
7 Literaturverzeichnis

- Aberle,H., Bauer,A., Stappert,J., Kispert,A. & Kemler,R. (1997). beta-catenin is a target for the ubiquitin-proteasome pathway. *EMBO J.* *16*, 3797-3804.
- Adler,P.N. (1992). The genetic control of tissue polarity in *Drosophila*. *Bioessays* *14*, 735-741.
- Adler,P.N. (2002). Planar signaling and morphogenesis in *Drosophila*. *Dev. Cell* *2*, 525-535.
- Amit,S., Hatzubai,A., Birman,Y., Andersen,J.S., Ben Shushan,E., Mann,M., Ben Neriah,Y. & Alkalay,I. (2002). Axin-mediated CKI phosphorylation of beta-catenin at Ser 45: a molecular switch for the Wnt pathway. *Genes Dev.* *16*, 1066-1076.
- Asbrand,C. (2002). Neue Mechanismen der Regulation von Conductin im Wnt/beta-Catenin-Signalweg. *Dissertationsschrift Freie Universität Berlin*.
- Ausubel,F.M., Brent,R., Kingston,R.E., Moore,D.D., Seidman,I.G., Smith,J.A., and Struhl,K. (1987). *Current protocols in molecular biology*. (Greene Publishing Associates and Wiley-Interscience, New York).
- Axelrod,J.D., Miller,J.R., Shulman,J.M., Moon,R.T. & Perrimon,N. (1998). Differential recruitment of Dishevelled provides signaling specificity in the planar cell polarity and Wingless signaling pathways. *Genes Dev.* *12*, 2610-2622.
- Bartel,P.L. & Fields,S. (1995). Analyzing protein-protein interactions using two-hybrid system. *Methods Enzymol.* *254*, 241-263.
- Bauer,A., Chauvet,S., Huber,O., Usseglio,F., Rothbacher,U., Aragnol,D., Kemler,R. & Pradel,J. (2000). Pontin52 and reptin52 function as antagonistic regulators of beta-catenin signalling activity. *EMBO J.* *19*, 6121-6130.
- Behrens,J. (1999). Cadherins and catenins: role in signal transduction and tumor progression. *Cancer Metastasis Rev.* *18*, 15-30.
- Behrens,J., Jerchow,B.A., Wurtele,M., Grimm,J., Asbrand,C., Wirtz,R., Kuhl,M., Wedlich,D. & Birchmeier,W. (1998). Functional interaction of an axin homolog, conductin, with beta-catenin, APC, and GSK3beta. *Science* *280*, 596-599.

- Behrens,J., von Kries,J.P., Kuhl,M., Bruhn,L., Wedlich,D., Grosschedl,R. & Birchmeier,W. (1996). Functional interaction of beta-catenin with the transcription factor LEF-1. *Nature* 382, 638-642.
- Bhanot,P., Brink,M., Samos,C.H., Hsieh,J.C., Wang,Y., Macke,J.P., Andrew,D., Nathans,J. & Nusse,R. (1996). A new member of the frizzled family from *Drosophila* functions as a Wingless receptor. *Nature* 382, 225-230.
- Bhanot,P., Fish,M., Jemison,J.A., Nusse,R., Nathans,J. & Cadigan,K.M. (1999). Frizzled and Dfrizzled-2 function as redundant receptors for Wingless during *Drosophila* embryonic development. *Development* 126 , 4175-4186.
- Bienz,M. (1999). APC: the plot thickens. *Curr. Opin. Genet. Dev.* 9, 595-603.
- Bienz,M. & Clevers,H. (2000). Linking colorectal cancer to Wnt signaling. *Cell* 103, 311-320.
- Boutros,M., Paricio,N., Strutt,D.I. & Mlodzik,M. (1998). Dishevelled activates JNK and discriminates between JNK pathways in planar polarity and wingless signaling. *Cell* 94, 109-118.
- Brabletz,T., Jung,A., Dag,S., Hlubek,F. & Kirchner,T. (1999). beta-catenin regulates the expression of the matrix metalloproteinase-7 in human colorectal cancer. *Am. J. Pathol.* 155, 1033-1038.
- Brannon,M., Brown,J.D., Bates,R., Kimelman,D. & Moon,R.T. (1999). XCtBP is a XTcf-3 co-repressor with roles throughout *Xenopus* development. *Development* 126, 3159-3170.
- Brunner,E., Peter,O., Schweizer,L. & Basler,K. (1997). pangolin encodes a Lef-1 homologue that acts downstream of Armadillo to transduce the Wingless signal in *Drosophila*. *Nature* 385, 829-833.
- Cadigan,K.M. & Nusse,R. (1997). Wnt signaling: a common theme in animal development. *Genes Dev.* 11, 3286-3305.
- Cavallo,R.A., Cox,R.T., Moline,M.M., Roose,J., Polevoy,G.A., Clevers,H., Peifer,M. & Bejsovec,A. (1998). *Drosophila* Tcf and Groucho interact to repress Wingless signalling activity. *Nature* 395, 604-608.

- Cheyette,B.N., Waxman,J.S., Miller,J.R., Takemaru,K., Sheldahl,L.C., Khlebtsova,N., Fox,E.P., Earnest,T. & Moon,R.T. (2002). Dapper, a Dishevelled-associated antagonist of beta-catenin and JNK signaling, is required for notochord formation. *Dev. Cell* 2, 449-461.
- Chijiwa,T., Hagiwara,M. & Hidaka,H. (1989). A newly synthesized selective casein kinase I inhibitor, N-(2- aminoethyl)-5-chloroisoquinoline-8-sulfonamide, and affinity purification of casein kinase I from bovine testis. *J. Biol. Chem.* 264, 4924-4927.
- Cohen,P. & Frame,S. (2001). The renaissance of GSK3. *Nat. Rev. Mol. Cell Biol.* 2, 769-776.
- Crawford,H.C., Fingleton,B.M., Rudolph-Owen,L.A., Goss,K.J., Rubinfeld,B., Polakis,P. & Matrisian,L.M. (1999). The metalloproteinase matrilysin is a target of beta-catenin transactivation in intestinal tumors. *Oncogene* 18, 2883-2891.
- Cross,D.A., Alessi,D.R., Cohen,P., Andjelkovich,M. & Hemmings,B.A. (1995). Inhibition of glycogen synthase kinase-3 by insulin mediated by protein kinase B. *Nature* 378, 785-789.
- Dajani,R., Fraser,E., Roe,S.M., Young,N., Good,V., Dale,T.C. & Pearl,L.H. (2001). Crystal structure of glycogen synthase kinase 3beta. structural basis for phosphate-primed substrate specificity and autoinhibition. *Cell* 105, 721-732.
- De Robertis,E.M., Larrain,J., Oelgeschlager,M. & Wessely,O. (2000). The establishment of Spemann's organizer and patterning of the vertebrate embryo. *Nat. Rev. Genet.* 1, 171-181.
- Depraetere,V. (2001). PAR-1 helps Wnt to get rid of JNK. *Nat. Cell Biol.* 3, E158.
- Ding,V.W., Chen,R.H. & McCormick,F. (2000). Differential regulation of glycogen synthase kinase 3beta by insulin and Wnt signaling. *J. Biol. Chem.* 275, 32475-32481.
- Djiane,A., Riou,J., Umbhauer,M., Boucaut,J. & Shi,D. (2000). Role of frizzled 7 in the regulation of convergent extension movements during gastrulation in *Xenopus laevis*. *Development* 127, 3091-3100.
- Driever,W., Stemple,D., Schier,A. & Solnica-Krezel,L. (1994). Zebrafish: genetic tools for studying vertebrate development. *Trends Genet.* 10, 152-159.
- Eaton,S. (1997). Planar polarization of *Drosophila* and vertebrate epithelia. *Curr. Opin. Cell Biol.* 9, 860-866.

- Embi,N., Rylatt,D.B. & Cohen,P. (1980). Glycogen synthase kinase-3 from rabbit skeletal muscle. Separation from cyclic-AMP-dependent protein kinase and phosphorylase kinase. *Eur. J. Biochem.* *107*, 519-527.
- Fanto,M., Weber,U., Strutt,D.I. & Mlodzik,M. (2000). Nuclear signaling by Rac and Rho GTPases is required in the establishment of epithelial planar polarity in the *Drosophila* eye. *Curr. Biol.* *10*, 979-988.
- Feiguin,F., Hannus,M., Mlodzik,M. & Eaton,S. (2001). The ankyrin repeat protein Diego mediates Frizzled-dependent planar polarization. *Dev. Cell* *1*, 93-101.
- Fodde,R., Kuipers,J., Rosenberg,C., Smits,R., Kielman,M., Gaspar,C., van Es,J.H., Breukel,C., Wiegant,J., Giles,R.H. & Clevers,H. (2001). Mutations in the APC tumour suppressor gene cause chromosomal instability. *Nat. Cell Biol.* *3*, 433-438.
- Frame,S., Cohen,P. & Biondi,R.M. (2001). A common phosphate binding site explains the unique substrate specificity of gsk3 and its inactivation by phosphorylation. *Mol. Cell* *7*, 1321-1327.
- Fujita,Y., Krause,G., Scheffner,M., Zechner,D., Leddy,H.E., Behrens,J., Sommer,T. & Birchmeier,W. (2002). Hakai, a c-Cbl-like protein, ubiquitinates and induces endocytosis of the E-cadherin complex. *Nat. Cell Biol.* *4*, 222-231.
- Gao,Z.H., Seeling,J.M., Hill,V., Yochum,A. & Virshup,D.M. (2002). Casein kinase I phosphorylates and destabilizes the beta-catenin degradation complex. *Proc. Natl. Acad. Sci. U. S. A* *99*, 1182-1187.
- Gat,U., DasGupta,R., Degenstein,L. & Fuchs,E. (1998). De Novo hair follicle morphogenesis and hair tumors in mice expressing a truncated beta-catenin in skin. *Cell* *95*, 605-614.
- Gloy,J., Hikasa,H. & Sokol,S.Y. (2002). Frodo interacts with Dishevelled to transduce Wnt signals. *Nat. Cell Biol.* *4*, 351-357.
- Grimm,J., Sachs,M., Britsch,S., Di Cesare,S., Schwarz-Romond,T., Alitalo,K. & Birchmeier,W. (2001). Novel p62dok family members, dok-4 and dok-5, are substrates of the c-Ret receptor tyrosine kinase and mediate neuronal differentiation. *J. Cell Biol.* *154*, 345-354.

- Groden,J., Thliveris,A., Samowitz,W., Carlson,M., Gelbert,L., Albertsen,H., Joslyn,G., Stevens,J., Spirio,L., Robertson,M. & . (1991). Identification and characterization of the familial adenomatous polyposis coli gene. *Cell* 66, 589-600.
- Gubb,D. (1993). Genes controlling cellular polarity in *Drosophila*. *Dev. Suppl* 269-277.
- Gumbiner,B.M. (1997). Carcinogenesis: a balance between beta-catenin and APC. *Curr. Biol.* 7, R443-R446.
- Habas,R., Kato,Y. & He,X. (2001). Wnt/Frizzled activation of Rho regulates vertebrate gastrulation and requires a novel Formin homology protein Daam1. *Cell* 107, 843-854.
- Hammerschmidt,M., Pelegri,F., Mullins,M.C., Kane,D.A., Brand,M., van Eeden,F.J., Furutani-Seiki,M., Granato,M., Haffter,P., Heisenberg,C.P., Jiang,Y.J., Kelsh,R.N., Odenthal,J., Warga,R.M. & Nusslein-Volhard,C. (1996). Mutations affecting morphogenesis during gastrulation and tail formation in the zebrafish, *Danio rerio*. *Development* 123, 143-151.
- Han,M. (1997). Gut reaction to Wnt signaling in worms. *Cell* 90, 581-584.
- Hart,M.J., de los,S.R., Albert,I.N., Rubinfeld,B. & Polakis,P. (1998). Downregulation of beta-catenin by human Axin and its association with the APC tumor suppressor, beta-catenin and GSK3 beta. *Curr. Biol.* 8, 573-581.
- He,T.C., Sparks,A.B., Rago,C., Hermeking,H., Zawel,L., da Costa,L.T., Morin,P.J., Vogelstein,B. & Kinzler,K.W. (1998). Identification of c-MYC as a target of the APC pathway. *Science* 281, 1509-1512.
- Heasman,J., Crawford,A., Goldstone,K., Garner-Hamrick,P., Gumbiner,B., McCrea,P., Kintner,C., Noro,C.Y. & Wylie,C. (1994). Overexpression of cadherins and underexpression of beta-catenin inhibit dorsal mesoderm induction in early *Xenopus* embryos. *Cell* 79, 791-803.
- Heisenberg,C.P., Houart,C., Take-Uchi,M., Rauch,G.J., Young,N., Coutinho,P., Masai,I., Caneparo,L., Concha,M.L., Geisler,R., Dale,T.C., Wilson,S.W. & Stemple,D.L. (2001). A mutation in the Gsk3-binding domain of zebrafish Masterblind/Axin1 leads to a fate transformation of telencephalon and eyes to diencephalon. *Genes Dev.* 15, 1427-1434.

- Heisenberg,C.P., Tada,M., Rauch,G.J., Saude,L., Concha,M.L., Geisler,R., Stemple,D.L., Smith,J.C. & Wilson,S.W. (2000). Silberblick/Wnt11 mediates convergent extension movements during zebrafish gastrulation. *Nature* 405, 76-81.
- Hsu,W., Zeng,L. & Costantini,F. (1999). Identification of a domain of Axin that binds to the serine/threonine protein phosphatase 2A and a self-binding domain. *J. Biol. Chem.* 274, 3439-3445.
- Huelsken,J. & Behrens,J. (2000). The Wnt signalling pathway. *J. Cell Sci.* 113 (Pt 20), 3545.
- Huelsken,J. & Birchmeier,W. (2001). New aspects of Wnt signaling pathways in higher vertebrates. *Curr. Opin. Genet. Dev.* 11, 547-553.
- Huelsken,J., Birchmeier,W. & Behrens,J. (1994). E-cadherin and APC compete for the interaction with beta-catenin and the cytoskeleton. *J. Cell Biol.* 127, 2061-2069.
- Huelsken,J., Vogel,R., Brinkmann,V., Erdmann,B., Birchmeier,C. & Birchmeier,W. (2000). Requirement for beta-catenin in anterior-posterior axis formation in mice. *J. Cell Biol.* 148, 567-578.
- Hulsken,J., Behrens,J. & Birchmeier,W. (1994). Tumor-suppressor gene products in cell contacts: the cadherin-APC- armadillo connection. *Curr. Opin. Cell Biol.* 6, 711-716.
- Ichii,S., Horii,A., Nakatsuru,S., Furuyama,J., Utsunomiya,J. & Nakamura,Y. (1992). Inactivation of both APC alleles in an early stage of colon adenomas in a patient with familial adenomatous polyposis (FAP). *Hum. Mol. Genet.* 1, 387-390.
- Ikeda,S., Kishida,M., Matsuura,Y., Usui,H. & Kikuchi,A. (2000). GSK-3beta-dependent phosphorylation of adenomatous polyposis coli gene product can be modulated by beta-catenin and protein phosphatase 2A complexed with Axin. *Oncogene* 19, 537-545.
- Ikeda,S., Kishida,S., Yamamoto,H., Murai,H., Koyama,S. & Kikuchi,A. (1998). Axin, a negative regulator of the Wnt signaling pathway, forms a complex with GSK-3beta and beta-catenin and promotes GSK-3beta- dependent phosphorylation of beta-catenin. *EMBO J.* 17, 1371-1384.
- Ishitani,T., Ninomiya-Tsuji,J., Nagai,S., Nishita,M., Meneghini,M., Barker,N., Waterman,M., Bowerman,B., Clevers,H., Shibuya,H. & Matsumoto,K. (1999). The TAK1-NLK-MAPK-

related pathway antagonizes signalling between beta- catenin and transcription factor TCF. *Nature* 399, 798-802.

Ito,H., Fukuda,Y., Murata,K. & Kimura,A. (1983). Transformation of intact yeast cells treated with alkali cations. *J. Bacteriol.* 153, 163-168.

Jho,E., Lomvardas,S. & Costantini,F. (1999). A GSK3beta phosphorylation site in axin modulates interaction with beta- catenin and Tcf-mediated gene expression. *Biochem. Biophys. Res. Commun.* 266, 28-35.

Kawahara,K., Morishita,T., Nakamura,T., Hamada,F., Toyoshima,K. & Akiyama,T. (2000). Down-regulation of beta-catenin by the colorectal tumor suppressor APC requires association with Axin and beta-catenin. *J. Biol. Chem.* 275, 8369-8374.

Kelly,C., Chin,A.J., Leatherman,J.L., Kozlowski,D.J. & Weinberg,E.S. (2000). Maternally controlled (beta)-catenin-mediated signaling is required for organizer formation in the zebrafish. *Development* 127, 3899-3911.

Kelly,G.M., Erezylmaz,D.F. & Moon,R.T. (1995). Induction of a secondary embryonic axis in zebrafish occurs following the overexpression of beta-catenin. *Mech. Dev.* 53, 261-273.

Kennelly,P.J. & Krebs,E.G. (1991). Consensus sequences as substrate specificity determinants for protein kinases and protein phosphatases. *J. Biol. Chem.* 266, 15555-15558.

Kim,C.H., Oda,T., Itoh,M., Jiang,D., Artinger,K.B., Chandrasekharappa,S.C., Driever,W. & Chitnis,A.B. (2000). Repressor activity of Headless/Tcf3 is essential for vertebrate head formation. *Nature* 407, 913-916.

Kinzler,K.W., Nilbert,M.C., Su,L.K., Vogelstein,B., Bryan,T.M., Levy,D.B., Smith,K.J., Preisinger,A.C., Hedge,P., McKechnie,D. & . (1991). Identification of FAP locus genes from chromosome 5q21. *Science* 253, 661-665.

Kinzler,K.W. & Vogelstein,B. (1996). Lessons from hereditary colorectal cancer. *Cell* 87, 159-170.

Kishida,M., Hino,S., Michiue,T., Yamamoto,H., Kishida,S., Fukui,A., Asashima,M. & Kikuchi,A. (2001). Synergistic activation of the Wnt signaling pathway by Dvl and casein kinase Iepsilon. *J. Biol. Chem.* 276, 33147-33155.

- Kishida,S., Yamamoto,H., Hino,S., Ikeda,S., Kishida,M. & Kikuchi,A. (1999). DIX domains of Dvl and axin are necessary for protein interactions and their ability to regulate beta-catenin stability. *Mol. Cell Biol.* *19*, 4414-4422.
- Kishida,S., Yamamoto,H., Ikeda,S., Kishida,M., Sakamoto,I., Koyama,S. & Kikuchi,A. (1998). Axin, a negative regulator of the wnt signaling pathway, directly interacts with adenomatous polyposis coli and regulates the stabilization of beta-catenin. *J. Biol. Chem.* *273*, 10823-10826.
- Kitagawa,M., Hatakeyama,S., Shirane,M., Matsumoto,M., Ishida,N., Hattori,K., Nakamichi,I., Kikuchi,A., Nakayama,K. & Nakayama,K. (1999). An F-box protein, FWD1, mediates ubiquitin-dependent proteolysis of beta-catenin. *EMBO J.* *18*, 2401-2410.
- Korinek,V., Barker,N., Morin,P.J., van Wichen,D., de Weger,R., Kinzler,K.W., Vogelstein,B. & Clevers,H. (1997). Constitutive transcriptional activation by a beta-catenin-Tcf complex in APC^{-/-} colon carcinoma. *Science* *275*, 1784-1787.
- Kramps,T., Peter,O., Brunner,E., Nellen,D., Froesch,B., Chatterjee,S., Murone,M., Zullig,S. & Basler,K. (2002). Wnt/wingless signaling requires BCL9/legless-mediated recruitment of pygopus to the nuclear beta-catenin-TCF complex. *Cell* *109*, 47-60.
- Kuhl,M., Sheldahl,L.C., Malbon,C.C. & Moon,R.T. (2000). Ca(2+)/calmodulin-dependent protein kinase II is stimulated by Wnt and Frizzled homologs and promotes ventral cell fates in *Xenopus*. *J. Biol. Chem.* *275*, 12701-12711.
- Laemmli,U.K. (1970). Cleavage of structural proteins during the assembly of the head of bacteriophage T4. *Nature* *227*, 680-685.
- Larabell,C.A., Torres,M., Rowning,B.A., Yost,C., Miller,J.R., Wu,M., Kimelman,D. & Moon,R.T. (1997). Establishment of the dorso-ventral axis in *Xenopus* embryos is presaged by early asymmetries in beta-catenin that are modulated by the Wnt signaling pathway. *J. Cell Biol.* *136*, 1123-1136.
- Lee,E., Salic,A. & Kirschner,M.W. (2001). Physiological regulation of [beta]-catenin stability by Tcf3 and CK1epsilon. *J. Cell Biol.* *154*, 983-993.
- Leyns,L., Bouwmeester,T., Kim,S.H., Piccolo,S. & De Robertis,E.M. (1997). Frzb-1 is a secreted antagonist of Wnt signaling expressed in the Spemann organizer. *Cell* *88*, 747-756.

- Li,L., Yuan,H., Xie,W., Mao,J., Caruso,A.M., McMahon,A., Sussman,D.J. & Wu,D. (1999). Dishevelled proteins lead to two signaling pathways. Regulation of LEF- 1 and c-Jun N-terminal kinase in mammalian cells. *J. Biol. Chem.* 274, 129-134.
- Lin,X. & Perrimon,N. (1999). Dally cooperates with Drosophila Frizzled 2 to transduce Wingless signalling. *Nature* 400, 281-284.
- Liu,C., Li,Y., Semenov,M., Han,C., Baeg,G.H., Tan,Y., Zhang,Z., Lin,X. & He,X. (2002). Control of beta-catenin phosphorylation/degradation by a dual-kinase mechanism. *Cell* 108, 837-847.
- Liu,W., Dong,X., Mai,M., Seelan,R.S., Taniguchi,K., Krishnadath,K.K., Halling,K.C., Cunningham,J.M., Boardman,L.A., Qian,C., Christensen,E., Schmidt,S.S., Roche,P.C., Smith,D.I. & Thibodeau,S.N. (2000). Mutations in AXIN2 cause colorectal cancer with defective mismatch repair by activating beta-catenin/TCF signalling. *Nat. Genet.* 26, 146-147.
- Lu,B., Roegiers,F., Jan,L.Y. & Jan,Y.N. (2001). Adherens junctions inhibit asymmetric division in the Drosophila epithelium. *Nature* 409, 522-525.
- Lustig,B., Jerchow,B., Sachs,M., Weiler,S., Pietsch,T., Karsten,U., van de,W.M., Clevers,H., Schlag,P.M., Birchmeier,W. & Behrens,J. (2002). Negative feedback loop of Wnt signaling through upregulation of conductin/axin2 in colorectal and liver tumors. *Mol. Cell Biol.* 22, 1184-1193.
- Mao,B., Wu,W., Li,Y., Hoppe,D., Stannek,P., Glinka,A. & Niehrs,C. (2001a). LDL-receptor-related protein 6 is a receptor for Dickkopf proteins. *Nature* 411, 321-325.
- Mao,J., Wang,J., Liu,B., Pan,W., Farr,G.H., III, Flynn,C., Yuan,H., Takada,S., Kimelman,D., Li,L. & Wu,D. (2001b). Low-density lipoprotein receptor-related protein-5 binds to Axin and regulates the canonical Wnt signaling pathway. *Mol. Cell* 7, 801-809.
- McKay,R.M., Peters,J.M. & Graff,J.M. (2001). The casein kinase i family: roles in morphogenesis. *Dev. Biol.* 235, 378-387.
- Meneghini,M.D., Ishitani,T., Carter,J.C., Hisamoto,N., Ninomiya-Tsuji,J., Thorpe,C.J., Hamill,D.R., Matsumoto,K. & Bowerman,B. (1999). MAP kinase and Wnt pathways converge to downregulate an HMG-domain repressor in *Caenorhabditis elegans*. *Nature* 399, 793-797.

Miller,J.R. (2002). The Wnts. *Genome Biol.* 3 , REVIEWS3001.

Miller,J.R., Rowning,B.A., Larabell,C.A., Yang-Snyder,J.A., Bates,R.L. & Moon,R.T. (1999). Establishment of the dorsal-ventral axis in *Xenopus* embryos coincides with the dorsal enrichment of dishevelled that is dependent on cortical rotation. *J. Cell Biol.* 146, 427-437.

Mlodzik,M. (1999). Planar polarity in the *Drosophila* eye: a multifaceted view of signaling specificity and cross-talk. *EMBO J.* 18, 6873-6879.

Mlodzik,M. (2000). Spiny legs and prickled bodies: new insights and complexities in planar polarity establishment. *Bioessays* 22, 311-315.

Molenaar,M., van de,W.M., Oosterwegel,M., Peterson-Maduro,J., Godsave,S., Korinek,V., Roose,J., Destree,O. & Clevers,H. (1996). XTcf-3 transcription factor mediates beta-catenin-induced axis formation in *Xenopus* embryos. *Cell* 86, 391-399.

Morin,P.J. (1999). beta-catenin signaling and cancer. *Bioessays* 21, 1021-1030.

Moser,A.R., Dove,W.F., Roth,K.A. & Gordon,J.I. (1992). The Min (multiple intestinal neoplasia) mutation: its effect on gut epithelial cell differentiation and interaction with a modifier system. *J. Cell Biol.* 116, 1517-1526.

Mullins,M.C., Hammerschmidt,M., Kane,D.A., Odenthal,J., Brand,M., van Eeden,F.J., Furutani-Seiki,M., Granato,M., Haffter,P., Heisenberg,C.P., Jiang,Y.J., Kelsh,R.N. & Nusslein-Volhard,C. (1996). Genes establishing dorsoventral pattern formation in the zebrafish embryo: the ventral specifying genes. *Development* 123, 81-93.

Munemitsu,S., Albert,I., Souza,B., Rubinfeld,B. & Polakis,P. (1995). Regulation of intracellular beta-catenin levels by the adenomatous polyposis coli (APC) tumor-suppressor protein. *Proc. Natl. Acad. Sci. U. S. A* 92, 3046-3050.

Nagafuchi,A. (2001). Molecular architecture of adherens junctions. *Curr. Opin. Cell Biol.* 13, 600-603.

Nagafuchi,A. & Takeichi,M. (1989). Transmembrane control of cadherin-mediated cell adhesion: a 94 kDa protein functionally associated with a specific region of the cytoplasmic domain of E-cadherin. *Cell Regul.* 1, 37-44.

- Nagase,T., Ishikawa,K., Suyama,M., Kikuno,R., Hirosawa,M., Miyajima,N., Tanaka,A., Kotani,H., Nomura,N. & Ohara,O. (1999). Prediction of the coding sequences of unidentified human genes. XIII. The complete sequences of 100 new cDNA clones from brain which code for large proteins in vitro. *DNA Res.* 6, 63-70.
- Nasevicius,A. & Ekker,S.C. (2000). Effective targeted gene 'knockdown' in zebrafish. *Nat. Genet.* 26, 216-220.
- Nusse,R., van Ooyen,A., Cox,D., Fung,Y.K. & Varmus,H. (1984). Mode of proviral activation of a putative mammary oncogene (int-1) on mouse chromosome 15. *Nature* 307, 131-136.
- Nusse,R. & Varmus,H.E. (1982). Many tumors induced by the mouse mammary tumor virus contain a provirus integrated in the same region of the host genome. *Cell* 31, 99-109.
- Nusslein-Volhard,C. & Wieschaus,E. (1980). Mutations affecting segment number and polarity in *Drosophila*. *Nature* 287, 795-801.
- Ozawa,M., Baribault,H. & Kemler,R. (1989). The cytoplasmic domain of the cell adhesion molecule uvomorulin associates with three independent proteins structurally related in different species. *EMBO J.* 8, 1711-1717.
- Park,M. & Moon,R.T. (2002). The planar cell-polarity gene *stbm* regulates cell behaviour and cell fate in vertebrate embryos. *Nat. Cell Biol.* 4, 20-25.
- Parker,D.S., Jemison,J. & Cadigan,K.M. (2002). *Pygopus*, a nuclear PHD-finger protein required for *Wingless* signaling in *Drosophila*. *Development* 129, 2565-2576.
- Perrimon,N. & Mahowald,A.P. (1987). Multiple functions of segment polarity genes in *Drosophila*. *Dev. Biol.* 119, 587-600.
- Peters,J.M., McKay,R.M., McKay,J.P. & Graff,J.M. (1999). Casein kinase I transduces Wnt signals. *Nature* 401, 345-350.
- Piccolo,S., Agius,E., Leyns,L., Bhattacharyya,S., Grunz,H., Bouwmeester,T. & De Robertis,E.M. (1999). The head inducer *Cerberus* is a multifunctional antagonist of *Nodal*, *BMP* and *Wnt* signals. *Nature* 397, 707-710.

- Pinna,L.A. & Ruzzene,M. (1996). How do protein kinases recognize their substrates? *Biochim. Biophys. Acta 1314*, 191-225.
- Pinson,K.I., Brennan,J., Monkley,S., Avery,B.J. & Skarnes,W.C. (2000). An LDL-receptor-related protein mediates Wnt signalling in mice. *Nature 407*, 535-538.
- Plyte,S.E., Hughes,K., Nikolakaki,E., Pulverer,B.J. & Woodgett,J.R. (1992). Glycogen synthase kinase-3: functions in oncogenesis and development. *Biochim. Biophys. Acta 1114*, 147-162.
- Polakis,P. (1995). Mutations in the APC gene and their implications for protein structure and function. *Curr. Opin. Genet. Dev. 5*, 66-71.
- Polakis,P. (2000). Wnt signaling and cancer. *Genes Dev. 14*, 1837-1851.
- Price,M.A. & Kalderon,D. (2002). Proteolysis of the Hedgehog signaling effector Cubitus interruptus requires phosphorylation by Glycogen Synthase Kinase 3 and Casein Kinase 1. *Cell 108*, 823-835.
- Riggleman,B., Schedl,P. & Wieschaus,E. (1990). Spatial expression of the Drosophila segment polarity gene armadillo is posttranscriptionally regulated by wingless. *Cell 63*, 549-560.
- Rijsewijk,F., Schuermann,M., Wagenaar,E., Parren,P., Weigel,D. & Nusse,R. (1987). The Drosophila homolog of the mouse mammary oncogene int-1 is identical to the segment polarity gene wingless. *Cell 50*, 649-657.
- Roose,J. & Clevers,H. (1999). TCF transcription factors: molecular switches in carcinogenesis. *Biochim. Biophys. Acta 1424*, M23-M37.
- Rothbacher,U., Laurent,M.N., Deardorff,M.A., Klein,P.S., Cho,K.W. & Fraser,S.E. (2000). Dishevelled phosphorylation, subcellular localization and multimerization regulate its role in early embryogenesis. *EMBO J. 19*, 1010-1022.
- Rousset,R., Mack,J.A., Wharton,K.A., Jr., Axelrod,J.D., Cadigan,K.M., Fish,M.P., Nusse,R. & Scott,M.P. (2001). Naked cuticle targets dishevelled to antagonize Wnt signal transduction. *Genes Dev. 15*, 658-671.

- Rubinfeld,B., Robbins,P., El Gamil,M., Albert,I., Porfiri,E. & Polakis,P. (1997). Stabilization of beta-catenin by genetic defects in melanoma cell lines. *Science* 275, 1790-1792.
- Rubinfeld,B., Souza,B., Albert,I., Muller,O., Chamberlain,S.H., Masiarz,F.R., Munemitsu,S. & Polakis,P. (1993). Association of the APC gene product with beta-catenin. *Science* 262, 1731-1734.
- Rubinfeld,B., Tice,D.A. & Polakis,P. (2001). Axin dependent phosphorylation of the adenomatous polyposis coli protein mediated by casein kinase 1 epsilon. *J. Biol. Chem.*
- Sakanaka,C., Leong,P., Xu,L., Harrison,S.D. & Williams,L.T. (1999). Casein kinase epsilon in the wnt pathway: regulation of beta-catenin function. *Proc. Natl. Acad. Sci. U. S. A* 96, 12548-12552.
- Sambrook,E.F., Fritsch,E.F., and Maniatis,T. (1989). *Molecular cloning: a laboratory handbook*. (Cold Spring Harbor Laboratory Press, New York).
- Satoh,S., Daigo,Y., Furukawa,Y., Kato,T., Miwa,N., Nishiwaki,T., Kawasoe,T., Ishiguro,H., Fujita,M., Tokino,T., Sasaki,Y., Imaoka,S., Murata,M., Shimano,T., Yamaoka,Y. & Nakamura,Y. (2000). AXIN1 mutations in hepatocellular carcinomas, and growth suppression in cancer cells by virus-mediated transfer of AXIN1. *Nat. Genet.* 24, 245-250.
- Schier,A.F. (2001). Axis formation and patterning in zebrafish. *Curr. Opin. Genet. Dev.* 11, 393-404.
- Schwarz-Romond,T., Asbrand,C., Bakkers,J., Kuhl,M., Schaeffer,H.J., Hulsken,J., Behrens,J. & Birchmeier,W. (2002). The ankyrin repeat protein Diversin recruits Casein kinase Iε to the β-catenin degradation complex and acts in both canonical Wnt and Wnt/JNK signaling. *Genes Dev.* 16, im Druck.
- Sedgwick,S.G. & Smerdon,S.J. (1999). The ankyrin repeat: a diversity of interactions on a common structural framework. *Trends Biochem. Sci.* 24, 311-316.
- Seidensticker,M.J. & Behrens,J. (2000). Biochemical interactions in the wnt pathway. *Biochim. Biophys. Acta* 1495, 168-182.
- Sharpe,C., Lawrence,N. & Martinez,A.A. (2001). Wnt signalling: a theme with nuclear variations. *Bioessays* 23, 311-318.

- Shimizu,H., Julius,M.A., Giarre,M., Zheng,Z., Brown,A.M. & Kitajewski,J. (1997). Transformation by Wnt family proteins correlates with regulation of beta-catenin. *Cell Growth Differ.* *8*, 1349-1358.
- Shulman,J.M., Perrimon,N. & Axelrod,J.D. (1998). Frizzled signaling and the developmental control of cell polarity. *Trends Genet.* *14*, 452-458.
- Siegfried,E., Wilder,E.L. & Perrimon,N. (1994). Components of wingless signalling in *Drosophila*. *Nature* *367*, 76-80.
- Smalley,M.J., Sara,E., Paterson,H., Naylor,S., Cook,D., Jayatilake,H., Fryer,L.G., Hutchinson,L., Fry,M.J. & Dale,T.C. (1999). Interaction of axin and Dvl-2 proteins regulates Dvl-2-stimulated TCF- dependent transcription. *EMBO J.* *18*, 2823-2835.
- Smith,W.C. & Harland,R.M. (1991). Injected Xwnt-8 RNA acts early in *Xenopus* embryos to promote formation of a vegetal dorsalizing center. *Cell* *67*, 753-765.
- Smits,R., Kielman,M.F., Breukel,C., Zurcher,C., Neufeld,K., Jagmohan-Changur,S., Hofland,N., van Dijk,J., White,R., Edelmann,W., Kucherlapati,R., Khan,P.M. & Fodde,R. (1999). Apc1638T: a mouse model delineating critical domains of the adenomatous polyposis coli protein involved in tumorigenesis and development. *Genes Dev.* *13*, 1309-1321.
- Sokol,S. (2000). A role for Wnts in morpho-genesis and tissue polarity. *Nat. Cell Biol.* *2*, E124-E125.
- Sokol,S., Christian,J.L., Moon,R.T. & Melton,D.A. (1991). Injected Wnt RNA induces a complete body axis in *Xenopus* embryos. *Cell* *67*, 741-752.
- Sokol,S.Y. (1996). Analysis of Dishevelled signalling pathways during *Xenopus* development. *Curr. Biol.* *6*, 1456-1467.
- Spink,K.E., Polakis,P. & Weis,W.I. (2000). Structural basis of the Axin-adenomatous polyposis coli interaction. *EMBO J.* *19*, 2270-2279.
- Strutt,D.I., Weber,U. & Mlodzik,M. (1997). The role of RhoA in tissue polarity and Frizzled signalling. *Nature* *387*, 292-295.
- Su,L.K., Vogelstein,B. & Kinzler,K.W. (1993). Association of the APC tumor suppressor protein with catenins. *Science* *262*, 1734-1737.

- Sumoy,L., Kiefer,J. & Kimelman,D. (1999). Conservation of intracellular Wnt signaling components in dorsal- ventral axis formation in zebrafish. *Dev. Genes Evol.* 209, 48-58.
- Sun,T.Q., Lu,B., Feng,J.J., Reinhard,C., Jan,Y.N., Fantl,W.J. & Williams,L.T. (2001). PAR-1 is a Dishevelled-associated kinase and a positive regulator of Wnt signalling. *Nat. Cell Biol.* 3, 628-636.
- Tada,M. & Smith,J.C. (2000). Xwnt11 is a target of Xenopus Brachyury: regulation of gastrulation movements via Dishevelled, but not through the canonical Wnt pathway. *Development* 127, 2227-2238.
- Takeichi,M., Nakagawa,S., Aono,S., Usui,T. & Uemura,T. (2000). Patterning of cell assemblies regulated by adhesion receptors of the cadherin superfamily. *Philos. Trans. R. Soc. Lond B Biol. Sci.* 355, 885-890.
- Tamai,K., Semenov,M., Kato,Y., Spokony,R., Liu,C., Katsuyama,Y., Hess,F., Saint-Jeannet,J.P. & He,X. (2000). LDL-receptor-related proteins in Wnt signal transduction. *Nature* 407, 530-535.
- Tetsu,O. & McCormick,F. (1999). Beta-catenin regulates expression of cyclin D1 in colon carcinoma cells. *Nature* 398, 422-426.
- Thisse,C., Thisse,B., Schilling,T.F. & Postlethwait,J.H. (1993). Structure of the zebrafish *snail1* gene and its expression in wild-type, spadetail and no tail mutant embryos. *Development* 119, 1203-1215.
- Thompson,B., Townsley,F., Rosin-Arbesfeld,R., Musisi,H. & Bienz,M. (2002). A new nuclear component of the Wnt signalling pathway. *Nat. Cell Biol.* 4, 367-373.
- Topczewski,J., Sepich,D.S., Myers,D.C., Walker,C., Amores,A., Lele,Z., Hammerschmidt,M., Postlethwait,J. & Solnica-Krezel,L. (2001). The zebrafish glypican knypek controls cell polarity during gastrulation movements of convergent extension. *Dev. Cell* 1, 251-264.
- Tsuda,M., Kamimura,K., Nakato,H., Archer,M., Staatz,W., Fox,B., Humphrey,M., Olson,S., Futch,T., Kaluza,V., Siegfried,E., Stam,L. & Selleck,S.B. (1999). The cell-surface proteoglycan Dally regulates Wingless signalling in *Drosophila*. *Nature* 400, 276-280.

- Vielhaber,E. & Virshup,D.M. (2001). Casein kinase I: from obscurity to center stage. *IUBMB. Life* 51, 73-78.
- von Kries,J.P., Winbeck,G., Asbrand,C., Schwarz-Romond,T., Sochnikova,N., Dell'Oro,A., Behrens,J. & Birchmeier,W. (2000). Hot spots in beta-catenin for interactions with LEF-1, conductin and APC. *Nat. Struct. Biol.* 7, 800-807.
- Wallingford,J.B., Fraser,S.E. & Harland,R.M. (2002). Convergent Extension. The Molecular Control of Polarized Cell Movement during Embryonic Development. *Dev. Cell* 2, 695-706.
- Wallingford,J.B., Rowning,B.A., Vogeli,K.M., Rothbacher,U., Fraser,S.E. & Harland,R.M. (2000). Dishevelled controls cell polarity during *Xenopus* gastrulation. *Nature* 405, 81-85.
- Wang,S., Krinks,M., Lin,K., Luyten,F.P. & Moos,M., Jr. (1997). Frzb, a secreted protein expressed in the Spemann organizer, binds and inhibits Wnt-8. *Cell* 88, 757-766.
- Wehrli,M., Dougan,S.T., Caldwell,K., O'Keefe,L., Schwartz,S., Vaizel-Ohayon,D., Schejter,E., Tomlinson,A. & DiNardo,S. (2000). arrow encodes an LDL-receptor-related protein essential for Wingless signalling. *Nature* 407, 527-530.
- Weidner,K.M., Di Cesare,S., Sachs,M., Brinkmann,V., Behrens,J. & Birchmeier,W. (1996). Interaction between Gab1 and the c-Met receptor tyrosine kinase is responsible for epithelial morphogenesis. *Nature* 384, 173-176.
- Weintraub,H., Davis,R., Tapscott,S., Thayer,M., Krause,M., Benezra,R., Blackwell,T.K., Turner,D., Rupp,R., Hollenberg,S. & . (1991). The myoD gene family: nodal point during specification of the muscle cell lineage. *Science* 251, 761-766.
- Willert,K., Brink,M., Wodarz,A., Varmus,H. & Nusse,R. (1997). Casein kinase 2 associates with and phosphorylates dishevelled. *EMBO J.* 16, 3089-3096.
- Willert,K., Shibamoto,S. & Nusse,R. (1999). Wnt-induced dephosphorylation of axin releases beta-catenin from the axin complex. *Genes Dev.* 13, 1768-1773.
- Winklbauer,R., Medina,A., Swain,R.K. & Steinbeisser,H. (2001). Frizzled-7 signalling controls tissue separation during *Xenopus* gastrulation. *Nature* 413, 856-860.
- Wodarz,A. & Nusse,R. (1998). Mechanisms of Wnt signaling in development. *Annu. Rev. Cell Dev. Biol.* 14, 59-88.

- Wong,H.C., Mao,J., Nguyen,J.T., Srinivas,S., Zhang,W., Liu,B., Li,L., Wu,D. & Zheng,J. (2000). Structural basis of the recognition of the dishevelled DEP domain in the Wnt signaling pathway. *Nat. Struct. Biol.* 7, 1178-1184.
- Yamamoto,H., Kishida,S., Kishida,M., Ikeda,S., Takada,S. & Kikuchi,A. (1999). Phosphorylation of axin, a Wnt signal negative regulator, by glycogen synthase kinase-3beta regulates its stability. *J. Biol. Chem.* 274, 10681-10684.
- Yan,D., Wallingford,J.B., Sun,T.Q., Nelson,A.M., Sakanaka,C., Reinhard,C., Harland,R.M., Fantl,W.J. & Williams,L.T. (2001). Cell autonomous regulation of multiple Dishevelled-dependent pathways by mammalian Nkd. *Proc. Natl. Acad. Sci. U. S. A* 98, 3802-3807.
- Yanagawa,S., Matsuda,Y., Lee,J.S., Matsubayashi,H., Sese,S., Kadowaki,T. & Ishimoto,A. (2002). Casein kinase I phosphorylates the Armadillo protein and induces its degradation in *Drosophila*. *EMBO J.* 21, 1733-1742.
- Yanagawa,S., van Leeuwen,F., Wodarz,A., Klingensmith,J. & Nusse,R. (1995). The dishevelled protein is modified by wingless signaling in *Drosophila*. *Genes Dev.* 9, 1087-1097.
- Yost,C., Farr,G.H., III, Pierce,S.B., Ferkey,D.M., Chen,M.M. & Kimelman,D. (1998). GBP, an inhibitor of GSK-3, is implicated in *Xenopus* development and oncogenesis. *Cell* 93, 1031-1041.
- Yost,C., Torres,M., Miller,J.R., Huang,E., Kimelman,D. & Moon,R.T. (1996). The axis-inducing activity, stability, and subcellular distribution of beta-catenin is regulated in *Xenopus* embryos by glycogen synthase kinase 3. *Genes Dev.* 10, 1443-1454.
- Zeng,L., Fagotto,F., Zhang,T., Hsu,W., Vasicek,T.J., Perry,W.L., III, Lee,J.J., Tilghman,S.M., Gumbiner,B.M. & Costantini,F. (1997). The mouse Fused locus encodes Axin, an inhibitor of the Wnt signaling pathway that regulates embryonic axis formation. *Cell* 90, 181-192.
- Zeng,W., Wharton,K.A., Jr., Mack,J.A., Wang,K., Gadbow,M., Suyama,K., Klein,P.S. & Scott,M.P. (2000). naked cuticle encodes an inducible antagonist of Wnt signalling. *Nature* 403, 789-795.