The present invention relates to a composition useful for the diagnosis of diseases associated with aberrant expression of the genes encoding the secreted proteins Futrin 1, 2, 3 and/or 4 (R-Spondins 2, 3, 1 and 4, respectively), e.g. in connection with tumors or diseases of the muscle, kidneys or bones. The present invention also relates to a pharmaceutical composition containing a compound which is capable of modifying (a) the expression of the gene encoding Futrin 1, 2, 3 and/or 4 or (b) the activity of the Futrin 1, 2, 3 and/or 4 protein.
Figure 1
Figure 2
Figure 4

hFut1  59
hFut2  62
hFut3  65
hFut4  68

hFut1  102
hFut2  103
hFut3  106
hFut4  109

hFut1  160
hFut2  163
hFut3  166
hFut4  169

hFut1  217
hFut2  220
hFut3  223
hFut4  226
Figure 5
pSuper Non. + + 
pSuper hFut1 + + + + 
pSuper hFut2 + + + + 
Wnt3A med. - + + + + + + 
mFut1 + + 

Figure 7
Figure 8
Figure 9
NCAM
n-tubulin
ctx2
m.actin
H4

Figure 11
Figure 12
Figure 14
hFutrin1  hFutrin3

hFutrin2  Ubiquitin

hFutrin4

Figure 15
Figure 16
COMPOSITIONS FOR DIAGNOSIS AND THERAPY OF DISEASES ASSOCIATED WITH ABERRANT EXPRESSION OF FUTRINS (R-SPONDINS) AND/OR WNT

[0001] The present invention relates to compositions useful for the diagnosis and therapy of diseases associated with aberrant expression of the genes encoding the proteins Futrin 1, 2, 3 and/or 4 (R-Spondin 2, 3, 1 and 4, respectively). These diseases include tumors of e.g. the breast, ovary, liver, uterus, cervix, colon, lung, ovary, rectum, testis, pancreas, bones and skin, as well as diseases involving muscle, bone, lipid and glucose metabolism, and obesity. The present invention also relates to a pharmaceutical composition containing a compound which is capable of modifying (a) the expression of the gene encoding Futrin 1, 2, 3 and/or 4 or (b) the activity of Futrin 1, 2, 3 and/or 4.

[0002] The Wnt signal cascade plays a crucial role as regards regulation of survival, proliferation and differentiation of cells during embryogenesis, and in the adult as shown, e.g., in Drosophila, Xenopus and mice (Nusse and Varmus, Cell 69 (1992), 1073-1087). Wnt-genes encode secretory glycoproteins which activate a well characterized signal cascade via a Wnt receptor called “frizzled”.

[0003] The Wnt signalling cascade and its components also play an important role in various diseases which it is desirable to modulate its activity:

i) Cancer

[0004] Tumorigenesis represents a complex multistage process in which genetic changes and environmental factors are thought to deregulate the cellular processes that control cell proliferation and differentiation. Several studies indicate that an aberrant Wnt signal cascade is involved in the development of colon cancer, breast cancer and melanoma (Pfeiffer, Science, 275 (1997), 1752-1753; Polakis, Genes Dev. 14 (2000), 1837-1851). The first gene encoding a protein of the Wnt signal cascade, int-1, was isolated from mouse mammary tumor virus (MMTV) and it could be shown that it is an oncogene. It is thus well established that an aberrant regulation of the activity of Wnt and/or components of the Wnt signal cascade downstream of the Wnt signal, e.g., beta-catenin and APC, are involved in tumorigenesis.

ii) Bone Disease


iii) Eye Disease


iv) Kidney


v) Lipid and Glucose Metabolism, Obesity

[0008] Deficiency of the Wnt receptor LRPS in mice leads to increased plasma cholesterol levels in mice fed a high-fat diet, because of the decreased hepatic clearance of chyloplin remnant lipoproteins. In addition, when fed a normal diet, LRPS-deficient mice show a marked improvement of glucose tolerance (Fujino, et al., 100 (2002) Proc Natl Acad Sci USA, 229-234.) Administration of the LRPS antagonist Didk to mice reduces glucose uptake in various cell lines and decreases fat deposition (WO 02/06509).

[0009] It is thus clear from the above that the Wnt signalling pathway is involved in a variety of human diseases. Yet, means for the therapy or diagnosis of diseases associated with a dis-regulated Wnt signal cascade are insufficiently available. Thus, the use of reliable diagnostic molecular markers would be helpful for an understanding of the molecular basis of diseases associated with an aberrant Wnt signal cascade. It can be expected that such markers are also useful for therapy and for the development of novel therapeutic avenues for treatment of Wnt signal cascade dependent diseases, as detailed above.

[0010] Thus, the technical problem underlying the present invention is to provide means for diagnosis and therapy of diseases associated with an aberrant Wnt signal cascade.

[0011] The solution to said technical problem is achieved by providing the embodiments characterized in the claims.

[0012] During the experiments resulting in the present invention four genes, futrin 1, 2, 3 and 4, could be identified the products of which are modulators of the Wnt pathway. Futrin 2 was previously identified as HPWTSR (Chen et al., 29 (2002), Mol. Biol. Rep. 287-292), a protein of before unknown role or function, expressed in numerous cell types. Further, human Futrin 1, 2, 3, and 4 were described as Stem Cell Growth Factor-Like Polypeptides, which are able to promote proliferation of hematopoietic stem cells (WO-A-01/77169; WO-A-01/07611). In the present invention the following is shown for the first time: 1) Futrins enhance Wnt signalling and this is of physiological relevance since inhibition of Futrin 1 or 2 results in inhibition of the Wnt signal cascade (Wnt/β-catenin signalling). These data show that Futrians can be regarded as Wnt modulators. Futrin 1 (Rspo2) is coexpressed with and positively regulated by Wnt signals and synergizes with Wnt to activate β-catenin. Analysis of functional interaction with components of the Wnt/β-catenin pathway suggests that Rsps2 functions extracellularly at the level of receptor ligand interaction. Antisense Morpholino experiments in Xenopus embryos and RNAi experiments in HeLa cells revealed that Rsps2 is required for Wnt/β-catenin signalling. In Xenopus embryos depleted of Rsps2 the muscle markers myoD and myf5 fail to be activated and later muscle development is impaired. The results indicate that Rsps2 is a novel activator of the Wnt/β-catenin cascade. Thus, Futrians like Rsps2 (Futrin 1) are useful for the diagnosis and the development of therapies for Wnt-LRP mediated diseases, including but not limited to tumor suppression, bone formation, cholesterol and glucose metabolism (including diabetes), obesity, kidney disease and eye disease. 2) Since the
data obtained show that Futrin 1 is required for muscle formation. Futrin 1 is useful for the diagnosis and the development of therapies for muscle related diseases, including muscle regeneration. 3.) The data show that Futrins are aberrantly expressed in a variety of human tumors. Thus, Futrins are useful for tumor diagnosis and the development of cancer therapies. For example it has been found that in most of the tumors the expression of Futrins 1-3 is dramatically decreased (colon, stomach, lung, rectum tumors for Futrin 1, breast, ovary, pancreatic, uterine, cervix, rectum tumors for Futrin 2, uterine and cervix tumors for Futrin 3). In a few cases the expression of Futrin 1-3 is upregulated in one case of stomach tumor for Futrin 1 and 2, ovary tumor for Futrin 3). Futrin 4 shows very low level of expression in most of the tissues studied, except ovary.

[0013] Thus, the inhibition of the Wnt signal cascade by inhibiting the expression/activity of Futrins or by stimulating the expression/activity of the Futrins will have a therapeutic effect. Likewise, the activation of the Wnt signal cascade by decreasing the expression of Futrin and/or by repressing the activity of the polypeptide itself will have a therapeutic effect.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] FIG. 1: Identification of Xenopus Futrin 1 (Rspo2)

[0015] TOP-FLASH reporter, vector DNA from pools of 250 clones each and pCSfrizzled8 were co-transfected. Luciferase reporter assays in 293T cells were carried out in 96 well plates in duplicates as described (Wu et al., Curr Biol 10 (2000), 1611-1614). Luciferase activity was normalized against cotransfected Remilla-luc activity using a commercial kit (Clontech). RLU: relative luciferase units

[0016] FIG. 2: Futrin 1 (Rspo2) promotes Wnt/β-catenin signalling

[0017] (A) Identification of Xenopus Rspo2 by expression screening. An expression screen was carried out in 293T cells transfected with a Wnt-responsive reporter (TOPFLASH) and plasmid DNA pools from a Xenopus eye cDNA library. RLU: relative light units.

[0018] (B) The C-terminal of Rspo2 mediates cell surface retention. Myc-tagged Rspo2 (wt) or Rspo2AC (AC) were transfected in 293T cells, and cell lysate and medium were analysed by Western blot. Co, untransfected cells.

[0019] (C) Rspo2 activates Wnt/β-catenin signalling. TOPFLASH luciferase reporter assays were carried out in 293T cells with the following transfected DNAs: mouse Wnt1 (Wnt1), 5 ng; mouse frizzled8 (Fz), 1 ng; Xenopus Rspo2 (Rspo2), 0.1, 0.3, 0.9 and 2.7 ng.

[0020] (D) Rspo2 enhances Wnt3a signalling. Mouse Wnt3a, Xenopus Rspo2AC (Rspo2AC) or mock-conditioned media were added to 293T cells followed by TOPFLASH luciferase reporter assays.

[0021] (E) Rspo2 stabilizes β-catenin. (top) 293T cells were treated with Rspo2AC, Wnt3a or mock-conditioned media for 1 or 4 hours as indicated. Cytosolic fractions were subjected to Western blot and probed for β-catenin and α-tubulin (loading control). (bottom) immunohistochemical staining of β-catenin in SHEP cells after 3 hour treatment with the conditioned media indicated. Arrowheads indicate nuclear β-catenin. The percentage of cells showing the represented staining is 90% (Co), 85% (Rspo2), 80% (Wnt3a) and 90% (Wnt3a+Rspo2).

[0022] (F) Domain analysis of Rspo2. (top) schematic drawing of Xenopus Rspo2 and deletion constructs. sp, signal peptide; FU1, 2, furin-like domains; TSP1, thrombospondin type 1 domain; C, positively charged C-terminus. (bottom) TOPFLASH luciferase reporter assays were carried out in 293T cells with the indicated constructs. Equal protein production was confirmed by Western blot (data not shown).

[0023] FIG. 3: Multisequence nucleic acid alignment of cDNAs encoding human Futrin 1, 2 and 3 and Xenopus Futrin 1

[0024] Identical nucleotides are highlighted in black. All nucleic acid sequences begin with the translation initiator ATG codon indicated with an asterisk. The mammalian sequence is shown in reference. The Xenopus sequence is shown in reference. (left)

[0025] FIG. 4: Multisequence amino acid alignment of human Futrin 1, 2 and 3 deduced from human cDNAs (see FIG. 3)

[0026] Identical amino acids are highlighted in black, similar amino acids are in grey.

[0027] FIG. 5: Futrins promote Wnt signalling

[0028] Cotransfection experiments in 293T cells, Wnt-responsive luciferase reporter assays were performed in 96 well plates in triplicates as described (Wu et al., Curr Biol 10 (2000), 1611-1614). Luciferase activity was normalized against Remilla activity using a commercial kit (Clontech). Wnt1→mouse Wnt1, Fz→mouse frizzled8, Futrin1→Xenopus Futrin 1, Wnt3A→mouse Wnt3A, 0.1 ng in A indicates amount of plasmid DNA transfected per well, RLU: relative luciferase units

[0029] FIG. 6: Sequence comparison of human Rspo proteins (hR-spoxin 1 to 4)

[0030] (A) Alignment of human (h) Rspo proteins (corresponding to the alignments of human Fut1-4 in FIG. 4 except that different designations are used). The signal peptide, furin-like domains and thrombospondin type 1 domain are underlined and conserved amino acids are shown in black. (B, C) Rspo homology matrix showing overview of amino acid identity in % between human Rspo proteins (B) and between Xenopus (X) or mouse (m) Rspo2 and human Rspo proteins, respectively (C).

[0031] FIG. 7: Human Futrin 1 and 2 are required for Wnt signalling

[0032] Hela cells were transfected in 24-well plates with the Wnt reporter 7LEF-Rev-fosLuc, pRL-TK and pSuper plasmids that produce either siRNA against human Futrin1 and 2 or a nonsense control. Three days after transfection, mouse Wnt3A conditioned medium was added to the culture to stimulate Wnt signalling. 24 hours later, luciferase activity was determined.

[0033] FIG. 8: Expression analysis of Xenopus and mouse R-spondins

[0034] (A) Rspo2 expression during Xenopus development at the indicated embryonic stages analysed by RT-PCR. Histone H4 was used for normalization. –RT, minus reverse transcription control.

[0035] (B-H) Xenopus whole mount in situ hybridizations of the indicated genes. (B) Stage 11 embryo, dorso-vegetal view; dbl, dorsal blastoporal lip. (C) Stage 12 embryo, dorsal view with anterior up. An anterior neural expression domain is indicated by arrowhead. (D) Stage 15 embryo, dorsal view with anterior up. (E) Stage 14 embryo, dorsal view with anterior up. (F-G) Tailbud stage embryos; lb, branchial arches; cm, cranial musculature; di, diencephalon; dnt, dorsal neural tube; mbh, midbrain-hindbrain boundary; ov, otic vesicle; pn, pronephros; pdm, proctodeum; s, somites; lb, tailbud mesoderm. Inset in (E) shows a transverse section at the level indicated by arrowhead, showing expression in dorsal neural tube and in the dorsal- and ventral-most parts of the
somites. (H) Dissected *Xenopus* tadpole brain (lateral view) showing expression in diencephalonal (di) and zona limitans intrathalamicum (zii), where sonic hedgehog is expressed (inset). dt, vt, dorsal and ventral thalamus, respectively, sc, spinal cord; tel, telencephalon.

[0036] (I-M) Mouse whole mount in situ hybridizations of the indicated genes. (J) limb buds of day 12.5 mouse embryos. AER, apical ectodermal ridge. (J) Day 7.5 mouse embryo showing Rspo3 expression in the primitive streak. (K-M) Day 9.5 mouse embryos. dt, diencephalon; dt, dorsal neural tube; inset, metencephalon; tel, telencephalon.

[0037] FIG. 9: Regulation of *Xenopus* R-spondins by Wnt signalling

[0038] (A) Comparison of XRspo2, XWnt8 and XWnt3a expression pattern in early neurula embryos by whole mount in situ hybridization. Dorsal view, anterior up.

[0039] (B) (top) Diagram of experiment. Four cell stage embryos were injected with 50 pg pCS-ppl (preprolactin), pCSXWnt8 or pCS-β-catenin into each blastomere. DMZs were dissected, cultured until stage 11 equivalent and analyzed by RT-PCR. (Bottom) RT-PCR analysis of the indicated genes. –RT, minus reverse transcription control.

[0040] (C-E) Four cell stage embryos were injected with 50 pg pCS-Wnt8, pCS-β-catenin into one blastomere and fixed at stage 11 for in situ hybridisation with XRspo2.

[0041] FIG. 10: Futrin 2 is required for muscle formation

[0042] A. Depletion of Futrin 1 protein causes downregulation of early muscle markers and muscle defects. (A,C,F,G,I,K,L) Embryos injected with control morpholino oligo (5 ng), with Fut1-Mo (5 ng). Oligos were mixed with lineage tracer mRNA (LacZ) (blue staining) in (C,D,E,F,G,H) or preprolactin (ppl) RNA, visualised by in situ hybridisation (red staining) (A,B,J,K,L). In situ hybridization with probes to Xmyf5 (A,B), XmyoD (C,D), Xbra (E,F), Xnot (G,H) and muscle actin (I-L) (magenta staining). Embryos in K and L are cut transversally. Note reduction of muscle in L (right side).

[0043] B. Fut1-Mo act specifically to inhibit translation of their cognate DNA input. Overexpressed in embryos, mRNA (C-terminal myc tagged Fut1) was injected equitatorially in both blastomeres at 2-cell stage embryos. The same embryos were then injected at the 8-cell stage with 5 ng of Fut1-Mo (lane3) or control morpholino (lane2) in all vegetal blastomeres and harvested at stage 11. Tagged, Futrin1 protein was then visualised with an a-myc antibody.

[0044] C. Rescue of muscle marker reduction caused by Fut1-Mo by coinjection of XFut1 mRNA containing point mutations in the 5’ region corresponding to morpholino oligo. Embryos were coinjected with 5 ng of Fut1-Mo (1,2) with 50 pg of ppl or XFut1 mRNA radially in one blastomere at 4-cell stage.

[0045] Expression of MyoD (1,3) and Myf5 (2,4) were analysed by in situ hybridization. All embryos were grouped into 3 classes (examples for MyoD are shown on the bottom of the figure): embryos with expression level on the injected side from 1-30% (class A); 30-70% (class B), and 70-100% (class C) from normal level. Bars represent the percentage of the embryos corresponding to type A, B or C. (a for Fut-Mo+ ppl: 57 embryos for MyoD, 45 embryos for Myf5; a for Fut-Mo+ ppl: 39 embryos for MyoD and 41 embryo for Myf5).

[0046] FIG. 11: Rspo2 promotes neural and muscle differentiation in *Xenopus*

[0047] (A) Four-cell stage embryos were injected animaly with 100 pg Rspo2, 100 pg Xwnt8, or 200 pg β-catenin mRNA in each blastomere. At stage 8, animal caps were dissected, cultured until stage 18 equivalent and analyzed for expression of the indicated marker genes. –RT, minus reverse transcription control.

[0048] (B) Two-cell stage embryos were injected with 100 pg Rspo2 or preprolactin (ppl) mRNA in each blastomere. Note ectopic cement glands (arrowhead) and shortened body axis in Rspo2 injected embryos.

[0049] (C-J) Whole mount in situ hybridisations of the indicated genes. Eight-cell stage embryos were injected with 100 pg of Rspo2 or ppl mRNAs as indicated into one animal blastomere. LacZ mRNA was co-injected as lineage tracer in all panels except C, G and H.

[0050] (C-H) Stage 15 neurule in anterior view.

[0051] (I-J) Stage 11 gastrulae in vegetal view, dorsal up.

[0052] (K-N) Rspo2 promotes muscle formation. (K) Diagram of the experiments. Four-cell stage embryos were injected with 50 pg plasmid DNA constructs in all blastomeres, the indicated fragments were explanted at stage 10.5, cultured, and processed for whole mount in situ hybridisation (M) of RT-PCR (N).

[0053] (L) Stage 40 equivalent VMZ of LMZ explants. Note tail-like structures in VMZs from Rspo2 injected embryos.

[0054] (M) In situ hybridization of stage 25 VMZs for muscle actin.

[0055] (N) RT-PCR analysis for the indicated genes in stage 25 equivalent VMZ and stage 11 equivalent DMZ explants. Xdd1, dominant negative. *Xenopus* dishevelled, Co, preprolactin.

[0056] FIG. 12: interferes with BMP-4, Activin and Nodal but not with FGF in *Xenopus*

[0057] (A-D) Four-cell stage embryos were injected animaly with indicated RNAs. At stage 8, animal caps were dissected, cultured until stage 10 equivalent and analyzed for expression of Vent2 (A) or Xbra (B-D). –RT, minus reverse transcription control. Embryos injected with 100 pg preprolactin (ppl) were used as control. Amount of mRNAs used: 100 pg Rspo2, 50 pg or 250 pg of BMP-4, 50 pg of activin, 25 or 100 pg of Wnt8, 200 pg of β-catenin, 50 or 100 pg of Xnr1, 2 or 20 pg of FGf8.

[0058] FIG. 13: Rspo2 is required for muscle formation

[0059] (A) Rspo2Mo specifically inhibits translation of its cognate DNA. Top, Diagram of the experiment. Two-cell stage *Xenopus* embryos were injected with 100 pg Myc-tagged Rspo2 mRNA in the animal region, at 8-cell stage, the same embryos were then injected with 5 ng of Rspo2Mo of CoMo in all animal blastomeres, harvested at stage 11 and processed for Western blot analysis of Myc-tagged Rspo2 and α-tubulin.

[0060] (B) Depletion of Rspo2 protein causes muscle defects and down-regulation of myogenic markers. Four-cell stage embryos were injected equatorially into one blastomere with 5 ng control morpholino oligonucleotides (CoMo) or Rspo2Mo as indicated together with 50 pg ppl mRNA or 50 pg LacZ RNA as lineage tracer and analysed at tailbud of gastrula stage by in situ hybridization for the indicated genes. In (a-f) double in situ hybridization for gene of interest (dark blue) and for ppl (red) was used. (a-d) Stage 23 embryos. (a-b): myotomes, visualised by muscle actin expression show malformations an Rspo2Mo injected side
(b). (c-d) Transversal section at the trunk level showing reduced muscle volume in (d). (e-h): myf5 and myoD expression (dark blue) is down-regulated in the Rspo2Mo injected region (red in e,f of light blue in g,h). (i-j): Xbra and Xnot2 expression (dark blue) is not affected in the region of Rspo2Mo injections (light blue).

[0061] (C) Rspo2Mo acts specifically. Rescue of myf5 reduction by coinjected Rspo2 mRNA. Four cell stage embryos were injected in one blastomere with 5 ng of control morpholino (CoMo), Rspo2Mo, 50 pg pp1. mRNA of 50 pg Rspo2 mRNA containing mismatches to Rspo2. Expression of myf5 was analysed by in situ hybridization at gastrula stage. The percentage of embryos with strongly affected (A), moderately reduced (B) and normal myf5 expression (C) as displayed in the representative embryos is indicated. Standard deviation was calculated from three independent experiments.

[0062] (D) Rspo2Mo Blocks Wnt signalling upstream of dishевelled during muscle formation. Four-cell stage embryos were radially injected with 5 ng of Rspo2Mo or CoMo, 50 pg pCS-XWnt8, pCS-dishévelled (Xdsh), pCS- dominant negative GS3-3′(dnGSK) or pCS-β-catenin. At stage 10.5 DMZs (a) or VMZs (b) or LMZs (c-d) were explanted and cultured until stage 11 (a,c) or 25 (b,d) for RT-PCR analysis of the genes indicated. −RT: minus reverse transcription control.

[0063] FIG. 14: R-spondins are required for Wnt signalling in HeLa cells

[0064] (A) RT-PCR analysis showing differential expression of human Rspo-1 in HeLa and 293T cell lines. Actin was used for normalisation.

[0065] (B) Specificity of siRNAs. 293T cells were cotransfected with pSUPER-Rspo2 or −3 (siRNA), FLAG-tagged Rspo3 and GFP (transfection control). Expression of Rspo3 and GFP were analyzed by Western blot.

[0066] (C-D) R-spondins are required for Wnt/β-catenin signalling in HeLa cells. Wnt luciferase reporter assay in HeLa cells co-transfected with the indicated constructs. Wnt3a was added as conditioned medium. RIU, relative light units.

[0067] FIG. 15: Furtin expression is deregulated in various human tumors

[0068] The expression of Furtin 1, 2, 3 and −4 or ubiquitin (to show equal loading) was analysed by radioactive hybridization on arrayed mRNAs (Clontech, Cancer Profiling Army II) from normal and cancerous tissue samples from different patients. Abbreviations: T, normal tissues; T, tumor tissues.

[0069] FIG. 16: Expression of human R-spondins in tumor samples Dot blot analysis of human Rspo1, 2 and 3 in normal and tumour samples. The same CDNA samples (Cancer Profiling Army II, Clontech) were hybridized with human Rspo1, 2, 3 and ubiquitin probes. (Top) The Cancer Profiling Array contains pairs of CDNAs from tumor and corresponding normal tissue samples from individual patients and spotted side-by-side as indicated. Organ abbreviations are: Br, breast; ov, ovary; co, colon; st, stomach; lu, lungs; kidney; bi, bleeder, vu, vulva; pr, prostate; tr, trachea; liv, liver; ut, uterus; ec, cervix; re, rectum; th, thyroid gland; te, testis; sk, skin; sin, small intestine, ps, pancreas.

[0070] FIG. 17: Interaction of R-spondins with components of the Wnt/β-catenin signalling pathway

[0071] (A-C) Wnt luciferase reporter assay in 293T cells co-transfected with the indicated constructs. Results are indicated as fold-stimulation over reporter alone. DNA doses were 5 ng Wnt1, 1 ng Fz8, 3 ng LRP6, 10 ng axin, 10 ng dntcf3, 5 ng dkk1, 10 ng Xdsh, 1 ng Wnt3a.

[0072] The present invention relates to a diagnostic composition comprising:

[0073] (a) at least one nucleic acid molecule comprising the nucleotide sequence encoding Furtin 1, 2, 3 or 4 as depicted in FIG. 3; and/or

[0074] (b) at least one polypeptide molecule comprising the amino acid sequence encoding Furtin 1, 2, 3 or 4 as depicted in FIG. 4 or 6a; and/or

[0075] (c) at least one molecule the complementary strand of which hybridizes to a nucleic acid molecule of (a) and which encodes a polypeptide with the biological activity of Furtin 1, 2, 3 or 4; and/or

[0076] (d) at least one fragment of (a), (b) or (c) having the biological activity of Furtin 1, 2, 3 or 4;

[0077] (e) at least one nucleic acid molecule the sequence of which differs from the sequence of the nucleic acid molecule of (a), (c) or (d) due to the degeneracy of the genetic code; and/or

[0078] (f) at least one ligand capable of specifically binding to the molecule of (a), (b), (c), (d) or (e).

[0079] As used herein the term “polypeptide” not only refers to polypeptides encoded by the nucleotide/amino acid sequences as depicted in FIGS. 3 and/or 4 but also to polypeptides differing in amino acid sequence due to insertion, deletion and/or substitution of one or more amino acids and showing at least one biological activity of a Furtin, e.g. the ability to promote Wnt signalling. Preferably, the related nucleic acids and/or polypeptides are nucleic acids and/or polypeptides the sequence of which shows an identity of at least 40%, in particular an identity of at least 65%, preferably of at least 80% and, particularly preferred, of at least 90% to the amino acid sequences of the polypeptides encoded by the nucleotide sequences shown in FIG. 3.

[0080] The nucleic acid molecules useful as probes can be both DNA and RNA molecules, preferably they are single-stranded DNA molecules. They can be isolated from natural sources or can be synthesized according to known methods.

[0081] As a hybridization probe nucleic acid molecules can be used, for example, that have a nucleotide sequence which is exactly or basically complementary to a nucleotide sequence as depicted in FIGS. 3 and/or 4, respectively, or parts of these sequences. The fragments used as hybridization probe can be synthetic fragments that were produced by means of conventional synthetic methods.

[0082] As used herein, the term “hybridizing” relates to hybridization under conventional hybridization conditions, preferably under stringent conditions as described, for example, in Sambrook et al., Molecular Cloning, A Laboratory Manual 2nd edition (1989) Cold Spring Harbor Laboratory Press, Cold Spring Harbor, N.Y. However, in certain cases, a hybridizing nucleic acid molecule can also be detected at lower stringency hybridization conditions. Changes in the stringency of hybridization and signal detection are primarily accomplished through the manipulation of formamide concentration (lower percentages of formamide result in lowered stringency), salt conditions, or temperature. For example, lower stringency conditions include an overnight incubation at 37° C. in a solution comprising 6xSSPE (20xSSPE=3M NaCl: 9.2M NaHPO₄: 0.02M EDTA, pH 7.4), 0.5% SDS, 30% formamide, 100 μg/ml salmon sperm blocking DNA, following by washes at 50° C. with 1xSSPE, 0.1% SDS. In addition, to achieve even lower stringency,
washes performed following stringent hybridization can be done at higher salt concentrations (e.g. 5xSSC). Variations in the above conditions may be accomplished through the inclusion and/or substitution of alternate blocking reagents used to suppress background in hybridization experiments. The inclusion of specific blocking reagents may require modification of the hybridization conditions described above, due to problems with compatibility.

The term “ligand” as used herein refers to any molecule which is capable of specifically binding to Futrin 1, 2, 3, or 4, thus allowing to determine the level of receptor molecules. Examples of such molecules include antibodies, oligonucleotides, proteins or small molecules. The molecule can be the natural ligand of Futrins, or can be closely related to said ligand, e.g., a fragment of the ligand, or a natural substrate, a structural or functional mimetic; see, e.g., Coligan, Current Protocols in Immunology (1991); Chapter 5. In either case, the molecule can be isolated or rationally designed using known techniques; see also infra.

Preferably, the ligand is an antibody. The term “antibody”, preferably, relates to antibodies which consist essentially of pooled monoclonal antibodies with different epitopic specificities, as well as distinct monoclonal antibody preparations. Monoclonal antibodies are made from an antigen containing Futrin 1, 2, 3, or 4 or fragments thereof by methods well known to those skilled in the art (see, e.g., Köhler et al., Nature 256 (1975), 495). As used herein, the term “antibody” (Ab) or “monoclonal antibody” (Mab) is meant to include intact molecules as well as antibody fragments (such as, for example, Fab and F(ab)2 fragments) which are capable of specifically binding to Futrin 1, 2, 3 and/or 4. Fab and F(ab)2 fragments lack the Fc fragment of intact antibody, clear more rapidly from the circulation, and may have less non-specific tissue binding than an intact antibody. (Wahl et al., J. Nucl. Med. 24: 316-325 (1983)). Thus, these fragments are preferred, as well as the products of a FAB or other immunoglobulin expression library. Moreover, antibodies of the present invention include chimerical, single chain, and humanized antibodies.

For certain purposes, e.g. diagnostic methods, the nucleic acid molecules can be used, for example, as probes or primers in the diagnostic assays described below and allow, e.g., the analysis of the expression of Futrin 1, 2, 3, or 4 by determining the mRNA level or the determination of mutations within the coding region or regulatory regions leading to polypeptide molecules with altered, e.g. destroyed, activity, or leading to altered expression. Preferably, the nucleic acid molecules are oligonucleotides having a length of at least 15, in particular of at least 15 and particularly preferred of at least 50 nucleotides. These nucleic acid molecules of the invention can also be used, for example, as primers for a PCR reaction.

The present invention also relates to the use of a nucleic acid molecule or ligand as defined above for the preparation of a diagnostic composition for the diagnosis of a disease associated with (a) aberrant expression of Futrin 1, 2, 3, or 4 and/or (b) aberrant activity of a Futrin 1, 2, 3, or 4 polypeptide. In a preferred embodiment, the target to which the nucleic acid molecule hybridizes is an mRNA.

The present invention also provides a method of diagnosing a disease associated with (a) aberrant expression of Futrin 1, 2, 3, or 4 and/or (b) aberrant activities or amounts of a Futrin 1, 2, 3, or 4 polypeptide in a subject comprising:

(a) determining (a) the amount of expression of Futrin 1, 2, 3, or 4 and/or (b) the amount of biologically active Futrin 1, 2, 3 and/or 4 polypeptide in a biological sample; and

(b) diagnosing a disease associated with (a) aberrant expression of Futrin 1, 2, 3 and/or 4 and/or (b) aberrant activities or amounts of a Futrin 1, 2, 3 and/or 4 polypeptide or a risk for the development of such disease based on an altered amount of expression of Futrin 1, 2, 3 and/or 4 and/or (b) altered activities or amounts of biologically active Futrin 1, 2, 3 and/or 4 polypeptide compared to a control.

Suitable assay formats are well known to the person skilled in the art and, in addition, described below. Suitable positive control samples expressing human Futrin proteins are, e.g., HEK 293 cells.

The Futrin 1, 2, 3, or 4 polypeptide or the corresponding mRNA, e.g. in biological fluids or tissues, may be detected directly in situ, e.g. by in situ hybridization or it may be isolated from other cell components by common methods known to those skilled in the art before contacting with a probe. Detection methods include Northern blot analysis, RNase protection, in situ methods, e.g. in situ hybridization, in vitro amplification methods (PCR, LCR, QRNA replication or RNA-transcription/amplification (TAS, 3SR), reverse dot blot disclosed in EP-B10 237 362), immunoassays, Western Blot and other detection assays that are known to those skilled in the art.

The probe (e.g. a specific antibody or specific oligonucleotide) of the diagnostic composition can be detectably labeled. In a preferred embodiment, said diagnostic composition contains an anti-Futrin 1, 2, 3 and/or 4 antibody and allows said diagnosis, e.g. by ELISA and contains the antibody bound to a solid support, for example, a polystyrene microtiter dish or nitrocellulose paper, using techniques known in the art. Alternatively, said diagnostic compositions are based on a RIA and contain said antibody marked with a radioactive isotope. Suitable antibody assay labels are known in the art and include enzyme labels, such as, glucose oxidase, and radioisotopes, such as iodine (¹²³I,¹²⁵I), carbon (¹⁴C), sulfur (³⁵S), tritium (³⁴H), indium (¹ⁱ⁵In) and technetium rhodamine, and biotin. In addition to assaying Futrin levels in a biological sample, the polypeptide can also be detected in vivo by imaging. Antibody labels or markers for in vivo imaging of protein include those detectable by X-radiography, NMR or ESR. For X-radiography, suitable labels include radioisotopes such as barium or cesium, which emit detectable radiation but are not overtly harmful to the subject. Suitable markers for NMR and ESR include those with a detectable characteristic spin, such as deuterium, which may be incorporated into the antibody by labeling of nutrients for the relevant hybridoma. A protein-specific antibody or antibody fragment which has been labeled with an appropriate detectable imaging moiety, such as a radioisotope (for example,¹³¹I,¹¹⁵In,²⁰⁳H) or radio-opaque substance, or a material detectable by nuclear magnetic resonance, is introduced (for example, parenterally, subcutaneously, or intraperitoneally) into the mammal. It will be understood in the art that the size of the subject and the imaging system used will
determine the quantity of imaging moiety needed to produce diagnostic images. In the case of a radiolabelled moiety, for a human subject, the quantity of radioactivity injected will normally range from about 5 to 20 millicuries of 99mTc. The labeled antibody or antibody fragment will then preferentially accumulate at the location of cells which contain the specific Futrin polypeptide. In vivo tumor imaging is, e.g., described in S. W. Burchiel et al., "Immunopharmacokinetics of Radiolabeled Antibodies and Their Fragments"; (Chapter 13 in Tumor Imaging: The Radiochemical Detection of Cancer, S. W. Burchiel and B. A. Rhodes, eds., Masson Publishing Inc. (1982)).

[0095] In a further aspect, the present invention relates to a method for identifying a binding partner to a Futrin 1, 2, 3 and/or 4 polypeptide comprising:

[0096] (a) contacting said polypeptide with a compound to be screened; and
[0097] (b) determining whether the compound affects an activity of the polypeptide.

[0098] The invention also includes a method of identifying compounds which bind to a Futrin 1, 2, 3 and/or 4 polypeptide comprising the steps of:

[0099] (a) incubating a candidate binding compound with said polypeptide; and
[0100] (b) determining if binding has occurred.

[0101] Futrin 1, 2, 3 or 4 polypeptides may be used to screen for proteins or other compounds that bind to Futrin 1, 2, 3 or 4 or for proteins or other compounds to which Futrin 1, 2, 3 and/or 4 bind. The binding of Futrin 1, 2, 3 or 4 and the molecule may activate (agonist), increase, inhibit (antagonist), or decrease activity of Futrin 1, 2, 3 or 4 or the molecule bound. Examples of such molecules include antibodies, oligonucleotides, proteins (e.g., ligands), or small molecules.

[0102] Preferably, the molecule is closely related to the natural ligand of Futrin 1, 2, 3 or 4, e.g., a fragment of the ligand, or a natural substrate, a ligand, a structural or functional mimic; see, e.g., Coligan, Current Protocols in Immunology 1(2) (1991); Chapter 5.

[0103] Preferably, the screening for these molecules involves producing appropriate cells which express Futrin 1, 2, 3 and/or 4 either as a secreted protein or on the cell membrane. Preferred cells include cells from mammals, yeast, Drosophila, or E. coli. Cells expressing Futrin 1, 2, 3 and/or 4 (or cell membrane containing the expressed polypeptide) are then preferably contacted with a test compound potentially containing the molecule to observe binding, stimulation, or inhibition of activity of Futrin 1, 2, 3 and/or 4.

[0104] The assay may simply test binding of a candidate compound to Futrin 1, 2, 3 and/or 4, wherein binding is detected by a label, or in an assay involving competition with a labeled competitor. Further, the assay may test whether the candidate compound results in a signal generated by binding to Futrin 1, 2, 3 and/or 4. Suitable assays to analyze the activity of Futrin 1, 2, 3 and/or 4 include Wnt-inducible luciferase reporter assays in transfected HEK 293 cells, where Futrin 1, 2, 3 and/or 4 synergizes with Wnt to enhance a Wnt-induced signal, such as is shown in FIG. 4.

[0105] Alternatively, the assay can be carried out using cell-free preparations, polypeptide/molecule affixed to a solid support, chemical libraries, or natural product mixtures. The assay may also simply comprise the steps of mixing a candidate compound with a solution containing Futrin 1, 2, 3 and/or 4, measuring Futrin/molecule activity or binding, and comparing the Futrin/molecule activity or binding to a standard.

[0106] Preferably, an ELISA assay can measure Futrin 1, 2, 3 and/or 4 level or activity in a sample (e.g., biological sample) using a monoclonal or polyclonal antibody. The antibody can measure Futrin 1, 2, 3 and/or 4 level or activity by either binding, directly or indirectly, to Futrin 1, 2, 3 and/or 4 or by competing with Futrin 1, 2, 3 and/or 4 for a substrate. All of these above assays can be used as diagnostic or prognostic markers. The molecules discovered using these assays can be used to treat disease or to bring about a particular result in a patient (e.g., elimination of a tumor, support of regenerative processes etc.) by modulating, preferably activating the Futrin 1, 2, 3 and/or 4 molecule. Moreover, the assays can discover agents which may inhibit or enhance the production of Futrin 1, 2, 3 and/or 4 from suitably manipulated cells or tissues.

[0107] Moreover, the invention includes a method of identifying activators/agonists or inhibitors/antagonists of a Futrin 1, 2, 3 and/or 4 polypeptide comprising the steps of:

[0108] (a) incubating a candidate compound with said polypeptide;
[0109] (b) assaying a biological activity, and
[0110] (c) determining if a biological activity of said polypeptide has been altered.

[0111] Suitable assays to analyze the activity of Futrin 1, 2, 3 and/or 4 include Wnt-inducible luciferase reporter assays in transfected HEK 293 cells, where Futrin 1, 2, 3 and/or 4 synergizes with Wnt to enhance a Wnt-induced signal, such as is shown in FIG. 4.

[0112] In a further embodiment, the present invention relates to a method of identifying and obtaining a drug candidate for therapy of diseases associated with (a) aberrant expression of Futrin 1, 2, 3 and/or 4 and/or (b) aberrant activities or amounts of a Futrin 1, 2, 3 and/or 4 polypeptide comprising the steps of

[0113] (a) contacting a Futrin 1, 2, 3 and/or 4 polypeptide or a cell expressing said polypeptide, and optionally the corresponding ligand(s), in the presence of components capable of providing a detectable signal in response to binding to said drug candidate to be screened; and
[0114] (b) detecting presence or absence of a signal or increase of the signal generated, wherein the presence or increase of the signal is indicative for a putative drug.

[0115] Suitable assays to analyze the activity of Futrin 1, 2, 3 and/or 4 include Wnt-inducible luciferase reporter assays in transfected HEK 293 cells, where Futrin 1, 2, 3 and/or 4 synergizes with Wnt to enhance a Wnt-induced signal, such as is shown in FIG. 4.

[0116] The drug candidate may be a single compound or a plurality of compounds. The term “plurality of compounds” in a method of the invention is to be understood as a plurality of substances which may or may not be identical.

[0117] Said compound or plurality of compounds may be chemically synthesized or microbologically produced and/or comprised in, for example, samples, e.g., cell extracts from, e.g., plants, animals or microorganisms. Furthermore, said compound(s) may be known in the art but hitherto not known to be capable of suppressing or activating Futrin 1, 2, 3 and/or 4 polypeptides. The reaction mixture may be a cell free extract or may comprise a cell or tissue culture. Suitable set ups for the method of the invention are known to the person skilled in the art and are, for example, generally described in
Alberts et al., Molecular Biology of the Cell, third edition (1994) and in the appended examples. The plurality of compounds may be, e.g., added to the reaction mixture, culture medium, injected into a cell or otherwise applied to a transgenic animal. The cell or tissue that may be employed in the method of the invention preferably is a host cell, mammalian cell or non-human transgenic animal.

[0118] If a sample containing a compound or a plurality of compounds is identified in the method of the invention, then it is either possible to isolate the compound from the original sample identified as containing the compound capable of suppressing or activating a Futrin 1, 2, 3 and/or 4 polypeptide, or one can further subdivide the original sample, for example, if it consists of a plurality of different compounds, so as to reduce the number of different substances per sample and repeat the method with the subdivisions of the original sample. Depending on the complexity of the samples, the steps described above can be performed several times, preferably until the sample identified according to the method of the invention only comprises a limited number of or only one substance(s). Preferably said sample comprises substances of similar chemical and/or physical properties, and most preferably said substances are identical.

[0119] Several methods are known to the person skilled in the art for producing and screening large libraries to identify compounds having specific affinity for a target. These methods include the phage-display method in which randomized peptides are displayed from phage and screened by affinity chromatography to an immobilized receptor; see, e.g., WO 91/17271, WO 92/01407, U.S. Pat. No. 5,223,409. In another approach, combinatorial libraries of polymers immobilized on a chip are synthesized using photolithography; see, e.g., U.S. Pat. No. 5,143,854, WO 90/15070 and WO 92/10092. The immobilized polymers are contacted with a labeled receptor and scanned for label to identify polymers binding to the receptor. The synthesis and screening of peptide libraries on continuous cellulose membrane supports that can be used for identifying binding ligands of the Futrin 1, 2, 3 and/or 4 polypeptides and, thus, possible inhibitors and activators is described, for example, in Kramer, Methods Mol. Biol. 37 (1998), 25-39. This method can also be used, for example, for determining the binding sites and the recognition motifs in the Futrin 1, 2, 3 and/or 4 polypeptide. In like manner, the substrate specificity of the DnaK chaperon was determined and the contact sites between human interleukin-6 and its receptor; see Rudiger, EMBO J. 16 (1997), 1501-1507 and Weiergraber, FEBS Lett. 379 (1996), 122-126, respectively. Furthermore, the above-mentioned methods can be used for the construction of binding supertopes derived from the Futrin 1, 2, 3 or 4 polypeptide. A similar approach was successfully described for peptide antigens of the anti-p24 (HIV-1) monoclonal antibody; see Kramer, Cell 91 (1997), 799-809. A general route to fingerprint analyses of peptide-antibody interactions using the clustered amino acid peptide library was described in Kramer, Mol. Immunol. 32 (1995), 459-465. In addition, antagonists of a Futrin 1, 2, 3 and/or 4 polypeptide can be derived and identified from monoclonal antibodies that specifically react with a Futrin 1, 2, 3 and/or 4 polypeptide in accordance with the methods as described in Doring, Mol. Immunol. 31 (1994), 1059-1067.

[0120] All these methods can be used in accordance with the present invention to identify activators/agonists and inhibitors/antagonists of a Futrin 1, 2, 3 and/or 4 polypeptide.

[0121] Various sources for the basic structure of such an activator or inhibitor can be employed and comprise, for example, mimetic analogs of a Futrin 1, 2, 3 and/or 4 polypeptide. Mimetic analogs of a Futrin 1, 2, 3 and/or 4 polypeptide or biologically active fragments thereof can be generated by, for example, substituting the amino acids that are expected to be essential for the biological activity with, e.g., stereoisomers, i.e. D-amino acids; see, e.g., Tsukida, J. Med. Chem. 40 (1997), 3534-3541. Furthermore, in case fragments are used for the design of biologically active analogs pro-mimetic components can be incorporated into a peptide to reestablish at least some of the conformational properties that may have been lost upon removal of part of the original polypeptide; see, e.g., Nachman, Regul. Pept. 57 (1995), 359-370. Furthermore, a Futrin 1, 2, 3 and/or 4 polypeptide can be used to identify synthetic chemical peptide mimetics that bind to or can function as a ligand, substrate or binding partner of said polypeptide(s) as effectively as does the natural polypeptide; see, e.g., Engleman, J. Clin. Invest. 99 (1997), 2284-2292. For example, folding simulations and computer redesign of structural motifs of a Futrin 1, 2, 3 and/or 4 polypeptide can be performed using appropriate computer programs (Olszewski, Proteins 25 (1996), 286-299; Hoffmann, Comput. Appl. Biosci. 11 (1995), 675-679). Computer modeling of protein folding can be used for the conformational and energetic analysis of detailed peptide and protein models (Monge, J. Mol. Biol. 247 (1995), 995-1012; Renouf, Adv. Exp. Med. Biol. 376 (1995), 37-45). In particular, the appropriate programs can be used for the identification of interactive sites of a Futrin 1, 2, 3 and/or 4 polypeptide and its ligand or other interacting proteins by computer assistant searches for complementary peptide sequences (Fassina, Immunomethods 5 (1994), 114-120). Further appropriate computer systems for the design of protein and peptides are described in the prior art, for example in Berry, Biochem. Soc. Trans. 22 (1994), 1033-1036; Wodak, Ann. N.Y. Acad. Sci. 501 (1987), 1-13; Pabo, Biochemistry 25 (1986), 5987-5991. The results obtained from the above-described computer analysis can be used for, e.g., the preparation of peptide mimetics of a Futrin 1, 2, 3 and/or 4 polypeptide or fragments thereof. Such peptoid analogue forms of the natural amino acid sequence of the protein may very efficiently mimic the parent protein (Bekirkan, J. Biol. Chem. 271 (1996), 33218-33224). For example, incorporation of easily available achiral L-amino acid residues into a Futrin 1, 2, 3 or -4 polypeptide or a fragment thereof results in the substitution of amide bonds by polyethylene units of an aliphatic chain, thereby providing a convenient strategy for constructing a peptide mimetic (Buraczynski, Biopolymers 39 (1996), 769-777). Superactive peptidotimidic analogues of small peptide hormones in other systems are described in the prior art (Zhang, Biochem. Biophys. Res. Commun. 224 (1996), 327-331). Appropriate peptide mimetics of a Futrin 1, 2, 3 and/or 4 polypeptide can also be identified by the synthesis of peptide mimetic combinatorial libraries through successive amide alkylation and testing the resulting compounds, e.g., for their binding and immunological properties. Methods for the generation and use of peptidotimidic combinatorial libraries are described in the prior art, for example in Ostresh, Methods in Enzymology 267 (1996), 220-234 and Dorner, Bioorg. Med. Chem. 4 (1996), 709-715. Furthermore, a three-dimensional and/or crystallographic structure of a Futrin 1, 2, 3 and/or 4 polypeptide can be used for the design of peptide mimetic inhibitors of the biological activity

[0122] It is also well known to the person skilled in the art, that it is possible to design, synthesize and evaluate mimetics of small organic compounds that, for example, can act as a substrate or ligand to a Futrin 1, 2, 3 and/or 4 polypeptide. For example, it has been described that D-glucose mimetics of haptolisin exhibited similar efficiency as haptolisin in antagonizing multidrug resistance assistance-associated protein in cytotoxicity; see Dinh, J. Med. Chem. 41 (1998), 981-987.

[0123] The nucleic acid molecule encoding a Futrin 1, 2, 3 and/or 4 polypeptide can also serve as a target for activators and inhibitors. Activators may comprise, for example, proteins that bind to the mRNA of a gene encoding a Futrin 1, 2, 3 and/or 4 polypeptide, thereby stabilizing the native conformation of the mRNA and facilitating transcription and/or translation, e.g., in like manner as Tat protein acts on HIV-RNA. Furthermore, methods are described in the literature for identifying nucleic acid molecules such as an RNA fragment that mimics the structure of a defined or undefined target RNA molecule to which a compound binds inside of a cell resulting in retardation of cell growth or cell death; see, e.g., WO 98/18947 and references cited therein. These nucleic acid molecules can be used for identifying unknown compounds of pharmaceutical interest, and for identifying unknown RNA targets for use in treating a disease. These methods and compositions can be used in screening for novel or for identifying compounds useful to alter expression levels of polypeptides encoded by a nucleic acid molecule. Alternatively, for example, the conformational structure of the RNA fragment which mimics the binding site can be employed in rational drug design to modify known drugs to make them bind more avidly to the target. One such methodology is nuclear magnetic resonance (NMR), which is useful to identify drug and RNA conformational structures. Still other methods are, for example, the drug design methods as described in WO 95/35367, U.S. Pat. No. 5,322,933, where the crystal structure of the RNA fragment can be deduced and computer programs are utilized to design novel binding compounds.

[0124] The compounds which can be tested and identified according to a method of the invention may be expression libraries, e.g., cDNA expression libraries, peptides, proteins, nucleic acids, antibodies, small organic compounds, hormones, peptidomimetics, PNA's or the like (Milner, Nature Medicine 1 (1995), 879-880; Hupp, Cell 83 (1995), 237-245; Gibbs, Cell 79 (1994), 193-198 and references cited supra).

Furthermore, genes encoding a putative regulator of a Futrin 1, 2, 3 and/or polypeptide and/or which exert their effects up- or downstream to a Futrin 1, 2, 3 and/or polypeptide may be identified using, for example, insertion mutagenesis using, for example, gene targeting vectors known in the art. Said compounds can also be functional derivatives or analogues of known inhibitors or activators. Such useful compounds can be for example, transfecting factors which bind to a Futrin 1, 2, 3 and/or polypeptide or regulatory sequences of the gene encoding it. Identification of transacting factors can be carried out using standard methods in the art (see, e.g., Sambrook, supra). To determine whether a protein binds to the protein itself or regulatory sequences, standard native gel-shift analyses can be carried out. In order to identify a transacting factor which binds to the protein or regulatory sequence, the protein or regulatory sequence can be used as an affinity reagent in standard protein purification methods, or as a probe for screening an expression library. The identification of nucleic acid molecules which encode polypeptides which interact with a Futrin 1, 2, 3 and/or 4 polypeptide described above can also be achieved, for example, as described in Scofield (Science 274 (1996), 2063-2065) by use of the so-called yeast “two-hybrid system”. In this system the Futrin 1, 2, 3 or 4 polypeptide or a smaller part thereof is linked to the DNA-binding domain of the GAL4 transcription factor. A yeast strain expressing this fusion polypeptide and comprising a lacZ reporter gene driven by an appropriate promoter, which is recognized by the GAL4 transcription factor, is transformed with a library of cDNAs which will express plant proteins or peptides thereof fused to an activation domain. Thus, if a peptide encoded by one of the cDNAs is able to interact with the fusion peptide comprising a peptide of a Futrin 1, 2, 3 and/or 4 polypeptide, the complex is able to direct expression of the reporter gene. In this way the nucleic acid molecules encoding Futrin 1, 2, 3 and 4, respectively, and the encoded peptide can be used to identify peptides and proteins interacting with a Futrin 1, 2, 3 and/or 4 polypeptide.

[0125] Once the transacting factor is identified, modulating of its binding to or regulation of expression of a Futrin 1, 2, 3 and/or 4 polypeptide can be pursued, beginning with, for example, screening for inhibitors against the binding of the transacting factor to a Futrin 1, 2, 3, and/or 4 polypeptide. Activation or repression of a Futrin 1, 2, 3 and/or 4 polypeptide could then be achieved in animals by applying the transacting factor (or its inhibitor) or the gene encoding it, e.g., in an expression vector. In addition, if the active form of the transacting factor is a dimer, dominant-negative mutants of the transacting factor could be made in order to inhibit its activity. Furthermore, upon identification of the transacting factor, further components in the signal cascade leading to activation (e.g., signal transduction) or repression of a gene involved in the control of a Futrin 1, 2, 3 and/or 4 polypeptide can then be identified. Modulation of the activities of these components can then be pursued, in order to develop additional drugs and methods for modulating the metabolism of protein degradation, in animals. Thus, the present invention also relates to the use of the two-hybrid system as defined above for the identification of activators or inhibitors of a Futrin 1, 2, 3 and/or 4 polypeptide. The compounds isolated by the above methods also serve as lead compounds for the development of analog compounds. The analogs should have a stabilized electronic configuration and molecular conformation that allows key functional groups to be presented to a Futrin 1, 2, 3 and/or 4 polypeptide or its ligand in substantially the same way as the lead compound. In particular, the analog compounds have spatial electronic properties which are comparable to the binding region, but can be smaller molecules than the lead compound, frequently having a molecular weight below about 2 KDa and preferably below about 1 KDa. Identification of analog compounds can be performed through use of techniques such as self-consistent field (SCF) analysis, configuration interaction (CI) analysis, and normal mode dynamics analysis. Computer programs for implementing these techniques are available; Rein, Computer-Assisted Modeling of Receptor-Ligand Interactions (Alan Liss, New York, 1989). Methods for the preparation of chemical derivatives and analogues are well known to those skilled in the art and are described in, for example, Beilstein, Handbook of Organic Chemistry, Springer edition New York Inc., 175 Fifth Avenue, New York, N.Y. 10010 U.S.A. and Organic Synthesis, Wiley, New York, USA. Furthermore, said derivatives and analogues can be tested for their effects according to methods known in
the art; see also supra. Furthermore, peptidomimetics and/or computer aided design of appropriate derivatives and analogues can be used, for example, according to the methods described above.

[0126] Once the described compound has been identified and obtained, it is preferably provided in a therapeutically acceptable form.

[0127] Accordingly, the present invention also relates to a pharmaceutical composition comprising a nucleic acid molecule encoding a Futrin 1, 2, 3 and/or 4 polypeptide, a Futrin 1, 2, 3 and/or 4 polypeptide itself, recombinant vector (for example, see below), antibody, activator/agonist, inhibitor/antagonist and/or binding partner of a Futrin 1, 2, and/or 4 polypeptide and a pharmaceutically acceptable excipient, diluent or carrier.

[0128] Preferably, for therapeutic purposes, the Futrin 1, 2, 3 and/or 4 polypeptide is recombinantly produced by use of the nucleic acid sequences shown in Figs. 1 and 2. Suitable vectors for recombinant expression are known to the person skilled in the art. Preferably, they are plasmids, cosmids, viruses, bacteriophages and other vectors usually used in the field of genetic engineering. Vectors suitable for use in the present invention include, but are not limited to the 17-based expression vector for expression in mammalian cells and baculovirus-derived vectors for expression in insect cells. Preferably, the nucleic acid molecule of the invention is operatively linked to the regulatory elements in the recombinant vector of the invention that guarantee the transcription and synthesis of a mRNA in prokaryotic and/or eukaryotic cells that can be translated. The nucleotide sequence to be transcribed can be operably linked to a promoter like a T7, metallothionein I or polyhedrin promoter. The host cells used for recombinant expression are prokaryotic or eukaryotic cells, for example mammalian cells, bacterial cells, insect cells or yeast cells. The polypeptide is isolated from the cultivated cells and/or the culture medium. Isolation and purification of the recombinantly produced polypeptide may be carried out by conventional means including preparative chromatography and affinity and immunological separations using, e.g., an anti-Futrin 1, 2, 3 or -4 antibody, or, e.g., can be substantially purified by the one-step method described in Smith and Johnson, Gene 67: 31-40 (1988).

[0129] Examples of suitable pharmaceutical carriers etc. are well known in the art and include phosphate buffered saline solutions, water, emulsions, such as oil/water emulsions, various types of wetting agents, sterile solutions etc. Such carriers can be formulated by conventional methods and can be administered to the subject at a suitable dose. Administration of the suitable compositions may be effected by different ways, e.g. by intravenous, intraperitoneal, subcutaneous, intramuscular, topical or intradermal administration. The route of administration, of course, depends on the nature of the disease and the kind of compound contained in the pharmaceutical composition. The dosage regimen will be determined by the attending physician and other clinical factors. As is well known in the medical arts, dosages for any one patient depends on many factors, including the patient's size, body surface area, age, sex, the particular compound to be administered, time and route of administration, the kind and stage of the disease, e.g., tumor; general health and other drugs being administered concurrently.

[0130] The delivery of the nucleic acid molecules encoding a Futrin 1, 2, 3 and/or 4 polypeptide can be achieved by direct application or, preferably, by using a recombinant expression vector such as a chimeric virus containing these compounds or a colloidal dispersion system. Direct application to the target site can be performed, e.g., by ballistical delivery, as a colloidal dispersion system or by catheter at a site in artery. The colloidal dispersion systems which can be used for delivery of the above nucleic acid molecules include macromolecular complexes, nanocapsules, microspheres, beads and lipid-based systems including oil-in-water emulsions (mixed), micelles, liposomes and lipoplexes. The preferred colloidal system is a liposome. Organ-specific or cell-specific liposomes can be used in order to achieve delivery only to the desired tissue. The targeting of liposomes can be carried out by the person skilled in the art by applying commonly known methods. This targeting includes passive targeting (utilizing the natural tendency of the liposomes to distribute to cells of the RES in organs which contain sinusoidal capillaries) or active targeting for example by coupling the liposome to a specific ligand, e.g., an antibody, a receptor, a sugar, glycolipid, protein etc., by well known methods). In the present invention monoclonal antibodies are preferably used to target liposomes to specific tissues, e.g., tumor tissue, via specific cell-surface ligands.

[0131] Preferred recombinant vectors useful for gene therapy are viral vectors, e.g., adenovirus, herpes virus, vaccinia, or, more preferably, an RNA virus such as a retrovirus. Even more preferably, the retroviral vector is a derivative of a murine or avian retrovirus. Examples of such retroviral vectors which can be used in the present invention are: Moloney murine leukemia virus (MoMuLV), Harvey murine sarcoma virus (HaMuSV), murine mammary virus (MuMTV) and Rous sarcoma virus (RSV). Most preferably, a non-human primate retroviral vector is employed, such as the macaque ape leukemia virus (GalV), providing a broader host range compared to murine vectors. Since recombinant retroviruses are defective, assistance is required in order to produce infectious particles. Such assistance can be provided, e.g., by using helper cell lines that contain plasmids encoding all of the structural genes of the retrovirus under the control of regulatory sequences within the LTR. Suitable helper cell lines are well known to those skilled in the art. Said vectors can additionally contain a gene encoding a selectable marker so that the transfected cells can be identified. Moreover, the retroviral vectors can be modified in such a way that they become tumor specific. This can be achieved, e.g., by inserting a polynucleotide encoding a sugar, a glycolipid, or a protein, preferably an antibody. Those skilled in the art know additional methods for generating target specific vectors. Further suitable vectors and methods for in vivo and in vivo-gene therapy are described in the literature and are known to the persons skilled in the art; see, e.g., WO 94/29469 or WO 97/09957.

[0132] In order to achieve expression only in the target organ, e.g., a tumor to be treated, the nucleic acid molecules encoding a Futrin 1, 2, 3 and/or 4 polypeptide can be linked to a tissue specific promoter and used for gene therapy. Such promoters are well known to those skilled in the art (see e.g. Zimmermann et al., (1994) Neuron 12, 11-24; Vidal et al.; (1990) EMBO J. 9, 833-840; Mayford et al., (1995), Cell 81, 891-904; Pinkert et al., (1987) Genes & Dev., 1, 268-76).

[0133] The present invention also relates to the use of the above compounds of the invention for the preparation of a pharmaceutical composition for treatment of a disease associated with (a) aberrant expression of Futrin 1, 2, 3 and/or 4 and/or genes involved into the Wnt signal cascade, and/or (b) aberrant activities or amounts of a Futrin 1, 2, 3 and/or 4
and/or a polypeptide involved into the Wnt signal cascade. In a preferred embodiment, said disease is a kidney, bone or muscle disease or tumor, preferably breast cancer, a colon carcinoma or a melanoma.

[0134] Finally, the present invention relates to the use of a nucleotide molecule encoding a polypeptide having a biological activity of Futerin 1, 2, 3 and/or 4, a Futerin 1, 2, 3 and/or 4 polypeptide, an activator/agonist of a Futerin 1, 2, 3 and/or 4 polypeptide or binding partner of said polypeptide(s) for the preparation of a pharmaceutical composition for inhibiting the Wnt signal cascade which might be useful for supporting regenerative processes in a patient, e.g. growth of tissue like muscle, bone, hair, etc.

[0135] The following examples illustrate the invention.

EXAMPLE 1

Materials and Methods

(A) Isolation of Futerins (=R-Spondins) and Constructs

[0136] A Xenopus adult eye cDNA library in pCS2+ was used to prepare pools of about 250 colonies. Plasmid DNA from each pool was transiently transfected into 293T cells together with the Wnt receptor frizzled8, the Wnt reporter TOPFLASH (Korinek et al., Science 275 (1997), 1784-7) and pRL-TK (Promega) using FuGENE 6 (Roche) transfection reagent. Luciferase assay was carried out 24 hours after transfection. A positive clone was isolated from the pool by in situ selection. Human Rspo2 and 3 cDNAs were obtained from RZPD. Fragments of hiRspo1 and 4 were RT-PCR amplified from mRNA of 293T cells and used as hybridization probes. Full length mouse Rspo1 and 2 were isolated from a mouse embryonic day 13.5 cDNA library. The sequence of X. tropicalis Rspo3 was obtained from Sanger Institute database and a cDNA fragment was cloned by RT-PCR from X. tropicalis embryos. C-terminally Myc or FLAGtagged constructs and all deletion constructs were created by PCR. Xenopus Rspo2AC was cloned by deleting the last 37 amino acids. The Rspo3 cDNAs were cloned in pCS2+ and Bluescript vectors for use in gene expression and as probes, respectively.

(B) Cell Culture, Recombinant Proteins and Luciferase Reporter Assays

[0137] HEK293T, SHEP and HeLa cell lines were maintained in DMEM, 10% FCS and 10% CO2. Xenopus Rspo2AC conditioned medium was produced by transient transfection in 293T cells. Mouse Wnt3a conditioned medium was produced from mouse L cells stably transfected with Wnt3a (ATCC #CRL-2647) (Shibamoto et al., Genes Cells 31 (1998), 659-670). Luciferase reporter assays in 293T cells were carried out in 96-well plates as described (Wu et al., Curr. Biol. 10 (2000), 1611-1614). Luciferase reporter assays in HeLa cells were carried out in 24 well plates in triplicates using Lipofectamine Plus transfection reagent (Invitrogen). Per well a total of 400 ng DNA were transfected, including 80 ng 7e1f-los:1-Ace (Novak et al., PNAS (1998), 4374-4379), 10 ng pRL-TK, 10 ng mouse frizzled8, 2 ng mouse lef1 and 300 ng pSuper plasmid DNAs. 3 days after transfection, either mouse Wnt3a conditioned medium or medium containing 30 mM LIC1 was added to stimulate Wnt signalling. 24 hours later, luciferase activity was determined using the Dual luciferase system (Promega).

(c) Embryos, Explants, In Situ Hybridization and RNA Synthesis

[0138] In vitro fertilisation, embryo culture, staging, microinjection and culture of Xenopus embryo explants were carried out as described (Gawantka et al., EMBO J. 14 (1995), 6268-79). Double- and single-labeling whole-mount in situ hybridization was carried out according to (Bradley et al., Development 122 (1996), 2739-50). A PCR fragment of tropicalis Rspo3 cDNA was used for in situ hybridization on Xenopus laevis embryos. For vibratome sectioning, embryos were placed in embedding medium (0.4% gelatine, 30% albumin, 20% sucrose in PBS) and mounted in the presence of 2% glutaraldehyde. Sectioning was carried out using a VT1000e vibratome (Leica). Brains of 4 day Xenopus embryos were excised in 1x Barth solution and fixed for in situ hybridisation. Whole-mount in situ hybridisation of mouse embryos was performed according to previously described procedures (Hoop, et al, Mech. Dev. 59 (1996), 73-78), reparation of mRNA for Xenopus injections was carried out using the Megascript in vitro transcription kit (Ambion), according to the manufacturer’s instructions.

(D) Morpholino, Antisense Oligonucleotides and siRNA Constructs

[0139] The 5′ nucleotide sequence of an additional (pseudo-) allele for Xenopus Rspo2 gene was obtained using 5′ RACE (GeneRacer kit, Invitrogen). Based on these sequences, an antisense morpholino oligonucleotide targeting both pseudos alleles around the ATG start codon was designed (Rspo2Mo): GCGTTCAGATTGATGTCACAC. pSuper constructs producing siRNA against human Rspo 2.5 or 2a, non-sense control were made according to Brummellkamp et al., Science 296 (2002), 550-3. The sequences are: human Rspo2, TCCCCATTTGCAAGGGTGAT; human Rspo3, AGCTGACTTGTAACCTGG; non-sense control, ACTACCGTGTTTAAGTGGT.

(E) Immunohistochemistry, Western Blot and Dot Blot Analysis

[0140] Immunohistochemistry to detect β-catenin in SHEP cells was carried out according to (Scheiffele et al., J. Cell. Biol. 140 (1998), 795-806) using anti-β-catenin antibody (Transduction laboratories, Newington). For detection of tagged Rspo proteins or loading controls on Western blot, anti-Myc (clone 9E10), anti-FLAG (M2, SIGMA) monoclonal antibodies, chick anti-GFP (Chemicon, Hampshire) and mouse anti-a-tubulin (SIGMA) antibodies were used. Chemiluminescence detection (SuperSignal® solution, Pierce) was carried out according to the manufacturer’s instructions after incubation of blots with anti-mouse IgG-HRP (Pierce). For Rspo expression analysis in tumour samples the Cancer Profiling Array II (Clontech, Palo Alto) was used and hybridization was carried out according to the manufacturer’s instructions.

(F) RT-PCR

[0141] RT-PCR assays were carried out as described (Dosech et al., Development 124 (1997), 2325-34; Glinka et al., Nature 389 (1997), 517-519); additional primers were

Xenopus Rspo2
(Forward, GAAATCCCAAGAGATTGAGC; reverse, GGGATGGTGCTTTGCTGAG);
EXAMPLE 2

Isolation of a cDNA Encoding Xenopus Futrin 1

[0142] A Xenopus adult eye cDNA library in the expression vector pCS2+ was used to prepare pools of about 250 colonies, and plasmid DNA from each pool was transiently transfected into 293T cells together with the Wnt receptor frizzled8, the Wnt reporter TOP-FLASH (Korinek et al. Science 275 (1997) 1784-1787) and Renilla-luciferase for normalization, in 96-well plates using FuGENE 6 (Roche, Basel). After 24 hours relative luciferase activity was determined. One pool yielding a signal above background was identified (FIGS. 1 and 2A) and a gene harboring this activity was isolated from the pool by sib selection. Sequencing analysis showed it represents Xenopus futrin 1. Database searches revealed four closely related genes in human, called futrin 1, 2, 3 and 4 (FIGS. 3 and 4 or 6). [0143] Xenopus futrin 1 (Rspo2) is predicted to encode a secreted protein with 243 amino acids (mature protein) and an isoelectric point of 9.8. All R-spondins contain an N-terminal signal peptide (SP), two furin-like domains (FU), one thrombospondin type I domain (TSP1) and a C-terminal low complexity region enriched with positively charged amino acids (C) (FIG. 2F). The furin-like cysteine rich domain is found in e.g. furin-like endoproteases, EGF receptor and insulin receptor. In signal transduction by certain receptor, tyrosine kinases furin repeats are required for receptor aggregation. TSP1 repeats are found in Thrombospondin and other extracellular matrix proteins like Mindin, F-spondin, SCO-spondin as well as in a number of proteins involved in the complement cascade. Proteins containing TSP1 repeats are involved in cell-cell interaction, inhibition of angiogenesis and apoptosis (Adams and Tucker, Dev. Dyn. 218 (2000), 280-99). [0144] While Xenopus Rspo2 contains a predicted N-terminal signal peptide, secreted protein is almost undetectable in the medium of transiently transfected 293T cells. Since the C-terminus is enriched with basic amino acids, which promotes cell surface retention a C-terminally truncated protein was tested. Rspo2ΔC is effectively secreted into the medium from 293T cells (FIG. 2B) and is functionally active (FIG. 2F). Since all R-spondins share the basic C-terminus and since there are no obvious ER- or Golgi retention signals, this suggests that the proteins are normally associated with the cell surface.

EXAMPLE 3

Futrins Promote Wnt Signalling

[0145] Xenopus Futrin1 and human Futrin1, 2, and 3 are able to stimulate Wnt-responsive reporter expression in HEK 293T cells when provided by transient transfection (FIGS. 2C and 5A). In addition, they are able to enhance reporter expression induced by Wnt (mouse Wnt3/3A) synergistically (FIGS. 2D and 5B). Cotransfection experiments in HEK293T cells were carried out with the indicated genes and the Wnt and reporter TOP-FLASH (Korinek et al. Science 275 (1997) 1784-1787) and Renilla-luciferase for normalization, in 96-well plates using FuGENE 6 (Roche). After 24 hours relative luciferase activity was determined.

[0146] All tested members of the Rspo family (e.g. murine Rspo-1, human Rspo-2, 3) show equivalent effects (FIG. 6A and data not shown). Rspo2 signalling is sensitive to the Wnt/β-catenin pathway inhibitors dominant negative TCF and dickkopf1 (FIG. 6B). A synergistic signalling effect is observed when Rspo2 is cotransfected with extracellular but not with intracellular components of the Wnt/β-catenin pathway (FIG. 6C). The greatest cooperation is reproducibly seen between Rspo2 and Wnts, either using conditioned media (FIG. 2D) or following cotransfection (FIG. 6C).

[0147] A hallmark of Wnt/β-catenin signalling activation is the cytosolic accumulation of β-catenin due to its stabilisation. Treatment of 293T cells with Wnt3a conditioned medium induces cytosolic β-catenin after 1 hour and while recombinant Rspo2ΔC alone is not able to stabilize β-catenin during this interval, it strongly enhances activity of Wnt3a to do so (FIG. 2E, top). After 4 hours treatment, both Wnt3a and Rspo2ΔC conditioned media are able to induce β-catenin accumulation to similar levels (FIG. 2E, bottom). β-catenin is known to enter the nuclei in response to Wnt stimulation and activate gene expression together with Lef/Tcf transcription factors. Treatment of SHEP cells by either Wnt3a or Rspo2ΔC conditioned media weakly induces β-catenin nuclear localization, while co-treatment with Wnt3a and Rspo2ΔC strongly enhances nuclear accumulation (FIG. 2E, bottom). It can be concluded that R-spondins represent a novel family of secreted proteins capable of promoting Wnt/β-catenin signalling.

[0148] To functionally study its signalling domains, the functional depletions of Xenopus Rspo2 (FIG. 2F) were created. As discussed, the basic C-terminus can be removed without loss of activity and this is also true for the TSP1 domain (FIG. 2F). However, the furin-like domains are necessary for Wnt/β-catenin signalling since deletion of either the furin-1 or -2 domains abolishes the activity in reporter assays (FIG. 2F).

EXAMPLE 4

Futrins are Required for Full Wnt Signalling

[0149] To test the requirement of Futrins in Wnt signalling, siRNA mediated gene knock-out was utilized (Brummelkamp et al., Science. 2002, 296(5576):550-3). Hela cells were transfected using Lipofectamine Plus with 80 ng Wnt reporter 7LEF-Rev-fosLuc, 10 ng pRL-TK (Promega) and 300 ng pSuper constructs (Brummelkamp et al.) that produce
either siRNA against human Futrin1 and 2, or a nonsense control. 7LEF-Rev fosLuc reporter construct containing seven LEF binding sites in front of minimal fos promoter followed by firefly luciferase ORF was kindly provided by R. Grosschedl (Howard Hughes Medical Institute). pSuper constructs contain 19-nucleotide sequences from human Futrin1 (sequence: TCCCATTTGCAAGGTGT), human Futrin2 (sequence: AGCTGACTGTTGATACCCG), or control nonsense sequence (ACTCCGTTTGTATAGGTT).

**EXAMPLE 5**

Expression of R-Spondin Genes in Xenopus and Mouse Embryos

**[0151]** In Xenopus embryos, no maternal Rspo2 RNA is detected by RT-PCR. Its zygotic expression starts at early gastrula stage and remains constant throughout neurulation and organogenesis (FIG. 8A). By whole-mount in situ hybridization, weak expression of Rspo2 is observed throughout the ectoderm of early gastrulae (not shown). During gastrulation strong expression is detected in the marginal zone in both deep and superficial layers, but is excluded from the Spemann organizer (FIG. 8B). At late gastrula stage Rspo2 expression persists in lateral plate mesoderm and becomes detectable in the anterior neural plate (FIG. 8C). At stage 15 expression is seen in two longitudinal stripes along the neural plate (future roof plate), in the anterior neural plate and in lateral and posterior mesoderm (FIG. 8D). Expression of Rspo2 at tailbud stage (FIG. 8F) is restricted to several regions of the brain, including diencephalon and midbrain/hindbrain boundary, prosencephalon and dorsal neural tube. Expression is also detected in the dorsal and ventral-most portions of somites, the dorsal fin and the procotoderm. Rspo2 expression in the brain of late tadpoles is mainly restricted to diencephalon, including the zona limitans intrathalamica (zli) (FIG. 8H).

**[0152]** Xenopus Rspo3 expression is related to that of Rspo2. It is first detected at gastrula stage (not shown) and in neurulae it is expressed in the anterior border of the neural plate and posterior mesoderm (FIG. 8E). At tailbud stage, it is coexpressed with Rspo2 in the central nervous system but shows additional expression in branchial arches and the tailbud (FIG. 8G).

**[0153]** In mouse, Rspo3 transcripts are detected by in situ hybridization at day 7.5 in the primitive streak (FIG. 8J) while expression of Rspo1 and 2 is not detectable. At day 9.5, Rspo1-3 show differential expression in various neural and mesodermal derivatives (FIG. 8K-M), mainly along dorsal neural tube (Rspo1 and 3), diencephalon (Rspo1, 2, 3), somites (Rspo3) and tailbud mesoderm (Rspo3). In limb buds all three genes show prominent differential expression (FIG. 8I), particularly, in the morphogenetically active region such as the apical ectodermal ridge (AER) (Rspo2).

**EXAMPLE 6**

R-Spondins are Co-Expressed with and Regulated by Wnts

**[0154]** R-spondins not only show functional interaction with Wnt signalling, but also co-expression with Wnt genes in many regions during Xenopus and mouse embryonic development. In gastrula embryos of both Xenopus and mouse, Rspo2 and -3 are co-expressed with XWnt8 and mWnt3, respectively. Similarly, at later stages, R-spondin family members are widely co-expressed with a number of Wnt genes e.g. in midbrain/hindbrain boundary, dorsal neural tube and limb bud and tail bud. A direct comparison between the expression patterns of Xenopus Rspo2 and Wnt8 and Wnt3a shows a large overlap (FIG. 9A).

**[0155]** Indeed, Wnts are able to induce Rspo expression since Xenopus embryos injected with pcS3-Wnt8 or pCS-fl-catenin DNA upregulate both Rspo2 and Rspo3 by RT-PCR (FIG. 9B). Likewise, embryos injected with pcS3-Wnt8 or pcS-Wnt3a DNA show ectopic Rspo2 expression by in situ hybridization (FIG. 9C-E). The results indicate that the observed co-expression is due to regulation of R-spondins by Wnts. This is consistent with the observation that Rspo1 expression is reduced in dorsal spinal cord of Wnt1 or Wnt3a knockout mouse embryos.

**EXAMPLE 7**

Futrin 1 (R-spondin 2) Activates Neural Markers and Regulates (Promotes) Muscle Formation

**[0156]** Loss-of-function analysis in Xenopus embryos show that Futrin is required for muscle formation. Injections of antisense morpholino oligo against futrin 1 (Fut1-Mo) cause downregulation of early muscle markers MyoD and Myf5 and induce muscle defects (FIG. 10A). The specificity of this effect was documented, first, by the ability of Fut1-Mo to inhibit translation of the cognate DNA construct when overexpressed in embryos (FIG. 10B) and, second, by the ability of XFut1 mRNA to rescue the effect of Fut1-Mo (FIG. 10C).

**[0157]** When the Wnt/beta-catenin pathway is overactivated in Xenopus embryos a variety of responses are observed: i) mRNA injection of pathway activators typically induces secondary embryonic axes in whole embryos and anterior neural markers in animal caps and whole embryos; ii) DNA injection of pathway activators driving expression after MBT, posteriorizes the central nervous system (CNS). To test if Rspo2 is able to mimic any of these effects synthetic mRNA was microinjected in Xenopus embryos. However, Rspo2 mRNA injection does not induce secondary axes in whole embryos and injection of pcS-Rspo2 DNA does not posteriorize CNS, since heads are normal sized, Otx2 expression is expanded and en2 unaffected (FIG. 11D, H).

**[0158]** In animal caps Rspo2 induces the pan-neural markers NCAM and N-tubulin and the anterior neural marker, Otx2, as do Xwnt9 and beta-catenin (FIG. 11A). Similarly, in whole embryos injected with Rspo2 mRNA, ectopic cement glands and lateral expansion of the neural plate are observed at the injected side, as shown by expression of neural markers Sox3, Otx2, ntx2, en2 and Rxl (FIGS. 11B-H). Ectopic Otx2 expression is observed already in gastrula stage embryos (FIG. 11I+J). These results are consistent with the ability of
Wnt/β-catenin signalling to block BMP4 expression and thereby to activate neural development. [0159] To further analyze the mRNA overexpression effect of Rspo2 an BMP4, Activin, Nodal and GGF signaling, animal cap assays were carried out and tested for the induction of target genes by three growth factor signals (FIG. 12). Rspo2 expectedly blocks BMP4 mediated Xvent2 expression but surprisingly also inhibits Activin and Nodal mediated Xbra induction (FIG. 12A-C). This is unlike Wnt8 and β-catenin mRNA injections which do not affect Xbra induction by Activin (FIG. 12B). In contrast to signaling by three TGF-β type growth factors, FGFR induced Xbra expression is unaffected by overexpressed Rspo2 (FIG. 12D). It can be concluded that Rspo2 overexpression in addition to activating the Wnt/β-catenin pathway, is also able to interfere with signaling by three TGF-β family growth factors.

[0160] Another well known effect of zygotic Wnt/β-catenin signalling is its ability to promote myogenesis. For example, XWnt8 can induce muscle formation in ventral mesodermal cells. When ventral marginal zones (VMZs) from Rspo2 injected embryos are dissected and cultured until stage 40, they elongate, form Cilia-like structures, and are translucent. This phenotype is indistinguishable from control lateral marginal zone explants (LMZs), which typically differentiate muscle (FIG. 4K-L). In situ hybridization confirmed induction of muscle actin in both Wnt8 and Rspo2 injected VMZs but not in control (propylthiouracil-injected) VMZs (FIG. 11M). Since R-spondins are able to enhance Wnt signalling in 293T cells, their cooperation in Xenopus myogenesis was tested. Myf5 is a myogenic marker characteristically expressed in lateral mesoderm. However, it is excluded from dorsal mesoderm and dorsal marginal zone (DMZ) explants express only little myf5 as determined by RT-PCR (FIG. 11N). In DMZs from embryos injected with DNA constructs driving post MBT expression, myf5 is weakly induced by Rspo2, moderately by Wnt8 and strongly by their combination (FIG. 11N, top). The myogenesis promoting effect of Rspo2 is repressed by dominant negative dishevelled (Dsh1), dkk1 and GSK-3β, which all block Wnt signalling (FIG. 11N, bottom). In summary, the results suggest that Rspo2 can promote myogenesis via the Wnt/β-catenin pathway.

EXAMPLE 8
R-Spondins are Required for Wnt/β-Catenin-Mediated Myogenesis

[0161] To investigate the physiological role of Rspo2 during Xenopus embryogenesis, antisense morpholino oligonucleotides were injected (Rspo2Mo). The ability of Rspo2Mo to block Rspo2 protein production is demonstrated by Western blot (FIG. 13A). Injection of this Morpholino into one dorso-animal blastomere at eight cell stage results in eye defects, although the expression of early eye—(Rxl, Pax6), anterior neural (Otx2) and pan-neural markers (Sox3) is not obviously affected (not shown).

[0162] Equatorial Injection of Rspo2Mo in one blastomere at eight cell stage leads to muscle defects at the injected side (FIG. 13B). In situ hybridisation for muscle actin and transverse trunk sections show that Rspo2Mo injection causes disorganized somites (panels a-b) and reduced myotomes (panels c-d). Lineage tracing experiments showed that Rspo2Mo injected cells contribute to lateral plate mesoderm instead of somites or undergo cell death (data not shown). At gastrula stage expression of the myogenic markers myf5 and myoD is strongly down-regulated at the Rspo2Mo injected side (panels e-h), while the pan-mesodermal marker Xbra and the organizer marker Xnot2 are unaffected (panels i-j).

[0163] To test the specificity of Rspo2Mo, rescue experiments were performed by co-injecting Rspo2Mo together with a Rspo2 RNA, in which six non-coding nucleotides were mutated so that it would not be targeted by this Morpholino. Expression of myf5 (FIG. 13C) and myoD (data not shown) is effectively rescued by this mutant Rspo2 RNA, indicating that the effect of Rspo2Mo an myogenesis is specific.

[0164] Rspo2Mo was used as a tool to examine the epistatic position of Rspo in the Wnt/β-catenin pathway. As read out for Wnt/β-catenin signalling the expression of myf5 and muscle actin in marginal zone explants was used (FIG. 13D). In DMZ and VMZ explants, Wnt8 DNA induces myf5 and muscle actin and this induction is significantly blocked by Rspo2Mo (FIG. 13D, panels a-b, lanes 3-4). However, myf5 and muscle actin induction by intracellular activators of the Wnt pathway like dishevelled, dkk1/GSK-3β and β-catenin is unaffected by Rspo2Mo (a-b, lanes 5-10). In LMX explants Rspo2Mo Injection down-regulates endogenous myf5 and muscle actin expression (FIG. 13D, panels c-d, lanes 1-2). In DNA coinjections this effect is rescued effectively by β-catenin—but only poorly by XWnt8 (lanes 3-6). The residual effect of XWnt8 is likely due to its non-cell autonomous action an cells that did not receive Rspo2Mo. Taken together these results indicate that Rspo2 affects the Wnt/β-catenin pathway at the level or upstream of dishevelled.

EXAMPLE 9
R-Spondins are Required for Wnt/E-Catenin Signalling in HeLa Cells

[0165] Next the requirement of Rspo2 for Wnt signalling was tested in mammalian cells using siRNA. Since there are four R-spondins with apparently redundant function, HeLa cells were selected, that only express Rspo3 and very weakly Rspo2 (FIG. 14A). Various other cell lines, such as 293T cells, express all four genes, complicating a siRNA approach.

[0166] siRNA mediated gene knock-down was carried out by transfecting pSUPER constructs (Brunmelkamp et al., Science 296 (2002), 3286-3305) to produce siRNAs targeted against Rspo2 and ~3 (siRNA Rspo 2,3). As control, a nonsense siRNA was used. To test the efficiency of siRNA, FLAG-tagged human Rspo3 was co-transfected with siRNAs and its production was repressed by siRNA Rspo3 but not siRNA Rspo2 (FIG. 14B).

[0167] In Wnt-reporter assays, both siRNA Rspo2 and ~3 decreased Wnt3a-induced luciferase activity compared to control siRNA (FIG. 14C). When siRNA Rspo2 and ~3 are co-transfected, reporter activity drops to 40%. This effect is specific since the decreased Wnt signalling can be rescued by co-transfected mouse Rspo2, which is not targeted by siRNAs against human R-spondins (FIG. 14C). Furthermore, unlike Wnt3a-induced reporter activity, siRNA Rspo2+3 do not affect L1-′-induced Wnt/β-catenin signalling (FIG. 14D). Since L1′ acts by inhibiting GSK3β activity, this again consistent with Rspo2 acting at the level or upstream of dishevelled conclusion that in HeLa cells R-spondins are required for full Wnt/β-catenin signalling.
EXAMPLE 10

Futrin Expression is Deregulated in Human Tumors

Misregulation of Wnt/β-catenin signalling is implicated in tumorigenesis, e.g., colon cancer, breast cancer and melanoma (Barker et al., 2000; Bienz and Clevers, 2000; Polakies, 2000). Since R-spondins (futrins) promote Wnt/β-catenin signalling they may also play a role in tumorigenesis. Thus, the expression of Futrin 1-4 in various normal and cancerous human tissues was studied using radioactive hybridisation on Clontech Cancer Profiling Array II. Hybridization with ubiquitin probe was used for normalisation. The results show that expression of Futrins 1-3 is dramatically deregulated in cancerous human tissues (FIG. 15). In most of the tumors the expression of Futrins 1-3 is dramatically decreased (colon, stomach, lung, rectum tumors for Futrin 1, breast, ovary, bladder, uterus, cervix, rectum tumors for Futrin 2, uterus and cervix tumors for Futrin 3). In a few cases the expression of Futrin 1-3 is upregulated (one case of stomach tumor for Futrin 1 and 2, ovary tumor for Futrin 3). Futrin 4 shows very low level of expression in most of the tissues studied, except ovary. Further results are shown in FIG. 16 also showing that HRsp01 is weakly expressed in adult organs. It shows upregulation in ovary tumours from two patients and in one stomach tumour sample. HRsp02 is expressed in organs of endodermal origin, including colon, rectum, small intestine and lung. Its expression decreased in corresponding tumour samples. HRsp03 is expressed widely and decreases in many tumour samples. In general, the expression of hrsp01-3 is deregulated in a number of tumours, while hrsp04 expression is very weak both in human adult organs and tumours (data not shown).

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<210> SEQ ID NO 25
<211> LENGTH: 25
<212> TYPE: PRT
<213> ORGANISM: Homo sapiens
<400> SEQUENCE: 25
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Leu Thr Ile Ser Ser Arg Gly Ile Lys Gly Lys Arg Gln Arg Arg Arg
20  25  30
Ser Ala Glu Gly Ser Gln Ala Cys Ala Lys Gly Cys Glu Leu Cys Ser
35  40  45
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Glu Val Asn Gly Cys Leu Lys Cys Ser Pro Lys Leu Phe Ile Leu Leu
  50  55  60
Glu Arg Asn Asp Ile Arg Glu Val Gly Val Cys Leu Pro Ser Cys Pro
  65  70  75  80
Pro Gly Tyr Phe Asp Ala Arg Asn Pro Asp Met Asn Lys Cys Ile Cys
  85  90  95
Lys Ile Glu His Cys Glu Ala Cys Phe Ser His Asn Phe Cys Thr Lys
 100 105 110
Cys Lys Glu Gly Leu Tyr Leu His Lyu Gly Arg Cys Tyr Pro Ala Cys
 115 120 125
Pro Glu Gly Ser Ser Ala Ala Asn Gly Thr Met Glu Cys Ser Ser Pro
 130 135 140
Ala Glu Cys Glu Met Ser Glu Thr Pro Trp Ser Pro Trp Gly Pro Cys Ser Lys
 145 150 155 160
Lys Glu Gln Leu Cys Gly Phe Arg Arg Gly Ser Glu Glu Arg Thr Arg
 165 170 175
Arg Val Leu His Ala Pro Val Gly Asp His Ala Ala Cys Ser Asp Thr
 180 185 190
Lys Glu Thr Arg Arg Cys Thr Val Arg Arg Val Pro Cys Pro Glu Gly
 195 200 205
Gln Lys Arg Arg Lys Gly Gly Gin Gly Arg Arg Glu Asn Ala Asn Arg
 210 215 220
Asn Leu Ala Arg Lys Glu Ser Lys Glu Ala Gly Ala Gly Ser Arg Arg
 225 230 235 240
Arg Lys Gly Gln Gin Gin Gin Gin Gin Gin Thr Val Gly Pro Leu
 245 250 255
Thr Ser Ala Gly Pro Ala
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<211> LENGTH: 243
<212> TYPE: PRT
<400> ORGANISM: Homo sapiens
SEQUENCE: 26
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Asp Tyr Ser His Cys Gin Gly Asn Arg Trp Arg Arg Ser Lys Arg Ala
  20  25  30
Ser Tyr Val Ser Asn Pro Ile Cys Lys Gly Cys Leu Ser Cys Ser Lys
  35  40  45
Asp Asn Gly Cys Ser Arg Cys Gin Gin Lys Leu Phe Phe Leu Arg
  50  55  60
Arg Glu Gly Met Arg Gin Tyr Gly Cys Leu His Ser Cys Pro Ser
  65  70  75  80
Gly Tyr Tyr Gly His Arg Ala Pro Asp Met Asn Arg Cys Ala Arg Cys
  85  90  95
Arg Ile Gin Asn Cys Asp Ser Cys Phe Ser Lys Asp Phe Cys Thr Lys
 100 105 110
Cys Lys Val Gly Phe Tyr Leu His Arg Gly Arg Ser Phe Asp Glu Cys
 115 120 125
Pro Asp Gly Phe Ala Pro Leu Glu Glu Thr Met Glu Cys Val Glu Gly
 130 135 140
Cys Glu Val Gly His Trp Ser Glu Trp Gly Thr Cys Ser Arg Asn Asn
145 150 155 160
Arg Thr Cys Gly Phe Lys Trp Gly Leu Glu Thr Arg Thr Arg Gln Ile
166 170 175
Val Lys Lys Pro Val Lys Asp Thr Ile Pro Cys Pro Thr Ile Ala Glu
180 185 190
Ser Arg Arg Cys Lys Met Thr Met Arg His Cys Pro Gly Gly Lys Arg
195 200 205
Thr Pro Lys Ala Lys Glu Arg Asn Lys Lys Lys Arg Lys Leu
210 215 220
Ile Glu Arg Ala Gln Glu Gly His Ser Val Phe Leu Ala Thr Asp Arg
225 230 235 240
Ala Asn Gln

<210> SEQ ID NO 27
<211> LENGTH: 272
<212> ORGANISM: Homo sapiens
<400> SEQUENCE: 27
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20 25 30
Met His Pro Asn Val Ser Ser Gly Cys Gln Gly Gly Cys Ala Thr Cys
35 40 45
Ser Asp Tyr Asn Gly Cys Leu Ser Cys Lys Pro Arg Leu Phe Ala
50 55 60
Leu Glu Arg Ile Gly Met Lys Gln Ile Gly Val Cys Leu Ser Ser Cys
65 70 75 80
Pro Ser Gly Tyr Tyr Gly Thr Arg Tyr Pro Asp Ile Aen Lys Cys Thr
85 90 95
Lys Cys Lys Ala Asp Cys Asp Thr Cys Phe Asn Lys Aen Phe Cys Thr
100 105 110
Lys Cys Lys Ser Gly Phe Tyr Leu His Leu Gly Lys Cys Leu Asp Aen
115 120 125
Cys Pro Glu Gly Leu Glu Ala Aen Asn His Thr Met Glu Cys Val Ser
130 135 140
Ile Val His Cys Glu Val Ser Glu Thr Aen Pro Trp Ser Pro Cys Thr
145 150 155 160
Lys Lys Gly Lys Thr Cys Gly Phe Lys Arg Gly Thr Glu Thr Arg Val
165 170 175
Arg Glu Ile Ile Gln His Pro Ser Ala Lys Gly Asn Leu Cys Pro Pro
180 185 190
Thr Aen Glu Thr Arg Lys Thr Val Glu Arg Lys Lys Arg Lys Pro Aen
195 200 205
Gly Glu Arg Gly Lys Gly Glu Arg Gly Lys Arg Lys Lys Pro Aen
210 215 220
Lys Gly Glu Ser Lys Glu Ala Ile Pro Aen Ser Lys Ser Leu Glu Ser
225 230 235 240
Ser Lys Glu Ile Pro Glu Gin Arg Glu Aen Lys Gin Gin Gin Lys Lys
245 250 255
Lys Ile Glu His Cys Glu Ala Cys Phe Ser His Asn Phe Cys Thr Lys 100 105 110
Cys Lys Glu Gly Leu Tyr Leu His Lys Gly Arg Cys Tyr Pro Ala Cys 115 120 125
Pro Glu Gly Ser Ser Ala Ala Asn Gly Thr Met Glu Cys Ser Ser Pro 130 135 140
Ala Gln Cys Glu Met Ser Glu Trp Ser Pro Trp Gly Pro Cys Ser Lys 145 150 155 160
Lys Gln Gln Leu Cys Gly Phe Arg Arg Gly Ser Glu Glu Arg Thr Arg 165 170 175
Arg Val Leu His Ala Pro Val Gly Asp His Ala Ala Cys Ser Asp Thr 180 185 190
Lys Glu Thr Arg Arg Cys Thr Val Arg Arg Val Pro Cys Pro Glu Gly 195 200 205
Gln Lys Arg Arg Lys Gly Gly Gly Arg Gly Arg Glu Asn Ala Asn Arg 210 215 220
Asn Leu Ala Arg Lys Glu Ser Lys Ala Gly Ala Gly Ser Arg Arg 225 230 235 240
Arg Lys Gly Gln Gln Gln Gln Gln Gly Thr Val Gly Pro Leu 245 250 255
Thr Ser Ala Gly Pro Ala 260

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<211> LENGTH: 243
<212> TYPE: PRT
<213> ORGANISM: Homo sapiens
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Ser Tyr Val Ser Asn Pro Ile Cys Lys Gly Cys Leu Ser Cys Ser Lys 35 40 45
Asp Asn Gly Cys Ser Arg Cys Gln Gln Lys Leu Phe Phe Leu Arg 50 55 60
Arg Glu Gly Met Arg Glu Tyr Gly Gly Cys Leu His Ser Cys Pro Ser 65 70 75 80
Gly Tyr Tyr Gly His Arg Ala Pro Asp Met Asn Arg Cys Ala Arg Cys 95 100 105 110
Arg Ile Glu Asn Cys Asp Ser Cys Phe Ser Lys Asp Phe Cys Thr Lys 100 105 110
Cys Lys Val Gln Phe Tyr Leu His Arg Gly Arg Ser Phe Asp Glu Cys 115 120 125
Pro Asp Gln Phe Ala Pro Leu Glu Glu Thr Met Glu Cys Val Glu Gly 130 135 140
Cys Glu Val Gly His Trp Ser Glu Trp Gly Thr Cys Ser Arg Asn Asn 145 150 155 160
Arg Thr Cys Gly Phe Lys Trp Gly Leu Glu Thr Arg Thr Arg Gln Ile 165 170 175
Val Lys Lys Pro Val Lys Asp Thr Ile Pro Cys Pro Thr Ile Ala Glu
Ser Arg Arg Cys Lys Met Thr Met Arg His Cys Pro Gly Gly Lys Arg
190 195 200 205
Thr Pro Lys Ala Lys Glu Lys Arg Arg Lys Lys Lys Arg Arg Lys Leu
210 215 220
Ile Glu Arg Ala Glu Gly His Ser Val Phe Leu Ala Thr Asp Arg
225 230 235 240
Ala Asn Gln

<210> SEQ ID NO 31
<211> LENGTH: 272
<212> TYPE: PRT
<213> ORGANISM: Homo sapiens

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

<210> SEQ ID NO 32
<211> LENGTH: 224
<212> TYPE: PRT
<213> ORGANISM: Homo sapiens
<400> SEQUENCE: 32

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

<210> SEQ ID NO: 32
<211> LENGTH: 280
<212> TYPE: DNA
<213> ORGANISM: Homo sapiens
<400> SEQUENCE: 33

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tgCCAaggg gcgtgctcaac atgtcatgat tcaaaaagtg gttgtctag taagccccag 180
cattaatcgg cttgcggaga aattggcatg agtgatgtct ctcctcagtg 240
ccacctaggg attaacaacc tggtaatcga gataataata aagtgataaaa atgcaaaagt 300
gacacttgat accttttta cacaaaaatt tgtgcaaaaa tgttaaagtg gatattttctt 360
acacccctga aagtgccctg acaatgccc agaaaggttg gaagcccaaca accatactat 420
ggagttggtc agatgttgct acgtggagt cagttgaatg aacotcctgg atcagttcg 480
gaaagggga aaacactgtg gttcctaaag agggactgaa acagcgttcc cagaaactat 540
acacatact tcaagcaaggg tgaacgggtg tcccccaaca aatgagacaa aagaggtac 600
gagtcaagg aagaaaggtc aaggggaga acggagaaaa aaggaaggg agagggagag 660
aaaaaacct aataagaggg aatgttaaga agcaatacct gcacgcaaaa gtctgggaatc 720
1-20. (canceled)

21. An isolated antibody, that binds the Futrin 1 polypeptide of SEQ ID NO:26, wherein the antibody inhibits Wnt signaling.

22. The antibody of claim 21, wherein the antibody is a monoclonal antibody.

23. The antibody of claim 22, wherein the antibody is a chimeric antibody or humanized antibody.

24. The antibody of claim 23, wherein the antibody is an antibody fragment.

25. The antibody of claim 24, wherein the antibody fragment is a Fab fragment or F(ab')2.

26. The antibody of claim 21, wherein the antibody binds furin-like domain 1 and/or furin-like domain 2 of SEQ ID NO:26.
27. The antibody of claim 26, wherein the antibody is a monoclonal antibody.

28. The antibody of claim 27, wherein the antibody is a chimeric antibody or humanized antibody.

29. The antibody of claim 28, wherein the antibody is an antibody fragment.

30. The antibody of claim 29, wherein the antibody fragment is a Fab fragment or F(\(ab\)')

31. The antibody of claim 21, wherein the antibody reduces wnt reporter signaling in a mammalian cell line cultured in the presence of Futrin 1 by at least 40%.

32. The antibody of claim 31, wherein the antibody is a monoclonal antibody.

33. The antibody of claim 32, wherein the antibody is a chimeric antibody or humanized antibody.

34. The antibody of claim 33, wherein the antibody is an antibody fragment.

35. The antibody of claim 34, wherein the antibody fragment is a Fab fragment or F(\(ab\)')

36. The antibody of claim 26, wherein the antibody reduces wnt reporter signaling in a mammalian cell line cultured in the presence of Futrin 1 by at least 40%.

37. The antibody of claim 36, wherein the antibody is a monoclonal antibody.

38. The antibody of claim 37, wherein the antibody is a chimeric antibody or humanized antibody.

39. The antibody of claim 38, wherein the antibody is an antibody fragment.

40. The antibody of claim 39, wherein the antibody fragment is a Fab fragment or F(\(ab\)')

41. The antibody of claim 22, wherein the antibody is labeled with a detectable label.

42. The antibody of claim 41, wherein the detectable label is a radioisotope or enzyme label.

* * * * *