1	ATPase, Ca++ transporting, cardiac muscle, fast twitch 1
		ATP2A2	ATPase, Ca++ transporting, cardiac muscle, slow twitch 2
ENSG00000186009	NM_000705	ATP4B	ATPase, H+/K+ exchanging, beta polypeptide
ENSG00000182220	NM_005765	ATP6AP2	ATPase, H+ transporting, lysosomal accessory protein 2
ENSG00000159720	NM_004691	ATP6V0D1	ATPase, H+ transporting, lysosomal 38 kDa, V0 subunit d1
		ATP6V1E2	ATPase, H+ transporting, lysosomal 31 kDa, V1 subunit E2
ENSG00000105193	NM_001020	ATP8A1	ATPase, aminophospholipid transporter (APLT), class I, type 8A, member 1
ENSG00000171953	NM_145691	ATPAF2	ATP synthase mitochondrial F1 complex assembly factor 2
ENSG00000149541	NM_012200	B3GAT3	Beta-1,3-glucuronyltransferase 3 (glucuronosyltransferase I)
ENSG00000118276	NM_004775	B4GALT6	UDP-Gal:betaGlcNAc beta 1,4-galactosyltransferase, polypeptide 6

TABLE 6-continued

All Targets of miR-148b

Transcript ID.	RefSeq Accession No.	Target Name	Gene
ENSG00000081014	NM_007347	BAG1	BCL2-associated athanogene
ENSG00000106588	NM_002787	BAG3	BCL2-associated athanogene 3
ENSG00000206580	NM_004722	BAGE	B melanoma antigen
ENSG00000135298	NM_001704	BAI3	Brain-specific angiogenesis inhibitor 3
		BAIAP2	BAI1-associated protein 2
ENSG00000011132	NM_004886	BARD1	BRCA1 associated RING domain 1
ENSG00000138376	NM_000465		
ENSG00000105327	NM_014417	BBC3	BCL2 binding component 3
		BBS1	Bardet-Biedl syndrome 1
ENSG00000138686	NM_018190.2	BBS7	Bardet-Biedl syndrome 7
	NM_176824		
ENSG00000153094	NM_006538.3	BCL2L11	BCL2-like 11 (apoptosis facilitator)
	NM_138621		
	NM_138623		
	NM_207002		
ENSG00000121380	NM_030766	BCL2L14	BCL2-like 14 (apoptosis facilitator)
	NM_138722		
	NM_138723		
	NM_138724		
ENSG00000099385	NM_004765	BCL7C	B-cell CLL/lymphoma 7C
ENSG00000100739	NM_000710	BDKRB1	Bradykinin receptor B1
ENSG00000117133	NM_025065	BXDC5	Brix domain containing 5
		C10orf130	
ENSG00000165669	NM_022063	C10orf84	Chromosome 10 open reading frame 84
ENSG00000204856	NM_013300	C12orf24	Chromosome 12 open reading frame 24
ENSG00000180116	NM_001031748.2	C12orf40	Chromosome 12 open reading frame 40
ENSG00000179088	NM_001099336.1	C12orf42	Chromosome 12 open reading frame 42
	NM_198521.2		
ENSG00000153495	NM_152324	C13orf16	Chromosome 13 open reading frame 16
ENSG00000050130	NM_001098625.1	C14orf100	Chromosome 14 open reading frame 100
	NM_016475.3		
ENSG00000165555	NM_138791	C14orf148	Chromosome 14 open reading frame 148
ENSG00000108671	NM_002815	C14orf2	Chromosome 14 open reading frame 2
		C14orf37	Chromosome 14 open reading frame 37
		C14orf8	
ENSG00000166920	NM_032413	C15orf48	Chromosome 15 open reading frame 48
	NM_197955		
ENSG00000125149	NM_025187	C16orf70	Chromosome 16 open reading frame 70
ENSG00000070761	NM_013242	C16orf80	Chromosome 16 open reading frame 80
ENSG00000101546	NM_024805	C18orf22	Chromosome 18 open reading frame 22
		C18orf8	
ENSG00000181392	NM_001039876.1	C19orf46	Chromosome 19 open reading frame 46
	NM_032878		
ENSG00000104979	NM_014047	C19orf53	Chromosome 19 open reading frame 53
ENSG00000106392	NM_020156	C1GALT1	Core 1 synthase, glycoprotein-N-acetylgalactosamine 3-beta-galactosyltransferase, 1
ENSG00000162384	NM_017887	C1orf123	Chromosome 1 open reading frame 123
ENSG00000160767	NM_006589	C1orf2	Chromosome 1 open reading frame 2
	NM_198264		
		C1orf68	Chromosome 1 open reading frame 68
ENSG00000153363	NM_032705.3	C1orf97	Chromosome 1 open reading frame 97

TABLE 6-continued

All Targets of miR-148b

Transcript ID.	RefSeq Accession No.	Target Name	Gene
ENSG00000165985	NM_001010908	C1QL3	Complement component 1, q subcomponent-like 3
ENSG00000213192	NM_015645	C1QTNF5	C1q and tumor necrosis factor related protein 5
ENSG00000133466	NM_031910 NM_182486	C1QTNF6	C1q and tumor necrosis factor related protein 6
ENSG00000186312		CA5BL	Carbonic anhydrase VB-like
ENSG00000157782	NM_001033677 NM_004276 NM_031205	CABP1	Calcium binding protein 1
ENSG00000153956	NM_000722	CACNA2D1	Calcium channel, voltage-dependent, alpha 2/delta subunit 1
ENSG00000169136	NM_012068	CAD	Carbamoyl-phosphate synthetase 2, aspartate transcarbamylase, and dihydroorotase
ENSG00000092529	NM_000070.2 NM_024344 NM_173087 NM_173088.1 NM_173089 NM_173090 NM_212464.2 NM_212465.2 NM_212467.2	CAPN3	Calpain 3, (p94)
ENSG00000180881	NM_032606	CAPS2	Calcyphosine 2
ENSG00000187796	NM_052813	CARD9	Caspase recruitment domain family, member 9
ENSG00000153113	NM_001042440.1 NM_001042441.1 NM_001042442.1 NM_001042443.1 NM_001042444.1 NM_001042445.1 NM_001042446.1 NM_001750.5 NM_173060 NM_173061 NM_173063.1	CAST	Calpastatin
ENSG00000175294	NM_053054	CATSPER1	Cation channel, sperm associated 1
ENSG00000100211	NM_001002880 NM_015373	CBY1	Chibby homolog 1 (*Drosophila*)
ENSG00000004766	NM_017667.2 NM_024553	CCDC132	Coiled-coil domain containing 132
ENSG00000122483	NM_206886.2	CCDC18	Coiled-coil domain containing 18
ENSG00000188848	NM_207406.2	CCDC4	Coiled-coil domain containing 4
ENSG00000130783	NM_032573 NM_201435	CCDC62	Coiled-coil domain containing 62
		CCDC71	Coiled-coil domain containing 71
ENSG00000105321	NM_015603	CCDC9	Coiled-coil domain containing 9
ENSG00000040275	NM_017785	CCDC99	Coiled-coil domain containing 99
ENSG00000110148	NM_176875	CCKBR	Cholecystokinin B receptor
ENSG00000118922	NM_007249 NM_016285	CCL1	Chemokine (C-C motif) ligand 1
ENSG00000146731	NM_001009186 NM_001762	CCT6A	Chaperonin containing TCP1, subunit 6A (zeta 1)
ENSG00000135624	NM_001009570.1 NM_006429.2	CCT7	Chaperonin containing TCP1, subunit 7 (eta)
ENSG00000177697	NM_001039490 NM_004357 NM_139029 NM_139030	CD151	CD151 molecule (Raph blood group)
ENSG00000161649	NM_145273	CD300LG	CD300 molecule-like family member g
ENSG00000137101	NM_001782	CD72	CD72 molecule

TABLE 6-continued

All Targets of miR-148b

Transcript ID.	RefSeq Accession No.	Target Name	Gene
ENSG00000151465	NM_006023	CDC123	Cell division cycle 123
ENSG00000158571	NM_002625		homolog (*S. cerevisiae*)
		CDK5	Cyclin-dependent kinase 5
		CDK8	Cyclin-dependent kinase 8
		CDY1_HUMAN	
		CELP	Carboxyl ester lipase pseudogene
ENSG00000183678	NM_001327	CENPI	Centromere protein I
ENSG00000184033	NM_139250		
ENSG00000138092	NM_024322	CENPO	Centromere protein O
ENSG00000101639	NM_032142	CEP192	Centrosomal protein 192 kDa
ENSG00000182923	NM_001042383.1	CEP63	Centrosomal protein 63 kDa
	NM_001042384.1		
	NM_001042400.1		
	NM_025180		
ENSG00000101624	NM_024899	CEP76	Centrosomal protein 76 kDa
ENSG00000147869	NM_005454	CER1	Cerberus 1, cysteine knot superfamily, homolog (*Xenopus laevis*)
ENSG00000152785	NM_001201	CETN3	Centrin, EF-hand protein, 3 (CDC31 homolog, yeast)
ENSG00000112175	NM_021073	CFL1	Cofilin 1 (non-muscle)
ENSG00000172757	NM_005507		
ENSG00000153922	NM_001270	CHD1	Chromodomain helicase DNA binding protein 1
ENSG00000131778	NM_004284	CHD1L	Chromodomain helicase DNA binding protein 1-like
ENSG00000111642	NM_001273	CHD4	Chromodomain helicase DNA binding protein 4
ENSG00000152518	NM_006887		
ENSG00000171316	NM_017780.2	CHD7	Chromodomain helicase DNA binding protein 7
		CHD9	Chromodomain helicase DNA binding protein 9
		CHMP4B	Chromatin modifying protein 4B
		CHUK	Conserved helix-loop-helix ubiquitous kinase
		CIR_HUMAN	
ENSG00000134825	NM_014206	CKS2	CDC28 protein kinase regulatory subunit 2
ENSG00000109572	NM_001829	CLCN3	Chloride channel 3
	NM_173872		
ENSG00000166527	NM_080387	CLEC4D	C-type lectin domain family 4, member D
ENSG00000172243	NM_022570	CLEC7A	C-type lectin domain family 7, member A
	NM_197947.2		
	NM_197948.2		
	NM_197950		
	NM_197954		
ENSG00000186222	NM_018366	CNO	Cappuccino homolog (mouse)
ENSG00000113300	NM_015455	CNOT6	CCR4-NOT transcription complex, subunit 6
ENSG00000144619	NM_175607.1	CNTN4	Contactin 4
	NM_175612.1		
	NM_175613		
ENSG00000155052	NM_130773.2	CNTNAP5	Contactin associated protein-like 5
ENSG00000084636	NM_001856.3	COL16A1	Collagen, type XVI, alpha 1
		COL20A1	Collagen, type XX, alpha 1
ENSG00000139219	NM_001844.4	COL2A1	Collagen, type II, alpha 1 (primary osteoarthritis, spondyloepiphyseal dysplasia, congenital)
	NM_033150		
		COX5B	Cytochrome c oxidase subunit Vb
ENSG00000160111	NM_015692.2	CPAMD8	C3 and PZP-like, alpha-2-macroglobulin domain containing 8
ENSG00000110090	NM_001031847	CPT1A	Carnitine palmitoyltransferase 1A (liver)
	NM_001876		

TABLE 6-continued

All Targets of miR-148b

Transcript ID.	RefSeq Accession No.	Target Name	Gene
ENSG00000060566	NM_032607	CREB3L3	CAMP responsive element binding protein 3-like 3
		CRSP7	
ENSG00000163254	NM_020989	CRYGC	Crystallin, gamma C
		CSTL1	Cystatin-like 1
ENSG00000188234	NM_133446	CTGLF1	Centaurin, gamma-like family, member 1
ENSG00000163453	NM_001553	CTSA	Cathepsin A
ENSG00000117984	NM_001909	CTSD	Cathepsin D
ENSG00000173681	NM_198279	CXorf23	Chromosome X open reading frame 23
ENSG00000205666		CXorf28	Chromosome X open reading frame 28
ENSG00000101901	NM_001099922.1 NM_018466	CXorf45	Chromosome X open reading frame 45
ENSG00000176034	NM_173695	CXorf59	Chromosome X open reading frame 59
ENSG00000065615	NM_016230	CYB5R4	Cytochrome b5 reductase 4
ENSG00000108468 ENSG00000160870	NM_006807 NM_000765	CYP3A7	Cytochrome P450, family 3, subfamily A, polypeptide 7
ENSG00000186529	NM_000896	CYP4F3	Cytochrome P450, family 4, subfamily F, polypeptide 3
ENSG00000180432	NM_004391	CYP8B1	Cytochrome P450, family 8, subfamily B, polypeptide 1
ENSG00000078725	NM_014618	DBC1	Deleted in bladder cancer 1
		DCC	Deleted in colorectal carcinoma
		DCTN3	Dynactin 3 (p22)
ENSG00000153904	NM_012137	DDAH1	Dimethylarginine dimethylaminohydrolase 1
ENSG00000181418	NM_015086	DDN	Dendrin
ENSG00000174243	NM_004818	DDX23	DEAD (Asp-Glu-Ala-Asp) box polypeptide 23
ENSG00000108654	NM_004396	DDX5	DEAD (Asp-Glu-Ala-Asp) box polypeptide 5
ENSG00000110367	NM_004397.3	DDX6	DEAD (Asp-Glu-Ala-Asp) box polypeptide 6
ENSG00000144231 ENSG00000158796	NM_004805 NM_001039711 NM_001039712 NM_032998	DEDD	Death effector domain containing
ENSG00000119522	NM_020946 NM_024820	DENND1A	DENN/MADD domain containing 1A
ENSG00000145214	NM_001347	DGKQ	Diacylglycerol kinase, theta 110 kDa
ENSG00000167536	NM_144683	DHRS13	Dehydrogenase/reductase (SDR family) member 13
ENSG00000105808	NM_006989	DIP2A	DIP2 disco-interacting protein 2 homolog A (*Drosophila*)
ENSG00000107984	NM_012242	DKK1	Dickkopf homolog 1 (*Xenopus laevis*)
ENSG00000155011	NM_014421	DKK2	Dickkopf homolog 2 (*Xenopus laevis*)
ENSG00000161249	NM_001035516.1 NM_033317	DMKN	Dermokine
ENSG00000104936	NM_001081560.1 NM_001081563.1 NM_004409	DMPK	Dystrophia myotonica-protein kinase
ENSG00000142700	NM_032110.1	DMRTA2	DMRT-like family A2
ENSG00000172869	NM_005509	DMXL1	Dmx-like 1
ENSG00000105877 ENSG00000214594	NM_003777.3 NM_018916.3 NM_032011.1	DNAH11	Dynein, axonemal, heavy chain 11
ENSG00000137094	NM_012266	DNAJB5	DnaJ (Hsp40) homolog, subfamily B, member 5
ENSG00000169403	NM_000952	DNAJC8	DnaJ (Hsp40) homolog, subfamily C, member 8
ENSG00000197959	NM_015569.2	DNM3	Dynamin 3
ENSG00000129757	NM_000076	DNMT1	DNA (cytosine-5-)-methyltransferase 1
ENSG00000123992	NM_012100.2	DNPEP	Aspartyl aminopeptidase

TABLE 6-continued

All Targets of miR-148b

Transcript ID.	RefSeq Accession No.	Target Name	Gene
ENSG00000130158	NM_020812.1	DOCK6	Dedicator of cytokinesis 6
ENSG00000108963	NM_001383.3	DPH1	DPH1 homolog (*S. cerevisiae*)
ENSG00000170946	NM_181706	DPH4	DPH4, JJJ3 homolog (*S. cerevisiae*)
		DTYMK	Deoxythymidylate kinase (thymidylate kinase)
ENSG00000140254	NM_144565	DUOXA1	Dual oxidase maturation factor 1
ENSG00000188542	NM_001033575	DUSP28	Dual specificity phosphatase 28
ENSG00000121083	NM_080677	DYNLL2	Dynein, light chain, LC8-type 2
ENSG00000165169	NM_006520	DYNLT3	Dynein, light chain, Tctex-type 3
ENSG00000105204	NM_004714 NM_006483.1 NM_006484	DYRK1B	Dual-specificity tyrosine-(Y)-phosphorylation regulated kinase 1B
ENSG00000101412	NM_005225	E2F1	E2F transcription factor 1
		ECEL1	Endothelin converting enzyme-like 1
ENSG00000170989	NM_001400	EDG1	Endothelial differentiation, sphingolipid G-protein-coupled receptor, 1
ENSG00000102189	NM_003566	EEA1	Early endosome antigen 1
ENSG00000153922 ENSG00000156508	NM_001270 NM_001402 NR_003586.1	EEF1A1	Eukaryotic translation elongation factor 1 alpha 1
ENSG00000165487	NM_152726	EFHA1	EF-hand domain family, member A1
ENSG00000100842	NM_005864 NM_032459	EFS	Embryonal Fyn-associated substrate
		EGLX_HUMAN	
ENSG00000134698	NM_017629	EIF2C4	Eukaryotic translation initiation factor 2C, 4
		EIF4E3	Eukaryotic translation initiation factor 4E family member 3
ENSG00000141642	NM_018696	ELAC1	ElaC homolog 1 (*E. coli*)
ENSG00000162374	NM_021952	ELAVL4	ELAV (embryonic lethal, abnormal vision, *Drosophila*)-like 4 (Hu antigen D)
ENSG00000126749	NM_006331.5	EMG1	EMG1 nucleolar protein homolog (*S. cerevisiae*)
		EML5	Echinoderm microtubule associated protein like 5
ENSG00000174837	NM_001974	EMR1	Egf-like module containing, mucin-like, hormone receptor-like 1
ENSG00000145293	NM_021204	ENOPH1	Enolase-phosphatase 1
ENSG00000136960	NM_001040092 NM_006209	ENPP2	Ectonucleotide pyrophosphatase/phosphodiesterase 2 (autotaxin)
ENSG00000176177	NM_152512	ENTHD1	ENTH domain containing 1
ENSG00000054179 ENSG00000143032	NM_001246 NM_203468 NM_020063	ENTPD2	Ectonucleoside triphosphate diphosphohydrolase 2
ENSG00000134873	NM_006984 NM_182848	EP300	E1A binding protein p300
ENSG00000113946	NM_006580	EPB41L2	Erythrocyte membrane protein band 4.1-like 2
		EPS15L2	
ENSG00000134899	NM_000123	ERCC5	Excision repair cross-complementing rodent repair deficiency, complementation group 5 (xeroderma pigmentosum, complementation group G (Cockayne syndrome))
ENSG00000143845	NM_018208	ETNK2	Ethanolamine kinase 2
ENSG00000182944	NM_005243 NM_013986	EWSR1	Ewing sarcoma breakpoint region 1

TABLE 6-continued

All Targets of miR-148b

Transcript ID.	RefSeq Accession No.	Target Name	Gene
ENSG00000104313	NM_000503 NM_172058 NM_172059 NM_172060.1	EYA1	Eyes absent homolog 1 (*Drosophila*)
ENSG00000124491	NM_000129	F13A1	Coagulation factor XIII, A1 polypeptide
ENSG00000117525 ENSG00000132259	NM_001993 NM_001037329	F3	Coagulation factor III (thromboplastin, tissue factor)
ENSG00000116473	NM_001010935 NM_002884	FARP2	FERM, RhoGEF and pleckstrin domain protein 2
ENSG00000124279	NM_024091	FASTKD3	FAST kinase domains 3
ENSG00000139219 ENSG00000166147	NM_001844.4 NM_033150 NM_000138	FBN1	Fibrillin 1
ENSG00000142449	NM_032447	FBN3	Fibrillin 3
ENSG00000165355	NM_203301	FBXO33	F-box protein 33
		FBXO7	F-box protein 7
ENSG00000159069	NM_018998	FBXW5	F-box and WD repeat domain containing 5
		FCMD	
ENSG00000107831	NM_006119 NM_033163 NM_033164 NM_033165	FGF8	Fibroblast growth factor 8 (androgen-induced)
		FHAD1	Forkhead-associated (FHA) phosphopeptide binding domain 1
ENSG00000145216	NM_030917	FIP1L1	FIP1 like 1 (*S. cerevisiae*)
ENSG00000010932 ENSG00000119203	NM_002021 NM_016207	FMO1	Flavin containing monooxygenase 1
ENSG00000115226	NM_022823	FNDC4	Fibronectin type III domain containing 4
ENSG00000145708	NM_001882	FPGS	Folylpolyglutamate synthase
ENSG00000151474	NM_018027	FRMD4A	FERM domain containing 4A
ENSG00000166225	NM_001042555.1 NM_006654.3	FRS2	Fibroblast growth factor receptor substrate 2
ENSG00000075618	NM_003088	FSCN1	Fascin homolog 1, actin-bundling protein (*Strongylocentrotus purpuratus*)
ENSG00000150667	NM_152597	FSIP1	Fibrous sheath interacting protein 1
ENSG00000160282	NM_006657 NM_206965	FTCD	Formiminotransferase cyclodeaminase
ENSG00000179163	NM_000147	FUCA1	Fucosidase, alpha-L-1, tissue
ENSG00000165060	NM_000144 NM_181425.1	FXN	Frataxin
ENSG00000137731	NM_001680 NM_021603	FXYD2	FXYD domain containing ion transport regulator 2
ENSG00000010810	NM_002037 NM_153047 NM_153048	FYN	FYN oncogene related to SRC, FGR, YES
ENSG00000111432	NM_007197	FZD10	Frizzled homolog 10 (*Drosophila*)
ENSG00000116717	NM_001924	GADD45A	Growth arrest and DNA-damage-inducible, alpha
ENSG00000166573	NM_001480	GALR1	Galanin receptor 1
ENSG00000140505	NM_000761	GAP43	Growth associated protein 43
ENSG00000165219	NM_015635	GAPVD1	GTPase activating protein and VPS9 domains 1
ENSG00000177628	NM_000157 NM_001005741 NM_001005742 NM_001005749 NM_001005750	GBA	Glucosidase, beta; acid (includes glucosylceramidase)
		GCLC	Glutamate-cysteine ligase, catalytic subunit
ENSG00000140297	NM_004751	GCNT3	Glucosaminyl (N-acetyl) transferase 3, mucin type

TABLE 6-continued

All Targets of miR-148b

Transcript ID.	RefSeq Accession No.	Target Name	Gene
ENSG00000146013 ENSG00000167657	NM_001496 NM_001348	GFRA3	GDNF family receptor alpha 3
ENSG00000167925	NM_032484	GHDC	GH3 domain containing
		GHRHR	Growth hormone releasing hormone receptor
ENSG00000106560 ENSG00000163026	NM_015660 NM_025203	GIMAP2	GTPase, IMAP family member 2
ENSG00000188910	NM_001005752 NM_024009	GJB3	Gap junction protein, beta 3, 31 kDa
ENSG00000198814	NM_000167 NM_203391	GK	Glycerol kinase
ENSG00000182512	NM_016417	GLRX5	Glutaredoxin 5
		GOLT1A	Golgi transport 1 homolog A (*S. cerevisiae*)
ENSG00000150625	NM_005277 NM_201591 NM_201592.1	GPM6A	Glycoprotein M6A
		GPR103	G protein-coupled receptor 103
ENSG00000069122	NM_001098518.1 NM_015234	GPR116	G protein-coupled receptor 116
ENSG00000152990	NM_145290	GPR125	G protein-coupled receptor 125
ENSG00000206294		GPR143	G protein-coupled receptor 143
		GPR157	G protein-coupled receptor 157
ENSG00000143147	NM_007369 NM_153832	GPR161	G protein-coupled receptor 161
ENSG00000136267 ENSG00000170837	NM_004080.1 NM_145695.1 NM_018971	GPR27	G protein-coupled receptor 27
ENSG00000134830	NM_018485	GPR77	G protein-coupled receptor 77
ENSG00000164199	NM_032119.3	GPR98	G protein-coupled receptor 98
ENSG00000132522 ENSG00000181019	NM_004489 NM_000903 NM_001025433 NM_001025434	GPS2	G protein pathway suppressor 2
ENSG00000211445	NM_002084.3	GPX3	Glutathione peroxidase 3 (plasma)
		GPX5	Glutathione peroxidase 5 (epididymal androgen-related protein)
ENSG00000089351	NM_020895.2	GRAMD1A	GRAM domain containing 1A
ENSG00000162946	NM_001012957.1 NM_001012958 NM_001012959 NM_018662.2	GRB14	Growth factor receptor-bound protein 14
ENSG00000140307 ENSG00000167968	NM_004492 NM_001374.2	GTF2A2	General transcription factor IIA, 2, 12 kDa
ENSG00000197265	NM_002095	GTF2E2	General transcription factor IIE, polypeptide 2, beta 34 kDa
		GTF3A	General transcription factor IIIA
		GTPBP6	GTP binding protein 6 (putative)
ENSG00000070019	NM_004963	GUCY2C	Guanylate cyclase 2C (heat stable enterotoxin receptor)
ENSG00000132518	NM_000180	GUCY2D	Guanylate cyclase 2D, membrane (retina-specific)
ENSG00000113088	NM_002104	GZMK	Granzyme K (granzyme 3; tryptase II)
ENSG00000128708	NM_001033085.1 NM_003642	HAT1	Histone acetyltransferase 1
ENSG00000185808 ENSG00000213931	NM_153681 NM_153682 NM_005330	HBE1	Hemoglobin, epsilon 1

TABLE 6-continued

All Targets of miR-148b

Transcript ID.	RefSeq Accession No.	Target Name	Gene
ENSG00000004961	NM_005333	HCCS	Holocytochrome c synthase (cytochrome c heme-lyase)
		hCG_1643692	
ENSG00000143321	NM_004494	HDGF	Hepatoma-derived growth factor (high-mobility group protein 1-like)
ENSG00000169660	NM_173620.2	HEXDC	Hexosaminidase (glycosyl hydrolase family 20, catalytic domain) containing
ENSG00000161202	NM_004423	HHEX	Hematopoietically expressed homeobox
ENSG00000124440	NM_022462.3 NM_152794 NM_152795	HIF3A	Hypoxia inducible factor 3, alpha subunit
ENSG00000112727 ENSG00000124693 ENSG00000178458 ENSG00000182572	NM_021018 NM_003537 NM_003534 NM_003533 NM_003531 NM_003532 NM_003535 NM_003530 NM_003529 NM_003536	HIST1H3H	Histone cluster 1, H3h
ENSG00000204523	NM_005514	HLA-B	Major histocompatibility complex, class I, B
ENSG00000204525	NM_002117	HLA-C	Major histocompatibility complex, class I, C
		HLA-DQB2	
ENSG00000204632 ENSG00000206443 ENSG00000206506	NM_002127	HLA-G	HLA-G histocompatibility antigen, class I, G
		HLA-J	
ENSG00000205581	NM_004965	HMGN1	High-mobility group nucleosome binding domain 1
ENSG00000103942	NM_004839.2 NM_199330.1	HOMER2	Homer homolog 2 (*Drosophila*)
		HOXA2	Homeobox A2
		HOXA5	Homeobox A5
ENSG00000127483	NM_016287	HP1BP3	Heterochromatin protein 1, binding protein 3
ENSG00000110756	NM_007216 NM_181507 NM_181508	HPS5	Hermansky-Pudlak syndrome 5
		HSP90B1	Heat shock protein 90 kDa beta (Grp94), member 1
		IBRDC1	
		IDH3G	Isocitrate dehydrogenase 3 (NAD+) gamma
ENSG00000127415	NM_000203	IDUA	Iduronidase, alpha-L-
ENSG00000188483	NM_203434.2	IER5L	Immediate early response 5-like
ENSG00000204869	NM_001002923	IGFL4	IGF-like family member 4
ENSG00000104365	NM_001556	IKBKB	Inhibitor of kappa light polypeptide gene enhancer in B-cells, kinase beta
ENSG00000077942	NM_001996 NM_006485 NM_006486 NM_006487.2	IL15	Interleukin 15
ENSG00000177663	NM_014339	IL17RA	Interleukin 17 receptor A
ENSG00000115602	NM_003856 NM_016232	IL1RL1	Interleukin 1 receptor-like 1
ENSG00000016402	NM_014432	IL20RA	Interleukin 20 receptor, alpha
ENSG00000182393	NM_172140	IL29	Interleukin 29 (interferon, lambda 1)
ENSG00000162747		INDO	Indoleamine-pyrrole 2,3 dioxygenase
ENSG00000128908	NM_017553	INOC1	INO80 complex homolog 1 (*S. cerevisiae*)

TABLE 6-continued

All Targets of miR-148b

Transcript ID.	RefSeq Accession No.	Target Name	Gene
ENSG00000102786	NM_001039937.1 NM_001039938.1 NM_012141	INTS6	Integrator complex subunit 6
ENSG00000119509	NM_014425 NM_183245	INVS	Inversin
ENSG00000120645	NM_015232	IQSEC3	IQ motif and Sec7 domain 3
ENSG00000186895	NM_005247	ITGAD	Integrin, alpha D
ENSG00000075388 ENSG00000083457	NM_002007 NM_002208	ITGAE	Integrin, alpha E (antigen CD103, human mucosal lymphocyte antigen 1; alpha polypeptide)
ENSG00000160867	NM_002011 NM_022963 NM_213647	ITGB4	Integrin, beta 4
		ITGB4BP	
ENSG00000198399	NM_006277 NM_019595 NM_147152.1	ITSN2	Intersectin 2
ENSG00000066135	NM_014663	JMJD2A	Jumonji domain containing 2A
		K0256_HUMAN	
ENSG00000173473 ENSG00000186625	NM_003074 NM_007044	KATNA1	Katanin p60 (ATPase-containing) subunit A 1
ENSG00000143603	NM_002249 NM_170782	KCNN3	Potassium intermediate/small conductance calcium-activated channel, subfamily N, member 3
ENSG00000117245	NM_020816	KIF17	Kinesin family member 17
ENSG00000130294 ENSG00000143412	NM_004321.4 NM_003568	KIF1A	Kinesin family member 1A
ENSG00000165115	NM_017576	KIF27	Kinesin family member 27
ENSG00000104892	NM_177417	KLC3	Kinesin light chain 3
ENSG00000163884	NM_014079	KLF15	Kruppel-like factor 15
ENSG00000138814	NM_000944	KLF4	Kruppel-like factor 4 (gut)
		KLF8	Kruppel-like factor 8
ENSG00000187961	NM_198317	KLHL17	Kelch-like 17 (*Drosophila*)
ENSG00000129451	NM_001077500.1 NM_002776 NM_145888	KLK10	Kallikrein-related peptidase 10
ENSG00000182481 ENSG00000215769	NM_002266	KPNA2	Karyopherin alpha 2 (RAG cohort 1, importin alpha 1)
ENSG00000118162	NM_007059.2	KPTN	Kaptin (actin binding protein)
ENSG00000108417	NM_003770	KRT37	Keratin 37
ENSG00000186860	NM_031964	KRTAP17-1	Keratin associated protein 17-1
ENSG00000172886	NM_001012503.1 NM_021046.2	KRTAP5-9	Keratin associated protein 5-9
ENSG00000141068	NM_014238.1	KSR1	Kinase suppressor of ras 1
ENSG00000087299	NM_024884	L2HGDH	L-2-hydroxyglutarate dehydrogenase
		L3MBTL	
ENSG00000167531	NM_002289	LALBA	Lactalbumin, alpha-
ENSG00000112769	NM_002290	LAMA4	Laminin, alpha 4
ENSG00000172037	NM_002292	LAMB2	Laminin, beta 2 (laminin S)
ENSG00000005893	NM_002294 NM_013995	LAMP2	Lysosomal-associated membrane protein 2
ENSG00000107929	NM_015155	LARP5	La ribonucleoprotein domain family, member 5
ENSG00000143815	NM_002296 NM_194442	LBR	Lamin B receptor
ENSG00000043462	NM_005565.3	LCP2	Lymphocyte cytosolic protein 2 (SH2 domain containing leukocyte protein of 76 kDa)
		LDOC1	Leucine zipper, down-regulated in cancer 1
ENSG00000136110 ENSG00000165349	NM_001011705.1 NM_007015 NM_001048164.1 NM_032803	LECT1	Leukocyte cell derived chemotaxin 1

TABLE 6-continued

All Targets of miR-148b

Transcript ID.	RefSeq Accession No.	Target Name	Gene
ENSG00000186007	NM_001001552	LEMD1	LEM domain containing 1
ENSG00000166477	NM_138792	LEO1	Leo1, Paf1/RNA polymerase II complex component, homolog (*S. cerevisiae*)
		LETMD1	LETM1 domain containing 1
ENSG00000153902	NM_139284	LGI4	Leucine-rich repeat LGI family, member 4
		LGP2_HUMAN	
ENSG00000070404	NM_005860	LHCGR	Luteinizing hormone/choriogonadotropin receptor
ENSG00000138039	NM_000233		
ENSG00000143355	NM_001014434	LHX9	LIM homeobox 9
	NM_020204		
ENSG00000101670	NM_006033	LIPG	Lipase, endothelial
ENSG00000188992	NM_198996	LIPI	Lipase, member I
ENSG00000168216	NM_018368	LMBRD1	LMBR1 domain containing 1
ENSG00000160789	NM_005572	LMNA	Lamin A/C
	NM_170707		
	NM_170708		
ENSG00000072201	NM_032622	LNX1	Ligand of numb-protein X 1
ENSG00000110002	NM_014622	LOH11CR2A	Loss of heterozygosity, 11, chromosomal region 2, gene A
ENSG00000176920	NM_198315		
	NM_000511		
	NM_001097638.1		
ENSG00000177595	NM_145886	LRDD	Leucine-rich repeats and death domain containing
ENSG00000081479	NM_004525	LRP2	Low density lipoprotein-related protein 2
ENSG00000125122	NM_001004055	LRRC29	Leucine rich repeat containing 29
	NM_012163		
ENSG00000132128	NM_006369	LRRC41	Leucine rich repeat containing 41
ENSG00000163221	NM_005621		
		LRRC44	Leucine rich repeat containing 44
ENSG00000197147	NM_015350	LRRC8B	Leucine rich repeat containing 8 family, member B
ENSG00000175928	NM_020873	LRRN1	Leucine rich repeat neuronal 1
ENSG00000149657		LSM14B	LSM14B, SCD6 homolog B (*S. cerevisiae*)
ENSG00000090006	NM_001042544.1	LTBP4	Latent transforming growth factor beta binding protein 4
	NM_001042545.1		
	NM_003573.2		
ENSG00000083099	NM_020466	LYRM2	LYR motif containing 2
ENSG00000140280	NM_153374	LYSMD2	LysM, putative peptidoglycan-binding, domain containing 2
ENSG00000163818	NM_020347	LZTFL1	Leucine zipper transcription factor-like 1
ENSG00000179632	NM_032272	MAF1	MAF1 homolog (*S. cerevisiae*)
		MAFB	V-maf musculoaponeurotic fibrosarcoma oncogene homolog B (avian)
ENSG00000068990	NM_001011548	MAGEA4	Melanoma antigen family A, 4
ENSG00000147381	NM_001011549		
ENSG00000198716	NM_001011550		
ENSG00000205777	NM_002362		
	NM_001475.1		
	NM_001477.1		
	NM_021123.2		
	NM_001040663.1		
	NM_001098406.1		
	NM_001098407.1		
	NM_001098408.1		
	NM_001098409.1		
	NM_001098410.1		
	NM_001098418.1		
	NM_001468		
	NM_001085441.1		
	NM_001098405.1		
	NM_001474.1		
	NM_001476.1		

TABLE 6-continued

All Targets of miR-148b

Transcript ID.	RefSeq Accession No.	Target Name	Gene
ENSG00000177383	NM_022149	MAGEF1	Melanoma antigen family F, 1
ENSG00000135040	NM_024635	MAK10	MAK10 homolog, amino-acid N-acetyltransferase subunit, (*S. cerevisiae*)
ENSG00000196782	NM_018717.3	MAML3	Mastermind-like 3 (*Drosophila*)
ENSG00000130758	NM_002446	MAP3K10	Mitogen-activated protein kinase kinase kinase 10
ENSG00000085511	NM_005922 NM_006724	MAP3K4	Mitogen-activated protein kinase kinase kinase 4
ENSG00000100324	NM_006116 NM_153497	MAP3K7IP1	Mitogen-activated protein kinase kinase kinase 7 interacting protein 1
ENSG00000128310	NM_003614	MAP4	Microtubule-associated protein 4
ENSG00000104814	NM_001042600.1 NM_007181.4	MAP4K1	Mitogen-activated protein kinase kinase kinase kinase 1
ENSG00000164114	NM_001039580	MAP9	Microtubule-associated protein 9
ENSG00000116141	NM_018650	MARK1	MAP/microtubule affinity-regulating kinase 1
		MBIP	MAP3K12 binding inhibitory protein 1
ENSG00000160294 ENSG00000171314	NM_003906 NM_002629	MCM3AP	Minichromosome maintenance complex component 3 associated protein
ENSG00000112139	NM_153487.3	MDGA1	MAM domain containing glycosylphosphatidylinositol anchor 1
ENSG00000184634	NM_005120.2	MED12	Mediator complex subunit 12
ENSG00000144893	NM_053002	MED12L	Mediator complex subunit 12-like
ENSG00000156603	NM_153450	MED19	Mediator complex subunit 19
ENSG00000123600	NM_024770	METTL8	Methyltransferase like 8
ENSG00000135953	NM_032718	MFSD9	Major facilitator superfamily domain containing 9
ENSG00000198160	NM_001077700.1 NM_001077701.1 NM_001077702.1 NM_001077703.1 NM_001077704.1 NM_020948.2	MIER1	Mesoderm induction early response 1 homolog (*Xenopus laevis*)
ENSG00000099964	NM_002415	MIF	Macrophage migration inhibitory factor (glycosylation-inhibiting factor)
ENSG00000099875	NM_017572 NM_199054	MKNK2	MAP kinase interacting serine/threonine kinase 2
ENSG00000089693	NM_005439	MLF2	Myeloid leukemia factor 2
ENSG00000076242	NM_000249	MLH1	MutL homolog 1, colon cancer, nonpolyposis type 2 (*E. coli*)
		MLLT10	Myeloid/lymphoid or mixed-lineage leukemia (trithorax homolog, *Drosophila*); translocated to, 10
ENSG00000115648	NM_001042467.1 NM_024101	MLPH	Melanophilin
ENSG00000142606	NM_033467	MMEL1	Membrane metallo-endopeptidase-like 1
ENSG00000106571	NM_000168	MMP10	Matrix metallopeptidase 10 (stromelysin 2)
ENSG00000137745	NM_002427	MMP13	Matrix metallopeptidase 13 (collagenase 3)
		MND1	Meiotic nuclear divisions 1 homolog (*S. cerevisiae*)
ENSG00000138587	NM_018365	MNS1	Meiosis-specific nuclear structural 1
ENSG00000165943	NM_022151	MOAP1 MOB2_HUMAN	Modulator of apoptosis 1

TABLE 6-continued

All Targets of miR-148b

Transcript ID.	RefSeq Accession No.	Target Name	Gene
ENSG00000182890	NM_012084	MOBP	Myelin-associated oligodendrocyte basic protein
ENSG00000075643	NM_017947	MOCOS	Molybdenum cofactor sulfurase
ENSG00000172680	NM_005372	MOS	V-mos Moloney murine sarcoma viral oncogene homolog
ENSG00000107186	NM_003829.3	MPDZ	Multiple PDZ domain protein
ENSG00000158186	NM_001085049.1 NM_012219	MRAS	Muscle RAS oncogene homolog
ENSG00000134042	NM_031939	MRO	Maestro
ENSG00000086504	NM_006428	MRPL28	Mitochondrial ribosomal protein L28
ENSG00000055950	NM_032112 NM_176792 NM_176793 NM_176794	MRPL43	Mitochondrial ribosomal protein L43
ENSG00000143436	NM_031420	MRPL9	Mitochondrial ribosomal protein L9
ENSG00000048544	NM_018141	MRPS10	Mitochondrial ribosomal protein S10
ENSG00000163319	NM_016067	MRPS18C	Mitochondrial ribosomal protein S18C
ENSG00000144029	NM_031902	MRPS5	Mitochondrial ribosomal protein S5
ENSG00000095002	NM_000251	MSH2	MutS homolog 2, colon cancer, nonpolyposis type 1 (*E. coli*)
ENSG00000172209	NM_005295	MSMB	Microseminoprotein, beta-
ENSG00000173531	NM_020998	MST1	Macrophage stimulating 1 (hepatocyte growth factor-like)
ENSG00000188786	NM_005955	MTF1	Metal-regulatory transcription factor 1
		MTHFD1L	Methylenetetrahydrofolate dehydrogenase (NADP+ dependent) 1-like
ENSG00000063601	NM_003828	MTMR1	Myotubularin related protein 1
ENSG00000163719	NM_001077525.1 NM_001077526.1 NM_022485.3	MTMR14	Myotubularin related protein 14
ENSG00000170873	NM_014751	MTSS1	Metastasis suppressor 1
ENSG00000063515 ENSG00000134323	NM_005315 NM_005378	MYCN	V-myc myelocytomatosis viral related oncogene, neuroblastoma derived (avian)
ENSG00000172428	NM_138336	MYEOV2	Myeloma overexpressed 2
		MYH13	
		MYO15B	Myosin XVB pseudogene
ENSG00000041515	NM_015011	MYO16	Myosin XVI
ENSG00000142661	NM_152372.3	MYOM3	Myomesin family, member 3
ENSG00000090971	NM_020378	NAT14	N-acetyltransferase 14
ENSG00000144035	NM_003960 NM_016347.2	NAT8B	N-acetyltransferase 8B (gene/pseudogene)
ENSG00000215691		NBR1	Neighbor of BRCA1 gene 1
ENSG00000025770	NM_014551.4 NM_152299	NCAPH2	Non-SMC condensin II complex, subunit H2
ENSG00000198646	NM_014071	NCOA6	Nuclear receptor coactivator 6
ENSG00000166579	NM_001025579 NM_030808	NDEL1	NudE nuclear distribution gene E homolog (*A. nidulans*)-like 1
ENSG00000124479	NM_000266	NDP	Norrie disease (pseudoglioma)
ENSG00000158864	NM_004550	NDUFS2	NADH dehydrogenase (ubiquinone) Fe—S protein 2, 49 kDa (NADH-coenzyme Q reductase)
ENSG00000109674	NM_018248	NEIL3	Nei endonuclease VIII-like 3 (*E. coli*)
ENSG00000197168	NM_199289	NEK5	NIMA (never in mitosis gene a)-related kinase 5

TABLE 6-continued

All Targets of miR-148b

Transcript ID.	RefSeq Accession No.	Target Name	Gene
ENSG00000072736	NM_004555 NM_173163 NM_173164.1 NM_173165	NFATC3	Nuclear factor of activated T-cells, cytoplasmic, calcineurin-dependent 3
ENSG00000050344 ENSG00000124212	NM_004289 NM_000961	NFE2L3	Nuclear factor (erythroid-derived 2)-like 3
ENSG00000124529 ENSG00000146232 ENSG00000158406 ENSG00000182217	NM_003544 NM_004556 NM_003543 NM_001034077 NM_003548 NM_003539 NM_003538 NM_003542 NM_021968 NM_175054 NM_003541 NM_003540 NM_003495 NM_003545 NM_003546	NFKBIE	Nuclear factor of kappa light polypeptide gene enhancer in B-cells inhibitor, epsilon
ENSG00000167984	NM_178844.2	NLRC3	NLR family, CARD domain containing 3
ENSG00000179873	NM_145007	NLRP11	NLR family, pyrin domain containing 11
ENSG00000160703	NM_024618 NM_170722.1	NLRX1	NLR family member X1
		NME7	
	—	NMI	N-myc (and STAT) interactor
ENSG00000183691	NM_005450	NOG	Noggin
ENSG00000130935	NM_015462	NOL11	Nucleolar protein 11
ENSG00000128731	NM_004667	NPHS1	Nephrosis 1, congenital, Finnish type (nephrin)
ENSG00000187258	NM_207172 NM_207173	NPSR1	Neuropeptide S receptor 1
ENSG00000156642	NM_012428 NM_017455	NPTN	Neuroplastin
ENSG00000181019	NM_000903 NM_001025433 NM_001025434	NQO1	NAD(P)H dehydrogenase, quinone 1
		NR_002593.1	
ENSG00000148572	NM_030759	NRBF2	Nuclear receptor binding factor 2
ENSG00000169752	NM_138573	NRG4	Neuregulin 4
ENSG00000173566	NM_024815.3	NUDT18	Nudix (nucleoside diphosphate linked moiety X)-type motif 18
ENSG00000167799	NM_181843	NUDT8	Nudix (nucleoside diphosphate linked moiety X)-type motif 8
ENSG00000136243	NM_007342	NUPL2	Nucleoporin like 2
		NXF3	Nuclear RNA export factor 3
		O95431_HUMAN	
ENSG00000135114	NM_003733 NM_198213	OASL	2'-5'-oligoadenylate synthetase-like
ENSG00000132297	NM_001080399.1	OC90	Otoconin 90
		ODZ3	Odz, odd Oz/ten-m homolog 3 (*Drosophila*)
ENSG00000181355	NM_153003	OFCC1	Orofacial cleft 1 candidate 1
ENSG00000011083 ENSG00000060491	NM_014228 NM_007346	OGFR	Opioid growth factor receptor
ENSG00000162745	NM_015441	OLFML2B	Olfactomedin-like 2B
		OPRM1	Opioid receptor, mu 1
ENSG00000198965	NM_001004472	OR10R2	Olfactory receptor, family 10, subfamily R, member 2
ENSG00000203662	NR_002141.1	OR2M1P	Olfactory receptor, family 2, subfamily M, member 1 pseudogene
ENSG00000177186	NM_001004691	OR2M7	Olfactory receptor, family 2, subfamily M, member 7

TABLE 6-continued

All Targets of miR-148b

Transcript ID.	RefSeq Accession No.	Target Name	Gene
ENSG00000122718	NM_019897	OR2S2	Olfactory receptor, family 2, subfamily S, member 2
ENSG00000180934	NM_001001917	OR56A1	Olfactory receptor, family 56, subfamily A, member 1
ENSG00000148215	NM_001001923	OR5C1	Olfactory receptor, family 5, subfamily C, member 1
ENSG00000179420	NR_002140.1	OR6W1P	Olfactory receptor, family 6, subfamily W, member 1 pseudogene
ENSG00000144909	NM_022776	OSBPL11	Oxysterol binding protein-like 11
ENSG00000134996	NM_012383	OSTF1	Osteoclast stimulating factor 1
ENSG00000036473	NM_000531	OTC	Ornithine carbamoyltransferase
ENSG00000149948	NM_003484		
ENSG00000068308	NM_017602	OTUD5	OTU domain containing 5
ENSG00000187950	NM_183378.2	OVCH1	Ovochymase 1
ENSG00000187848	NM_012226	P2RX2	Purinergic receptor P2X, ligand-gated ion channel, 2
	NM_016318		
	NM_170682		
	NM_170683		
	NM_174872		
	NM_174873		
ENSG00000171631	NM_004154	P2RY6	Pyrimidinergic receptor P2Y, G-protein coupled, 6
	NM_176796		
	NM_176797		
	NM_178798		
ENSG00000112530	NM_001080378.1	PACRG	PARK2 co-regulated
	NM_001080379.1		
	NM_152410		
ENSG00000198682	NM_001015880.1	PAPSS2	3'-phosphoadenosine 5'-phosphosulfate synthase 2
	NM_004670		
ENSG00000140694	NM_002582.1	PARN	Poly(A)-specific ribonuclease (deadenylation nuclease)
ENSG00000148600	NM_033100	PCDH21	Protocadherin 21
ENSG00000120265	NM_005389	PCMT1	Protein-L-isoaspartate (D-aspartate) O-methyltransferase
ENSG00000135749	NM_014801.3	PCNXL2	Pecanex-like 2 (*Drosophila*)
ENSG00000173282		PCNXL3	Pecanex-like 3 (*Drosophila*)
ENSG00000197136			
ENSG00000099783	NM_005968	PCSK6	Proprotein convertase subtilisin/kexin type 6
ENSG00000140479	NM_031203		
	NM_002570.3		
	NM_138319.2		
	NM_138320.1		
	NM_138321.1		
	NM_138322.2		
	NM_138323.1		
	NM_138324.1		
	NM_138325.2		
ENSG00000102230	NM_004845	PCYT1B	Phosphate cytidylyltransferase 1, choline, beta
ENSG00000154678	NM_005020	PDE1C	Phosphodiesterase 1C, calmodulin-dependent 70 kDa
ENSG00000121905	NM_002143	PDE4D	Phosphodiesterase 4D, cAMP-specific (phosphodiesterase E3 dunce homolog, *Drosophila*)
ENSG00000167004	NM_005313	PDIA3	Protein disulfide isomerase family A, member 3
		PDK3	Pyruvate dehydrogenase kinase, isozyme 3
ENSG00000125430	NM_006041	PFAS	Phosphoribosylformylglycinamidine synthase (FGAR amidotransferase)
ENSG00000170525	NM_004566	PFKFB3	6-phosphofructo-2-kinase/fructose-2,6-biphosphatase 3
ENSG00000025293	NM_016436	PHF20	PHD finger protein 20
ENSG00000172943	NM_015107	PHF8	PHD finger protein 8

TABLE 6-continued

All Targets of miR-148b

Transcript ID.	RefSeq Accession No.	Target Name	Gene
ENSG00000144381 ENSG00000156873	NM_002156 NM_199440 NM_000294	PHKG2	Phosphorylase kinase, gamma 2 (testis)
ENSG00000087111	NM_033198	PIGS	Phosphatidylinositol glycan anchor biosynthesis, class S
ENSG00000121879	NM_006218.2	PIK3CA	Phosphoinositide-3-kinase, catalytic, alpha polypeptide
		PIK4CA	
ENSG00000107959	NM_014889.2	PITRM1	Pitrilysin metallopeptidase 1
ENSG00000197181	NM_018068	PIWIL2	Piwi-like 2 (*Drosophila*)
ENSG00000118762	NM_000297	PKD2	Polycystic kidney disease 2 (autosomal dominant)
ENSG00000143627	NM_000298 NM_181871.2	PKLR	Pyruvate kinase, liver and RBC
ENSG00000116711	NM_024420	PLA2G4A	Phospholipase A2, group IVA (cytosolic, calcium-dependent)
ENSG00000168907	NM_213600	PLA2G4F	Phospholipase A2, group IVF
ENSG00000127472	NM_000929	PLA2G5	Phospholipase A2, group V
ENSG00000137055	NM_001031689 NM_004253	PLAA	Phospholipase A2-activating protein
		PLEKHQ1	
		PLGB_HUMAN	
		PLGLA1	Plasminogen-like A1
ENSG00000003147 ENSG00000125551 ENSG00000183281	NM_004968 NM_022307 NM_002665 NM_001032392	PLGLB1	Plasminogen-like B1
		PLSCR5	Phospholipid scramblase family, member 5
ENSG00000127957	NM_001003686 NM_005395	PMS2L3	Postmeiotic segregation increased 2-like 3
ENSG00000146453	NM_173516	PNLDC1	Poly(A)-specific ribonuclease (PARN)-like domain containing 1
ENSG00000177666	NM_020376	PNPLA2	Patatin-like phospholipase domain containing 2
ENSG00000032444	NM_006702	PNPLA6	Patatin-like phospholipase domain containing 6
ENSG00000146278	NM_006813	PNRC1	Proline-rich nuclear receptor coactivator 1
ENSG00000189266 ENSG00000215700	NM_017761	PNRC2	Proline-rich nuclear receptor coactivator 2
ENSG00000047315	NM_000938	POLR2B	Polymerase (RNA) II (DNA directed) polypeptide B, 140 kDa
ENSG00000172336	NM_005837	POP7	Processing of precursor 7, ribonuclease P/MRP subunit (*S. cerevisiae*)
		PPAP2C	Phosphatidic acid phosphatase type 2C
		PPIB	Peptidylprolyl isomerase B (cyclophilin B)
ENSG00000084072	NM_006112 NM_203456 NM_203457.1	PPIE	Peptidylprolyl isomerase E (cyclophilin E)
ENSG00000156475	NM_004576 NM_181674 NM_181675 NM_181676 NM_181677.1 NM_181678.1	PPP2R2B	Protein phosphatase 2 (formerly 2A), regulatory subunit B, beta isoform
ENSG00000204481	NM_001099854.1	PRAMEF14	PRAME family member 14
ENSG00000106617	NM_001040633.1 NM_016203 NM_024429.1	PRKAG2	Protein kinase, AMP-activated, gamma 2 non-catalytic subunit
ENSG00000067606	NM_001033581.1 NM_001033582.1 NM_002744	PRKCZ	Protein kinase C, zeta

TABLE 6-continued

All Targets of miR-148b

Transcript ID.	RefSeq Accession No.	Target Name	Gene
ENSG00000138669	NM_006259	PRKG2	Protein kinase, cGMP-dependent, type II
		PROM1	Prominin 1
ENSG00000197746	NM_001042465.1 NM_001042466.1 NM_002778	PSAP	Prosaposin (variant Gaucher disease and variant metachromatic leukodystrophy)
ENSG00000100055	NM_013385	PSCD4	Pleckstrin homology, Sec7 and coiled-coil domains 4
ENSG00000142507	NM_002798	PSMB6	Proteasome (prosome, macropain) subunit, beta type, 6
		PSMC3IP	
ENSG00000173692	NM_002807	PSMD1	Proteasome (prosome, macropain) 26S subunit, non-ATPase, 1
ENSG00000095261	NM_005047	PSMD5	Proteasome (prosome, macropain) 26S subunit, non-ATPase, 5
ENSG00000121390	NM_001042414.1 NR_003272.1	PSPC1	Paraspeckle component 1
ENSG00000125384	NM_000956	PTGER2	Prostaglandin E receptor 2 (subtype EP2), 53 kDa
ENSG00000175354	NM_002828 NM_080422 NM_080423	PTPN2	Protein tyrosine phosphatase, non-receptor type 2
		PXMP2	Peroxisomal membrane protein 2, 22 kDa
ENSG00000041353	NM_004163	RAB27B	RAB27B, member RAS oncogene family
ENSG00000109113	NM_031934	RAB34	RAB34, member RAS oncogene family
ENSG00000179331	NM_017516	RAB39	RAB39, member RAS oncogene family
ENSG00000172780	NM_020701.2 NM_198490	RAB43	RAB43, member RAS oncogene family
ENSG00000137955	NM_004582	RABGGTB	Rab geranylgeranyltransferase, beta subunit
		RAC2	Ras-related C3 botulinum toxin substrate 2 (rho family, small GTP binding protein Rac2)
ENSG00000051180	NM_002875 NM_133487.2	RAD51	RAD51 homolog (RecA homolog, *E. coli*) (*S. cerevisiae*)
ENSG00000185379	NM_002878 NM_133629	RAD51L3	RAD51-like 3 (*S. cerevisiae*)
ENSG00000155918	NM_130900	RAET1L	Retinoic acid early transcript 1L
ENSG00000175097	NM_000536	RAG2	Recombination activating gene 2
ENSG00000080823	NM_014226	RAGE	Renal tumor antigen
ENSG00000124233	NM_003007	RAI2	Retinoic acid induced 2
ENSG00000131831	NM_198139.1 NM_021785		
ENSG00000125970	NM_007367 NM_016732	RALY	RNA binding protein, autoantigenic (hnRNP-associated with lethal yellow homolog (mouse))
ENSG00000076864	NM_002885	RAP1GAP	RAP1 GTPase activating protein
ENSG00000111344	NM_004658	RASAL1	RAS protein activator like 1 (GAP1 like)
ENSG00000107551	NM_032023	RASSF4	Ras association (RalGDS/AF-6) domain family 4
ENSG00000122257	NM_006910 NM_018703	RBBP6	Retinoblastoma binding protein 6
ENSG00000179051	NM_018715	RCC2	Regulator of chromosome condensation 2

TABLE 6-continued

All Targets of miR-148b

Transcript ID.	RefSeq Accession No.	Target Name	Gene
ENSG00000160957	NM_004260.2	RECQL4	RecQ protein-like 4
		RG9MTD1	RNA (guanine-9-) methyltransferase domain containing 1
ENSG00000158315	NM_017821	RHBDL2	Rhomboid, veinlet-like 2 (*Drosophila*)
ENSG00000187010	NM_016124	RHD	Rh blood group, D antigen
		RHOT2	Ras homolog gene family, member T2
ENSG00000176406	NM_014677.3	RIMS2	Regulating synaptic membrane exocytosis 2
ENSG00000153561	NM_022780	RMND5A	Required for meiotic nuclear division 5 homolog A (*S. cerevisiae*)
ENSG00000137075	NM_022781 NM_194328 NM_194329 NM_194330 NM_194332	RNF38	Ring finger protein 38
ENSG00000169855	NM_002941.2 NM_133631.1	ROBO1	Roundabout, axon guidance receptor, homolog 1 (*Drosophila*)
ENSG00000161016	NM_000973 NM_033301	RPL8	Ribosomal protein L8
ENSG00000124614 ENSG00000177606	NM_001014 NM_002228	RPS10	Ribosomal protein S10
ENSG00000166133	NM_152260	RPUSD2	RNA pseudouridylate synthase domain containing 2
ENSG00000144580	NM_005444	RQCD1	RCD1 required for cell differentiation1 homolog (*S. pombe*)
ENSG00000083750	NM_006064 NM_016656	RRAGB	Ras-related GTP binding B
		RSBN1L	Round spermatid basic protein 1-like
		RSHL2	
ENSG00000115310	NM_007008.2 NM_020532.4 NM_153828 NM_207520.1 NM_207521	RTN4	Reticulon 4
ENSG00000133105	NM_130806	RXFP2	Relaxin/insulin-like family peptide receptor 2
ENSG00000188015	NM_002960	S100A3	S100 calcium binding protein A3
		S100A7A	S100 calcium binding protein A7A
ENSG00000151835	NM_014363	SACS	Spastic ataxia of Charlevoix-Saguenay (sacsin)
ENSG00000203943	NM_001010971	SAMD13	Sterile alpha motif domain containing 13
ENSG00000161526	NM_013260	SAP30BP	SAP30 binding protein
ENSG00000189001	NM_198538	SBSN	Suprabasin
		SCAMP2	Secretory carrier membrane protein 2
ENSG00000114650 ENSG00000173572	NM_012235 NM_176810	SCAP	SREBF chaperone
ENSG00000136448 ENSG00000171951	NM_021079 NM_003469	SCG2	Secretogranin II (chromogranin C)
ENSG00000079689 ENSG00000153253	NM_006998 NM_006922	SCGN	Secretagogin, EF-hand calcium binding protein
ENSG00000102098 ENSG00000134419	NM_006089 NM_001019 NM_001030009	SCML2	Sex comb on midleg-like 2 (*Drosophila*)
ENSG00000215767	NM_012313.1 NM_014512.1 NM_014513.2	SCN9A	Sodium channel, voltage-gated, type IX, alpha subunit
ENSG00000080293 ENSG00000133116	NM_002980 NM_004795	SCTR	Secretin receptor
ENSG00000140612	NM_014300.2	SEC11A	SEC11 homolog A (*S. cerevisiae*)
ENSG00000188404	NM_000655.3	SELL	Selectin L (lymphocyte adhesion molecule 1)

TABLE 6-continued

All Targets of miR-148b

Transcript ID.	RefSeq Accession No.	Target Name	Gene
ENSG00000174175	NM_003005	SELP	Selectin P (granule membrane protein 140 kDa, antigen CD62)
ENSG00000112701 ENSG00000144659	NM_001100409.1 NM_015571.2 NM_017875	SENP6	SUMO1/sentrin specific peptidase 6
		SERPINE2	Serpin peptidase inhibitor, clade E (nexin, plasminogen activator inhibitor type 1), member 2
ENSG00000149212	NM_144665	SESN3	Sestrin 3
ENSG00000104897	NM_007165	SF3A2	Splicing factor 3a, subunit 2, 66 kDa
ENSG00000116754	NM_004768	SFRS11	Splicing factor, arginine/serine-rich 11
ENSG00000139218	NM_004719	SFRS2IP	Splicing factor, arginine/serine-rich 2, interacting protein
		SG494_HUMAN	
ENSG00000160410	NM_138392	SHKBP1	SH3KBP1 binding protein 1
ENSG00000112246 ENSG00000135862	NM_005068 NM_002293	SIM1	Single-minded homolog 1 (*Drosophila*)
ENSG00000089163 ENSG00000164303	NM_012240 NM_153343	SIRT4	Sirtuin (silent mating type information regulation 2 homolog) 4 (*S. cerevisiae*)
ENSG00000077463	NM_016539	SIRT6	Sirtuin (silent mating type information regulation 2 homolog) 6 (*S. cerevisiae*)
ENSG00000187531	NM_016538	SIRT7	Sirtuin (silent mating type information regulation 2 homolog) 7 (*S. cerevisiae*)
ENSG00000126903	NM_019848	SLC10A3	Solute carrier family 10 (sodium/bile acid cotransporter family), member 3
ENSG00000145283	NM_197965	SLC10A6	Solute carrier family 10 (sodium/bile acid cotransporter family), member 6
ENSG00000139370	NM_145648	SLC15A4	Solute carrier family 15, member 4
ENSG00000102743	NM_014252	SLC25A15	Solute carrier family 25 (mitochondrial carrier; ornithine transporter) member 15
ENSG00000125648	NM_024103	SLC25A23	Solute carrier family 25 (mitochondrial carrier; phosphate carrier), member 23
ENSG00000153046	NM_004824 NM_170751.1 NM_170752	SLC26A3	Solute carrier family 26, member 3
ENSG00000008300	NM_001040454.1 NM_001407 NM_022911.2 NM_134263.2 NM_134426.2	SLC26A6	Solute carrier family 26, member 6
ENSG00000169359	NM_004733	SLC33A1	Solute carrier family 33 (acetyl-CoA transporter), member 1
ENSG00000175782	NM_018656.2	SLC35E3	Solute carrier family 35, member E3
ENSG00000141424	NM_001099406.1 NM_012319.3	SLC39A6	Solute carrier family 39 (zinc transporter), member 6
		SLC5A3	
ENSG00000170920	NM_001001958	SMARCA5	SWI/SNF related, matrix associated, actin dependent regulator of chromatin, subfamily a, member 5
ENSG00000146830	NM_022574	SMC3	Structural maintenance of chromosomes 3

TABLE 6-continued

All Targets of miR-148b

Transcript ID.	RefSeq Accession No.	Target Name	Gene
ENSG00000102172	NM_004595	SMS	Spermine synthase
		SNAPAP	
ENSG00000205302	NM_003100	SNX2	Sorting nexin 2
		SNX3	Sorting nexin 3
ENSG00000115904	NM_005633	SOS1	Son of sevenless homolog 1 (*Drosophila*)
		SOS2	Son of sevenless homolog 2 (*Drosophila*)
ENSG00000123352	NM_023071	SPATS2	Spermatogenesis associated, serine-rich 2
		SPESP1	
ENSG00000147059	NM_019003	SPIN2A	Spindlin family, member 2A
		SPINT4	Serine peptidase inhibitor, Kunitz type 4
ENSG00000188766	NM_001039616.1 NM_001042522.1	SPRED3	Sprouty-related, EVH1 domain containing 3
ENSG00000070182	NM_000347 NM_001024858	SPTB	Spectrin, beta, erythrocytic (includes spherocytosis, clinical type I)
ENSG00000213523	NM_001035235	SRA1	Steroid receptor RNA activator 1
		SRP9	Signal recognition particle 9 kDa
ENSG00000135250	NM_182691 NM_182692	SRPK2	SFRS protein kinase 2
ENSG00000138385	NM_003142	SSB	Sjogren syndrome antigen B (autoantigen La)
ENSG00000160075	NM_014188	SSU72	SSU72 RNA polymerase II CTD phosphatase homolog (*S. cerevisiae*)
ENSG00000117155	NM_014021	SSX2IP	Synovial sarcoma, X breakpoint 2 interacting protein
ENSG00000115525	NM_001042437.1 NM_003896	ST3GAL5	ST3 beta-galactoside alpha-2,3-sialyltransferase 5
ENSG00000177511	NM_015879	ST8SIA3	ST8 alpha-N-acetyl-neuraminide alpha-2,8-sialyltransferase 3
ENSG00000101972	NM_001042749.1 NM_001042750.1 NM_001042751.1 NM_006603	STAG2	Stromal antigen 2
ENSG00000066923	NM_012447	STAG3	Stromal antigen 3
		STAP1_HUMAN	
ENSG00000124214	NM_001037328	STAU1	Staufen, RNA binding protein, homolog 1 (*Drosophila*)
ENSG00000185022	NM_004602 NM_017452 NM_017453 NM_017454 NM_012323 NM_152878		
ENSG00000117632	NM_005563 NM_203399 NM_203401	STMN1	Stathmin 1/oncoprotein 18
		STRA13	Stimulated by retinoic acid 13 homolog (mouse)
ENSG00000137868	NM_022369	STRA6	Stimulated by retinoic acid gene 6 homolog (mouse)
		STX4	Syntaxin 4
ENSG00000076944	NM_006949	STXBP2	Syntaxin binding protein 2
ENSG00000164506	NM_139244	STXBP5	Syntaxin binding protein 5 (tomosyn)
		SUCLG1	Succinate-CoA ligase, GDP-forming, alpha subunit
ENSG00000088002	NM_004605 NM_177973	SULT2B1	Sulfotransferase family, cytosolic, 2B, member 1
ENSG00000106868	NM_022486	SUSD1	Sushi domain containing 1
ENSG00000179751	NM_001080468.1	SYCN	Syncollin
		SYNC1	Syncoilin, intermediate filament 1

TABLE 6-continued

All Targets of miR-148b

Transcript ID.	RefSeq Accession No.	Target Name	Gene
ENSG00000159082	NM_003895 NM_203446	SYNJ1	Synaptojanin 1
ENSG00000163630	NM_144642.3	SYNPR	Synaptoporin
ENSG00000006432 ENSG00000129990	NM_033141 NM_003180	SYT5	Synaptotagmin V
ENSG00000134207	NM_205848	SYT6	Synaptotagmin VI
ENSG00000176358	NM_001077503.1 NM_001077504.1 NM_001077505.1 NM_001077506.1 NM_170685.2	TAC4	Tachykinin 4 (hemokinin)
ENSG00000141384	NM_005640.1	TAF4B	TAF4b RNA polymerase II, TATA box binding protein (TBP)-associated factor, 105 kDa
ENSG00000206233 ENSG00000206297		TAP1	Transporter 1, ATP-binding cassette, sub-family B (MDR/TAP)
ENSG00000179002	NM_152232	TAS1R2	Taste receptor, type 1, member 2
ENSG00000121318	NM_023921	TAS2R10	Taste receptor, type 2, member 10
ENSG00000106052	NM_001079864.1 NM_006024	TAX1BP1	Tax1 (human T-cell leukemia virus type I) binding protein 1
ENSG00000131374	NM_014744	TBC1D5	TBC1 domain family, member 5
ENSG00000132561	NM_002380.3 NM_030583.2	TBP	TATA box binding protein
ENSG00000136270	NM_004749 NM_030900 NM_199122	TBRG4	Transforming growth factor beta regulator 4
ENSG00000059377	NM_001061 NM_030984	TBXAS1	Thromboxane A synthase 1 (platelet, cytochrome P450, family 5, subfamily A)
ENSG00000133142	NM_001006935.1 NM_001006936.1 NM_001006937.1 NM_024863	TCEAL4	Transcription elongation factor A (SII)-like 4
ENSG00000148737	NM_030756	TCF7L2	Transcription factor 7-like 2 (T-cell specific, HMG-box)
ENSG00000120156	NM_000459	TEK	TEK tyrosine kinase, endothelial (venous malformations, multiple cutaneous and mucosal)
ENSG00000132604	NM_005652	TERF2	Telomeric repeat binding factor 2
ENSG00000100109	NM_001008697 NM_012143	TFIP11	Tuftelin interacting protein 11
ENSG00000092295	NM_000359	TGM1	Transglutaminase 1 (K polypeptide epidermal type I, protein-glutamine-gamma-glutamyltransferase)
ENSG00000180176	NM_000360 NM_199292 NM_199293	TH	Tyrosine hydroxylase
ENSG00000143198 ENSG00000172009	NM_004528 NM_003249	THOP1	Thimet oligopeptidase 1
ENSG00000179886	NM_032862	TIGD5	Tigger transposable element derived 5
ENSG00000071242 ENSG00000138297	NM_001006932 NM_021135 NM_006327	TIMM23	Translocase of inner mitochondrial membrane 23 homolog (yeast)
		TLE4	Transducin-like enhancer of split 4 (E(sp1) homolog, *Drosophila*)
ENSG00000162604	NM_032027.2	TM2D1	TM2 domain containing 1
ENSG00000136404	NM_023003	TM6SF1	Transmembrane 6 superfamily member 1
		TMEM112B	
		TMEM128	Transmembrane protein 128
ENSG00000161558	NM_018273	TMEM143	Transmembrane protein 143

TABLE 6-continued

All Targets of miR-148b

Transcript ID.	RefSeq Accession No.	Target Name	Gene
ENSG00000168890	NM_001031738 NM_153342	TMEM150	Transmembrane protein 150
ENSG00000166822	NM_145254	TMEM170 TMEM177	Transmembrane protein 170 Transmembrane protein 177
ENSG00000177854	NM_003492	TMEM187 TMEM49	Transmembrane protein 187 Transmembrane protein 49
ENSG00000118600	NM_014254	TMEM5	Transmembrane protein 5
ENSG00000142188	NM_006134	TMEM50B	Transmembrane protein 50B
ENSG00000121900	NM_033504	TMEM54	Transmembrane protein 54
ENSG00000116857	NM_016456	TMEM9	Transmembrane protein 9
ENSG00000175348	NM_020644	TMEM9B	TMEM9 domain family, member B
ENSG00000178297	NM_182973	TMPRSS9	Transmembrane protease, serine 9
ENSG00000034510	NM_021103	TMSB10 TMSL1	Thymosin, beta 10 Thymosin-like 1
ENSG00000026036	NM_003823 NM_016434 NM_032945 NM_032957	TNFRSF6B	Tumor necrosis factor receptor superfamily, member 6b, decoy
ENSG00000131165	NM_001083314.1 NM_002768.2	TNFSF14	Tumor necrosis factor (ligand) superfamily, member 14
ENSG00000168884	NM_024309	TNIP2 TNPO2	TNFAIP3 interacting protein 2 Transportin 2 (importin 3, karyopherin beta 2b)
ENSG00000090905	NM_014494	TNRC6A	Trinucleotide repeat containing 6A
ENSG00000079308	NM_022648	TNS1	Tensin 1
ENSG00000196655	NM_016146	TRAPPC4 TRAV24 TRBV10-1 TRBV4-3	Trafficking protein particle complex 4
ENSG00000213689	NM_016381.3 NM_033627 NM_033628 NM_033629	TREX1	Three prime repair exonuclease 1
ENSG00000137394 ENSG00000204613 ENSG00000206424	NM_006778 NM_052828	TRIM10	Tripartite motif-containing 10
ENSG00000134253	NM_025188	TRIM45	Tripartite motif-containing 45
ENSG00000163462	NM_025058	TRIM46	Tripartite motif-containing 46
ENSG00000070985	NM_014555	TRPM5	Transient receptor potential cation channel, subfamily M, member 5
ENSG00000104447	NW_014112	TRPS1	Trichorhinophalangeal syndrome I
ENSG00000111199	NM_021625 NM_147204	TRPV4	Transient receptor potential cation channel, subfamily V, member 4
ENSG00000103197	NM_000548 NM_021055	TSC2	Tuberous sclerosis 2
ENSG00000074319	NM_006292	TSG101	Tumor susceptibility gene 101
ENSG00000171045	NM_145003	TSNARE1	T-SNARE domain containing 1
ENSG00000064201	NM_005705.4 NM_139022	TSPAN32	Tetraspanin 32
ENSG00000163728	NM_001042601.1 NM_133462	TTC14	Tetratricopeptide repeat domain 14
ENSG00000176014	NM_032525	TUBB6	Tubulin, beta 6
ENSG00000074935	NM_016262	TUBE1	Tubulin, epsilon 1
ENSG00000104723	NM_006765 NM_178234	TUSC3 U464_HUMAN	Tumor suppressor candidate 3
ENSG00000125976 ENSG00000143569	NM_006047 NM_152838 NM_014847	UBAP2L	Ubiquitin associated protein 2-like
ENSG00000170035	NM_006357 NM_182678	UBE2E4P	Ubiquitin-conjugating enzyme E2E 4 pseudogene

TABLE 6-continued

All Targets of miR-148b

Transcript ID.	RefSeq Accession No.	Target Name	Gene
ENSG00000175564	NM_003356 NM_022803.1	UCP3	Uncoupling protein 3 (mitochondrial, proton carrier)
ENSG00000102595	NM_020121	UGCGL2	UDP-glucose ceramide glucosyltransferase-like 2
		UGT1A1	
ENSG00000135226	NM_053039	UGT2B28	UDP glucuronosyltransferase 2 family, polypeptide B28
ENSG00000147854	NM_152896	UHRF2	Ubiquitin-like, containing PHD and RING finger domains, 2
ENSG00000111981	NM_025218	ULBP1	UL16 binding protein 1
ENSG00000131015	NM_025217	ULBP2	UL16 binding protein 2
ENSG00000182168	NM_003728	UNC5C	Unc-5 homolog C (*C. elegans*)
ENSG00000164405	NM_014402	UQCRQ	Ubiquinol-cytochrome c reductase, complex III subunit VII, 9.5 kDa
ENSG00000159650	NM_144639	UROC1	Urocanase domain containing 1
ENSG00000158773	NM_007122 NM_207005.1	USF1	Upstream transcription factor 1
ENSG00000135093	NM_032663	USP30	Ubiquitin specific peptidase 30
ENSG00000170185	NM_032557	USP38	Ubiquitin specific peptidase 38
ENSG00000168883	NM_006590	USP39	Ubiquitin specific peptidase 39
ENSG00000170242	NM_017944.3	USP47	Ubiquitin specific peptidase 47
		USP7	Ubiquitin specific peptidase 7 (herpes virus-associated)
ENSG00000198382	NM_003369	UVRAG	UV radiation resistance associated gene
ENSG00000103043	NM_018052	VAC14	Vac14 homolog (*S. cerevisiae*)
ENSG00000111786 ENSG00000168899	NM_003769 NM_006634	VAMP5	Vesicle-associated membrane protein 5 (myobrevin)
ENSG00000162692	NM_001078 NM_080682	VCAM1	Vascular cell adhesion molecule 1
ENSG00000147852	NM_001018056 NM_003383	VLDLR	Very low density lipoprotein receptor
ENSG00000197969	NM_001018037.1 NM_001018038.1 NM_015186 NM_033305	VPS13A	Vacuolar protein sorting 13 homolog A (*S. cerevisiae*)
ENSG00000104142	NM_020857	VPS18	Vacuolar protein sorting 18 homolog (*S. cerevisiae*)
ENSG00000115561	NM_001005753.1 NM_016079	VPS24	Vacuolar protein sorting 24 homolog (*S. cerevisiae*)
		VPS37A	Vacuolar protein sorting 37 homolog A (*S. cerevisiae*)
ENSG00000073111 ENSG00000163159	NM_004526 NM_005997	VPS72	Vacuolar protein sorting 72 homolog (*S. cerevisiae*)
ENSG00000100568	NM_006370	VTI1B	Vesicle transport through interaction with t-SNAREs homolog 1B (yeast)
ENSG00000167992	NM_152718	VWCE	Von Willebrand factor C and EGF domains
ENSG00000139668	NM_052950	WDFY2	WD repeat and FYVE domain containing 2
ENSG00000128815		WDFY4	WDFY family member 4
ENSG00000157796	NM_025132.3	WDR19	WD repeat domain 19
ENSG00000163811		WDR43	WD repeat domain 43
ENSG00000103091	NM_030581	WDR59	WD repeat domain 59
		WDR85	WD repeat domain 85
ENSG00000166483	NM_003390	WEE1	WEE1 homolog (*S. pombe*)
ENSG00000120662 ENSG00000185049	NM_004294 NM_005663	WHSC2	Wolf-Hirschhorn syndrome candidate 2
ENSG00000135925	NM_025216	WNT10A	Wingless-type MMTV integration site family, member 10A
ENSG00000169884	NM_003394	WNT10B	Wingless-type MMTV integration site family, member 10B

TABLE 6-continued

All Targets of miR-148b

Transcript ID.	RefSeq Accession No.	Target Name	Gene
ENSG00000154767	NM_004628.3	XPC	Xeroderma pigmentosum, complementation group C
		XR_016777.1	
		XR_019191.1	
ENSG00000015532	NM_022167	XYLT2	Xylosyltransferase II
		YPEL3	Yippee-like 3 (*Drosophila*)
ENSG00000182223	NM_175619	ZAR1	Zygote arrest 1
ENSG00000160062	NM_001040441	ZBTB8	Zinc finger and BTB domain
ENSG00000215897			containing 8
ENSG00000100722	NM_024824	ZC3H14	Zinc finger CCCH-type
	NM_207660		containing 14
	NM_207661		
	NM_207662		
ENSG00000186908	NM_015336.2	ZDHHC17	Zinc finger, DHHC-type containing 17
ENSG00000180776	NM_153251.2	ZDHHC20	Zinc finger, DHHC-type containing 20
		ZDHHC6	Zinc finger, DHHC-type containing 6
ENSG00000166140	NM_001077268.1	ZFYVE19	Zinc finger, FYVE domain containing 19
ENSG00000157077	NM_004799	ZFYVE9	Zinc finger, FYVE domain
	NM_007323		containing 9
	NM_007324		
ENSG00000156925	NM_003413	ZIC3	Zic family member 3 heterotaxy 1 (odd-paired homolog, *Drosophila*)
ENSG00000186272	NM_006959.2	ZNF17	Zinc finger protein 17
ENSG00000105497	NM_007147	ZNF175	Zinc finger protein 175
ENSG00000188629	NM_003451	ZNF177	Zinc finger protein 177
ENSG00000178386	NM_013361	ZNF223	Zinc finger protein 223
ENSG00000171606	NM_016324.2	ZNF274	Zinc finger protein 274
	NM_016325.2		
	NM_133502.1		
ENSG00000181315	NM_024639	ZNF322A	Zinc finger protein 322A
ENSG00000188801	NM_199005	ZNF322B	Zinc finger protein 322B
ENSG00000175213	NM_024741	ZNF408	Zinc finger protein 408
ENSG00000112200	NM_001031623.2	ZNF451	Zinc finger protein 451
	NM_015555		
		ZNF508	
ENSG00000144331	NM_152520	ZNF533	Zinc finger protein 533
ENSG00000188171	NM_001076675.1	ZNF626	Zihc finger protein 626
	NM_145297		
ENSG00000198551	NM_145295.2	ZNF627	Zinc finger protein 627
ENSG00000175809	NM_152577	ZNF645	Zinc finger protein 645
ENSG00000161914	NM_138783	ZNF653	Zinc finger protein 653
ENSG00000156853	NM_138447	ZNF689	Zinc finger protein 689
ENSG00000167766	NM_018300	ZNF83	Zinc finger protein 83
ENSG00000106400	NM_006349	ZNHIT1	Zinc finger, HIT type 1

TABLE 7

miR-148b targets identified by miRanda and L2L

Target Gene	Accession No:	Gene Name
ARSE	NM_000047.2 GI:157266308	arylsulfatase E (chondrodysplasia punctata 1)
COL2A1	NM_001844.4 GI:111118975	collagen, type II, alpha 1 (primary osteoarthritis, spondyloepiphyseal dysplasia, congenital)
COL2A1	NM_033150.2 GI:111118973	collagen, type II, alpha 1 (primary osteoarthritis, spondyloepiphyseal dysplasia, congenital)
FBN1	NM_000138.3 GI:93589095	fibrillin 1

TABLE 7-continued

miR-148b targets identified by miRanda and L2L

Target Gene	Accession No:	Gene Name
GHRHR	NM_000823.2 GI:58530850	growth hormone releasing hormone receptor
GHRHR	NM_001009824.1 GI:58530852	growth hormone releasing hormone receptor
HOXA2	NM_006735.3 GI:37596298	homeobox A2
HOXA5	NM_019102.2 GI:24497516	homeobox A5
LECT1	NM_007015.2 GI:59806341	leukocyte cell derived chemotaxin 1

TABLE 7-continued

miR-148b targets identified by miRanda and L2L

Target Gene	Accession No:	Gene Name
LECT1	NM_001011705.1 GI:59806342	leukocyte cell derived chemotaxin 1
NOG	NM_005450.2 GI:38788425	Noggin
OSTF1	NM_012383.3 GI:38257156	osteoclast stimulating factor 1
PAPSS2	NM_001015880.1 GI:62912491	3'-phosphoadenosine 5'-phosphosulfate synthase 2

TABLE 7-continued

miR-148b targets identified by miRanda and L2L

Target Gene	Accession No:	Gene Name
PAPSS2	NM_004670.3 GI:62912490	3'-phosphoadenosine 5'-phosphosulfate synthase 2
TFIP11	NM_012143.2 GI:56788354	tuftelin interacting protein 11
TFIP11	NM_001008697.1 GI:56788355	tuftelin interacting protein 11
TRPS1	NM_014112.2 GI:90652850	trichorhinophalangeal syndrome I

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1-32. (canceled)

33. A method of promoting mesenchymal stem cell (MSC) differentiation towards the osteogenic cell fate, the method comprising introducing into a MSC an effective amount of a composition comprising at least one differentiation promoting agent selected from the group consisting of inhibitors of miR-489, inhibitors of miR-27a, mimics of miR-148b, and siRNAs specific for genes from Tables 6-7.

34. The method of claim **33** wherein said method is performed ex vivo.

35. The method of claim **33** wherein said method is performed in vivo.

36. The method of claim **33** wherein said composition comprises at least one siRNA specific for a gene selected from the group consisting of ARSE, COL2A1, FBN1, GHRHR, HOXA2, HOXA5, LECT1, NOG, OSTF1, PAPSS2, TFIP11, and TRPS1.

37. The method of claim **33** wherein said composition comprises at least one siRNA specific for NOG.

38. The method of claim **33** wherein said composition comprises at least one inhibitor of miR-489.

39. The method of claim **33** wherein said composition comprises at least one inhibitor of miR-27a.

40. The method of claim **33** wherein said composition comprises at least one mimic of miR-148b.

41. A method of inhibiting mesenchymal stem cell (MSC) differentiation towards the osteogenic cell fate, the method comprising introducing into a MSC an effective amount of a composition comprising at least one differentiation inhibitor selected from the group consisting of mimics of miR-489, mimics of miR-27a, siRNA specific for genes from Tables 2-5, and inhibitors of miR-148b.

42. The method of claim **41** wherein said composition comprises at least one siRNA specific for a gene selected from the group consisting of ADAMTS4, AHSG, ALPL, BMI1, CHRD, DLX5, HOXA13, MATN1, MINPP1, PEX7, PRKRA, THRA, AMELY, BMP7, CDH11, CHRD, CHRDL2, EN1, MAPK8, MGP, PAX1, POSTN, SPP1, SUFU, TRAPPC2, TWIST1, GCA, and SLC22A2.

43. The method of claim **41** wherein said composition comprises at least one siRNA specific for a gene selected from the group consisting of CHRD, GCA, and SLC22A2.

44. The method of claim **41** wherein said composition comprises at least one mimic of miR-489.

45. The method of claim **9** wherein said composition comprises at least one mimic of miR-27a.

46. The method of claim **41** wherein said composition comprises at least one inhibitor of miR-148b.

47. The method of claim **41** wherein said method is performed ex vivo.

48. The method of claim **41** wherein said method is performed in vivo.

* * * * *