
5. 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.

Amit, S., Hatzubai, A., Birman, Y., Andersen, J. S., Ben-Shushan, E., Mann, M., Ben-Neriah, Y., and Alkalay, Y. (2002). Axin-mediated CKI phosphorylation of beta-catenin at Ser45: a molecular switch for the Wnt pathway. *Genes Dev.*, im Druck.

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.

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.

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.
- Boyle,W.J., Smeal,T., Defize,L.H., Angel,P., Woodgett,J.R., Karin,M. & Hunter,T. (1991). Activation of protein kinase C decreases phosphorylation of c-Jun at sites that negatively regulate its DNA-binding activity. *Cell* 64, 573-584.
- 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.
- Brannon,M., Gomperts,M., Sumoy,L., Moon,R.T. & Kimelman,D. (1997). A beta-catenin/XTcf-3 complex binds to the siamois promoter to regulate dorsal axis specification in *Xenopus*. *Genes Dev.* 11, 2359-2370.
- Cadigan,K.M. & Nusse,R. (1997). Wnt signaling: a common theme in animal development. *Genes Dev.* 11, 3286-3305.
- Capdevila,J., Tabin,C. & Johnson,R.L. (1998). Control of dorsoventral somite patterning by Wnt-1 and beta-catenin. *Dev. Biol.* 193, 182-194.
- 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.
- Chen,C.M., Kraut,N., Groudine,M. & Weintraub,H. (1996). I-mf, a novel myogenic repressor, interacts with members of the MyoD family. *Cell* 86, 731-741.
- Cohen,P. & Frame,S. (2001). The renaissance of GSK3. *Nat. Rev. Mol. Cell Biol.* 2, 769-776.
- 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.
- Culbert,A.A., Brown,M.J., Frame,S., Hagen,T., Cross,D.A., Bax,B. & Reith,A.D. (2001). GSK-3 inhibition by adenoviral FRAT1 overexpression is neuroprotective and induces Tau dephosphorylation and beta-catenin stabilisation without elevation of glycogen synthase activity. *FEBS Lett.* 507, 288-294.

- 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.
- Dann,C.E., Hsieh,J.C., Rattner,A., Sharma,D., Nathans,J. & Leahy,D.J. (2001). Insights into Wnt binding and signalling from the structures of two Frizzled cysteine-rich domains. *Nature* 412, 86-90.
- 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.
- Dominguez,I. & Green,J.B. (2000). Dorsal downregulation of GSK3beta by a non-Wnt-like mechanism is an early molecular consequence of cortical rotation in early *Xenopus* embryos. *Development* 127, 861-868.
- 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.
- Fagotto,F., Jho,E., Zeng,L., Kurth,T., Joos,T., Kaufmann,C. & Costantini,F. (1999). Domains of axin involved in protein-protein interactions, Wnt pathway inhibition, and intracellular localization. *J. Cell Biol.* 145, 741-756.
- Fan,C.M., Lee,C.S. & Tessier-Lavigne,M. (1997). A role for WNT proteins in induction of dermomyotome. *Dev. Biol.* 191, 160-165.
- Farr,G.H., III, Ferkey,D.M., Yost,C., Pierce,S.B., Weaver,C. & Kimelman,D. (2000). Interaction among GSK-3, GBP, axin, and APC in *Xenopus* axis specification. *J. Cell Biol.* 148, 691-702.
- Feiguin,F., Hannus,M., Mlodzik,M. & Eaton,S. (2001). The ankyrin repeat protein Diego mediates Frizzled-dependent planar polarization. *Dev. Cell* 1, 93-101.
- Fiol,C.J., Mahrenholz,A.M., Wang,Y., Roeske,R.W. & Roach,P.J. (1987). Formation of protein kinase recognition sites by covalent modification of the substrate. Molecular mechanism for the synergistic action of casein kinase II and glycogen synthase kinase 3. *J. Biol. Chem.* 262, 14042-14048.

- 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.
- Furuhashi,M., Yagi,K., Yamamoto,H., Furukawa,Y., Shimada,S., Nakamura,Y., Kikuchi,A., Miyazono,K. & Kato,M. (2001). Axin Facilitates Smad3 Activation in the Transforming Growth Factor beta Signaling Pathway. *Mol. Cell Biol.* 21, 5132-5141.
- Graham,T.A., Weaver,C., Mao,F., Kimelman,D. & Xu,W. (2000). Crystal structure of a beta-catenin/Tcf complex. *Cell* 103, 885-896.
- Greaves,S., Sanson,B., White,P. & Vincent,J.P. (1999). A screen for identifying genes interacting with armadillo, the Drosophila homolog of beta-catenin. *Genetics* 153, 1753-1766.
- Hanger,D.P., Hughes,K., Woodgett,J.R., Brion,J.P. & Anderton,B.H. (1992). Glycogen synthase kinase-3 induces Alzheimer's disease-like phosphorylation of tau: generation of paired helical filament epitopes and neuronal localisation of the kinase. *Neurosci. Lett.* 147, 58-62.
- 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., Chan,T.A., Vogelstein,B. & Kinzler,K.W. (1999). PPARdelta is an APC-regulated target of nonsteroidal anti-inflammatory drugs. *Cell* 99, 335-345.
- 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.

- Hedgepeth,C.M., Deardorff,M.A., Rankin,K. & Klein,P.S. (1999). Regulation of glycogen synthase kinase 3beta and downstream Wnt signaling by axin. *Mol. Cell Biol.* *19*, 7147-7157.
- 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.
- Henderson,B.R. (2000). Nuclear-cytoplasmic shuttling of APC regulates beta-catenin subcellular localization and turnover. *Nat. Cell Biol.* *2*, 653-660.
- Hobmayer,B., Rentzsch,F., Kuhn,K., Happel,C.M., von Laue,C.C., Snyder,P., Rothbacher,U. & Holstein,T.W. (2000). WNT signalling molecules act in axis formation in the diploblastic metazoan Hydra. *Nature* *407*, 186-189.
- 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.
- Huber,A.H., Nelson,W.J. & Weis,W.I. (1997). Three-dimensional structure of the armadillo repeat region of beta- catenin. *Cell* *90*, 871-882.
- 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.
- 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.

- Itoh,K., Antipova,A., Ratcliffe,M.J. & Sokol,S. (2000). Interaction of dishevelled and Xenopus axin-related protein is required for wnt signal transduction. *Mol. Cell Biol.* 20, 2228-2238.
- Jho,E.H., Zhang,T., Domon,C., Joo,C.K., Freund,J.N. & Costantini,F. (2002). Wnt/beta-catenin/Tcf signaling induces the transcription of Axin2, a negative regulator of the signaling pathway. *Mol. Cell Biol.* 22, 1172-1183.
- 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.
- Jonkers,J., Korswagen,H.C., Acton,D., Breuer,M. & Berns,A. (1997). Activation of a novel proto-oncogene, Frat1, contributes to progression of mouse T-cell lymphomas. *EMBO J.* 16, 441-450.
- Jonkers,J., van Amerongen,R., van,d., V, Robanus-Maandag,E., Molenaar,M., Destree,O. & Berns,A. (1999). In vivo analysis of Frat1 deficiency suggests compensatory activity of Frat3. *Mech. Dev.* 88, 183-194.
- Kadoya,T., Kishida,S., Fukui,A., Hinoi,T., Michiue,T., Asashima,M. & Kikuchi,A. (2000). Inhibition of Wnt signaling pathway by a novel axin-binding protein. *J. Biol. Chem.* 275, 37030-37037.
- 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.
- 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.

- 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.
- Klingensmith,J., Yang,Y., Axelrod,J.D., Beier,D.R., Perrimon,N. & Sussman,D.J. (1996). Conservation of dishevelled structure and function between flies and mice: isolation and characterization of Dvl2. *Mech. Dev.* *58*, 15-26.
- 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.
- Korinek,W.S., Copeland,M.J., Chaudhuri,A. & Chant,J. (2000). Molecular linkage underlying microtubule orientation toward cortical sites in yeast. *Science* *287*, 2257-2259.
- Kraut,N., Snider,L., Chen,C.M., Tapscott,S.J. & Groudine,M. (1998). Requirement of the mouse I-mfa gene for placental development and skeletal patterning. *EMBO J.* *17*, 6276-6288.
- Krieg,P.A. & Melton,D.A. (1984). Functional messenger RNAs are produced by SP6 in vitro transcription of cloned cDNAs. *Nucleic Acids Res.* *12*, 7057-7070.
- Kuhl,M., Sheldahl,L.C., Park,M., Miller,J.R. & Moon,R.T. (2000). The Wnt/Ca²⁺ pathway: a new vertebrate Wnt signaling pathway takes shape. *Trends Genet.* *16*, 279-283.
- Laemmli,U.K. (1970). Cleavage of structural proteins during the assembly of the head of bacteriophage T4. *Nature* *227*, 680-685.
- Lee,E., Salic,A. & Kirschner,M.W. (2001). Physiological regulation of [beta]-catenin stability by Tcf3 and CK1epsilon. *J. Cell Biol.* *154*, 983-993.
- Li,L., Yuan,H., Weaver,C.D., Mao,J., Farr,G.H., III, Sussman,D.J., Jonkers,J., Kimelman,D. & Wu,D. (1999a). Axin and Frat1 interact with dvl and GSK, bridging Dvl to GSK in Wnt-mediated regulation of LEF-1. *EMBO J.* *18*, 4233-4240.
- Li,L., Yuan,H., Xie,W., Mao,J., Caruso,A.M., McMahon,A., Sussman,D.J. & Wu,D. (1999b). 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.

- Li,X., Yost,H.J., Virshup,D.M. & Seeling,J.M. (2001). Protein phosphatase 2A and its B56 regulatory subunit inhibit Wnt signaling in *Xenopus*. *EMBO J.* 20, 4122-4131.
- 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,T., DeCostanzo,A.J., Liu,X., Wang,H., Hallagan,S., Moon,R.T. & Malbon,C.C. (2001). G protein signaling from activated rat frizzled-1 to the beta-catenin-Lef-Tcf pathway. *Science* 292, 1718-1722.
- 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.
- 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,J., Wang,J., Liu,B., Pan,W., Farr,G.H., III, Flynn,C., Yuan,H., Takada,S., Kimelman,D., Li,L. & Wu,D. (2001). 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 in wnt signaling. *Dev. Biol.* 235, 388-396.
- Mimori-Kiyosue,Y., Shiina,N. & Tsukita,S. (2000). Adenomatous polyposis coli (APC) protein moves along microtubules and concentrates at their growing ends in epithelial cells. *J. Cell Biol.* 148, 505-518.
- Miyaki,M., Konishi,M., Kikuchi-Yanoshita,R., Enomoto,M., Igari,T., Tanaka,K., Muraoka,M., Takahashi,H., Amada,Y., Fukayama,M. & . (1994). Characteristics of somatic mutation of the adenomatous polyposis coli gene in colorectal tumors. *Cancer Res.* 54, 3011-3020.

- Miyoshi, Y., Nagase, H., Ando, H., Horii, A., Ichii, S., Nakatsuru, S., Aoki, T., Miki, Y., Mori, T. & Nakamura, Y. (1992). Somatic mutations of the APC gene in colorectal tumors: mutation cluster region in the APC gene. *Hum. Mol. Genet.* *1*, 229-233.
- Mlodzik, M. (1999). Planar polarity in the *Drosophila* eye: a multifaceted view of signaling specificity and cross-talk. *EMBO J.* *18*, 6873-6879.
- 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.
- Monkley, S.J., Delaney, S.J., Pennisi, D.J., Christiansen, J.H. & Wainwright, B.J. (1996). Targeted disruption of the *Wnt2* gene results in placentation defects. *Development* *122*, 3343-3353.
- Moon, R.T. & Kimelman, D. (1998). From cortical rotation to organizer gene expression: toward a molecular explanation of axis specification in *Xenopus*. *Bioessays* *20*, 536-545.
- Morin, P.J. (1999). beta-catenin signaling and cancer. *Bioessays* *21*, 1021-1030.
- Morin, P.J., Sparks, A.B., Korinek, V., Barker, N., Clevers, H., Vogelstein, B. & Kinzler, K.W. (1997). Activation of beta-catenin-Tcf signaling in colon cancer by mutations in beta-catenin or APC. *Science* *275*, 1787-1790.
- 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.
- Nagase, H. & Nakamura, Y. (1993). Mutations of the APC (adenomatous polyposis coli) gene. *Hum. Mutat.* *2*, 425-434.
- Nishida, T., Kaneko, F., Kitagawa, M. & Yasuda, H. (2001). Characterization of a Novel Mammalian SUMO-1/Smt3-specific Isopeptidase, a Homologue of Rat Axam, Which Is an Axin-binding Protein Promoting beta-Catenin Degradation. *J. Biol. Chem.* *276*, 39060-39066.

- Noordermeer,J., Klingensmith,J., Perrimon,N. & Nusse,R. (1994). Dishevelled and armadillo act in the wingless signalling pathway in *Drosophila*. *Nature* 367, 80-83.
- Nusse,R., Brown,A., Papkoff,J., Scambler,P., Shackleford,G., McMahon,A., Moon,R. & Varmus,H. (1991). A new nomenclature for int-1 and related genes: the Wnt gene family. *Cell* 64, 231.
- 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.
- 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., Dean,M., Cooper,C.S., Schmidt,M., O'Brien,S.J., Blair,D.G. & Vande Woude,G.F. (1986). Mechanism of met oncogene activation. *Cell* 45, 895-904.
- Peters,J.M., McKay,R.M., McKay,J.P. & Graff,J.M. (1999). Casein kinase I transduces Wnt signals. *Nature* 401, 345-350.
- Polakis,P. (2000). Wnt signaling and cancer. *Genes Dev.* 14, 1837-1851.
- Popperl,H., Schmidt,C., Wilson,V., Hume,C.R., Dodd,J., Krumlauf,R. & Beddington,R.S. (1997). Misexpression of *Cwnt8C* in the mouse induces an ectopic embryonic axis and causes a truncation of the anterior neuroectoderm. *Development* 124, 2997-3005.
- Ratcliffe,M.J., Itoh,K. & Sokol,S.Y. (2000). A positive role for the PP2A catalytic subunit in Wnt signal transduction. *J. Biol. Chem.* 275, 35680-35683.
- 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.
- Rosin-Arbesfeld,R., Townsley,F. & Bienz,M. (2000). The APC tumour suppressor has a nuclear export function. *Nature* 406, 1009-1012.
- 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.

- 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., Albert,I., Porfiri,E., Fiol,C., Munemitsu,S. & Polakis,P. (1996). Binding of GSK3beta to the APC-beta-catenin complex and regulation of complex assembly. *Science* 272, 1023-1026.
- 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., Tice,D.A. & Polakis,P. (2001). Axin dependent phosphorylation of the adenomatous polyposis coli protein mediated by casein kinase 1 epsilon. *J. Biol. Chem.*
- Saitoh,O., Kubo,Y., Miyatani,Y., Asano,T. & Nakata,H. (1997). RGS8 accelerates G-protein-mediated modulation of K⁺ currents. *Nature* 390, 525-529.
- Saitoh,T., Moriwaki,J., Koike,J., Takagi,A., Miwa,T., Shiokawa,K. & Katoh,M. (2001). Molecular cloning and characterization of FRAT2, encoding a positive regulator of the WNT signaling pathway. *Biochem. Biophys. Res. Commun.* 281, 815-820.
- 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.
- Sakanaka,C. & Williams,L.T. (1999). Functional domains of axin. Importance of the C terminus as an oligomerization domain. *J. Biol. Chem.* 274, 14090-14093.
- 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.
- Schwarz-Romond, T., Asbrand, C., Bakkers, J., Kühl, M., Schaeffer, H. J., Huelsken, J., Behrens, J., Hammerschmidt, M., and Birchmeier, W. (2002). The ankyrin repeat protein

- Diversin recruits CKIepsilon to the beta-catenin degradation complex and acts in both canonical Wnt and Wnt/JNK signaling. *Genes Dev.*, im Druck.
- Seeling,J.M., Miller,J.R., Gil,R., Moon,R.T., White,R. & Virshup,D.M. (1999). Regulation of beta-catenin signaling by the B56 subunit of protein phosphatase 2A. *Science* 283, 2089-2091.
- Siegfried,E., Wilder,E.L. & Perrimon,N. (1994). Components of wingless signalling in *Drosophila*. *Nature* 367, 76-80.
- Slusarski,D.C., Corces,V.G. & Moon,R.T. (1997). Interaction of Wnt and a Frizzled homologue triggers G-protein-linked phosphatidylinositol signalling. *Nature* 390, 410-413.
- 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.
- 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.
- Snider,L., Thirlwell,H., Miller,J.R., Moon,R.T., Groudine,M. & Tapscott,S.J. (2001). Inhibition of Tcf3 binding by I-mfa domain proteins. *Mol. Cell Biol.* 21, 1866-1873.
- Sokol,S.Y. (1996). Analysis of Dishevelled signalling pathways during *Xenopus* development. *Curr. Biol.* 6, 1456-1467.
- Strovel,E.T., Wu,D. & Sussman,D.J. (2000). Protein phosphatase 2Calpha dephosphorylates axin and activates LEF-1- dependent transcription. *J. Biol. Chem.* 275, 2399-2403.
- 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.

- Sussman,D.J., Klingensmith,J., Salinas,P., Adams,P.S., Nusse,R. & Perrimon,N. (1994). Isolation and characterization of a mouse homolog of the *Drosophila* segment polarity gene *dishevelled*. *Dev. Biol.* *166*, 73-86.
- Tajbakhsh,S., Borello,U., Vivarelli,E., Kelly,R., Papkoff,J., Duprez,D., Buckingham,M. & Cossu,G. (1998). Differential activation of *Myf5* and *MyoD* by different Wnts in explants of mouse paraxial mesoderm and the later activation of myogenesis in the absence of *Myf5*. *Development* *125*, 4155-4162.
- 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.
- Thebault,S., Gachon,F., Lemasson,I., Devaux,C. & Mesnard,J.M. (2000). Molecular cloning of a novel human I-mfa domain-containing protein that differently regulates human T-cell leukemia virus type I and HIV-1 expression. *J. Biol. Chem.* *275*, 4848-4857.
- Thomas,G.M., Frame,S., Goedert,M., Nathke,I., Polakis,P. & Cohen,P. (1999). A GSK3-binding peptide from FRAT1 selectively inhibits the GSK3-catalysed phosphorylation of axin and beta-catenin. *FEBS Lett.* *458*, 247-251.
- Tsang,M., Lijam,N., Yang,Y., Beier,D.R., Wynshaw-Boris,A. & Sussman,D.J. (1996). Isolation and characterization of mouse *dishevelled-3*. *Dev. Dyn.* *207*, 253-262.
- 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.
- Webster,M.T., Rozycka,M., Sara,E., Davis,E., Smalley,M., Young,N., Dale,T.C. & Wooster,R. (2000). Sequence variants of the axin gene in breast, colon, and other cancers: an analysis of mutations that interfere with GSK3 binding. *Genes Chromosomes. Cancer* *28*, 443-453.

- 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.
- 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.
- Welsh,G.I. & Proud,C.G. (1993). Glycogen synthase kinase-3 is rapidly inactivated in response to insulin and phosphorylates eukaryotic initiation factor eIF-2B. *Biochem. J.* 294 (Pt 3), 625-629.
- 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.
- Winter,C.G., Wang,B., Ballew,A., Royou,A., Karess,R., Axelrod,J.D. & Luo,L. (2001). *Drosophila* Rho-associated kinase (Drok) links Frizzled-mediated planar cell polarity signaling to the actin cytoskeleton. *Cell* 105, 81-91.
- Wodarz,A. & Nusse,R. (1998). Mechanisms of Wnt signaling in development. *Annu. Rev. Cell Dev. Biol.* 14, 59-88.
- Wong,C.M., Fan,S.T. & Ng,I.O. (2001). beta-Catenin mutation and overexpression in hepatocellular carcinoma: clinicopathologic and prognostic significance. *Cancer* 92, 136-145.
- Yamaguchi,T.P. (2001). Heads or tails: Wnts and anterior-posterior patterning. *Curr. Biol.* 11, R713-R724.
- Yamamoto,H., Hinoi,T., Michiue,T., Fukui,A., Usui,H., Janssens,V., Hoof,C.V., Goris,J., Asashima,M. & Kikuchi,A. (2001). Inhibition of the Wnt signaling pathway by the PR61 subunit of protein phosphatase 2A. *J. Biol. Chem.*
- 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.

- Yanagawa, S., Matsuda, Y., Lee, J. S., Matsubayashi, H., Sese, S., Kadowaki, T., and Ishimoto, A. (2002). Casein kinase I phosphorylates the Armadillo protein and induces its degradation in *Drosophila*. *EMBO J.* 21, 1733-1742.
- Yaron, A., Hatzubai, A., Davis, M., Lavon, I., Amit, S., Manning, A.M., Andersen, J.S., Mann, M., Mercurio, F. & Ben Neriah, Y. (1998). Identification of the receptor component of the I κ B-ubiquitin ligase. *Nature* 396, 590-594.
- 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.
- 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.
- Zhang, Y., Neo, S.Y., Wang, X., Han, J. & Lin, S.C. (1999). Axin forms a complex with MEKK1 and activates c-Jun NH(2)-terminal kinase/stress-activated protein kinase through domains distinct from Wnt signaling. *J. Biol. Chem.* 274, 35247-35254.