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### The zebrafish *floating head* mutant demonstrates podocytes play an important role in directing glomerular differentiation

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In zebrafish, the pronephric glomerulus occupies a middle position underneath the notochord and is vascularized through angiogenic capillary ingrowth from the dorsal aorta. The midline mutants *floating head* (*flh*), *sonic you* (*syu*), and *you-too* (*yot*) provide the opportunity to study glomerular differentiation in the absence of the notochord and vascularization from the dorsal aorta. In *flh*, *syn*, and *yot* mutants, glomeruli differentiate at ectopic lateral positions within the embryo and contain morphologically identifiable podocyte and endothelial cell types. In the absence of the dorsal aorta, endothelia from an alternate source are recruited by podocytes during glomerular vascularization to make functional glomeruli. Our results suggest that middle signals are required for proper glomerular morphogenesis but not for the differentiation of podocytes. Podocytes appear to play an important role in directing cellular recruitment events leading to glomerular differentiation. Furthermore, we find defects in sclerotomal development that correlate with defects in glomerular morphogenesis suggesting a possible link between the formation of these embryonic structures.

#### Key Words

zebrafish; *floating head*; pronephos; glomerulus; podocyte; sclerotome



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## References

[Abrahamson, 1991](#) D.R. Abrahamson

**Glomerulogenesis in the developing kidney**

Semin. Nephrol., 11 (1991), pp. 375-389

[Abrahamson et al., 1998](#) D.R. Abrahamson, B. Robert, D.P. Hyink, P.L. St. John, T.O. Daniel

**Origins and formation of microvasculature in the developing kidney**

Kidney Int. Suppl., 67 (1998), pp. S7-S11

[Article](#)   [PDF \(319KB\)](#)

[Armstrong, 1932](#) P.B. Armstrong

**The embryonic origin of function in the pronephros through differentiation and parenchyma-vascular association**

Am. J. Anat., 51 (1932), pp. 157-188

[Borycki et al., 1999](#) A. Borycki, B. Brunk, S. Tajbakhsh, M. Buckingham, C. Chiang, C.P. Emerson

**Sonic hedgehog controls epaxial muscle determination through Myf5 activation**

Development, 126 (1999), pp. 4053-4063

[Breier et al., 1995](#) G. Breier, M. Clauss, W. Risau

**Coordinate expression of vascular endothelial growth factor receptor-1 (flt-1) and its ligand suggests a paracrine regulation of murine vascular development**

Dev. Dyn., 204 (1995), pp. 228-239

[Carmeliet et al., 1996](#) P. Carmeliet, V. Ferreira, G. Breier, S. Pollefeyt, L. Kieckens, M. Gertsenstein, M. Fahrig, A. Vandenhoek, K. Harpal, C.

Eberhardt, C. Declercq, J. Pawling, L. Moons, D. Collen, W. Risau, A. Nagy

**Abnormal blood vessel development and lethality in embryos lacking a single VEGF allele**

Nature, 380 (1996), pp. 435-439

[Chandrasekhar et al., 1998](#) A. Chandrasekhar, J.T. Warren Jr., K. Takahashi, H.E. Schauerte, P.J. van Eeden, P. Haffter, J.Y. Kuwada

**Role of sonic hedgehog in branchiomotor neuron induction in zebrafish**

Mech. Dev., 76 (1998), pp. 101-115

[Article](#)   [PDF \(256KB\)](#)

[Concordet et al., 1996](#) J.P. Concordet, K.E. Lewis, J.W. Moore, L.V. Goodrich, R.L. Johnson, M.P. Scott, P.W. Ingham

**Spatial regulation of a zebrafish patched homologue reflects the roles of sonic hedgehog and protein kinase A in neural tube and somite patterning**

Development, 122 (1996), pp. 2835-2846

Currie and Ingham, 1996 P.D. Currie, P.W. Ingham

**Induction of a specific muscle cell type by a hedgehog-like protein in zebrafish**

Nature, 382 (1996), pp. 452-455

Dodd et al., 1998 J. Dodd, T.M. Jessell, M. Placzek

**The when and where of floor plate induction**

Science, 282 (1998), pp. 1654-1657

Drummond et al., 1998 I.A. Drummond, A. Majumdar, H. Hentschel, M. Elger, L. Solnica-Krezel, A.F. Schier, S.C. Neuhauss, D.L. Stemple, F.

Zwartkruis, Z. Rangini, W. Driever, M.C. Fishman

**Early development of the zebrafish pronephros and analysis of mutations affecting pronephric function**

Development, 125 (1998), pp. 4655-4667

Dumont et al., 1995 D.J. Dumont, G.H. Fong, M.C. Puri, G. Gradwohl, K. Alitalo, M.L. Breitman

**Vascularization of the mouse embryo: A study of *flk-1*, *tek*, *tic*, and vascular endothelial growth factor expression during development**

Dev. Dyn., 203 (1995), pp. 80-92

Esser et al., 1998 S. Esser, K. Wolburg, H. Wolburg, G. Breier, T. Kurzchalia, W. Risau

**Vascular endothelial growth factor induces endothelial fenestrations in vitro**

J. Cell Biol., 140 (1998), pp. 947-959

Fan et al., 1995 C.M. Fan, J.A. Porter, C. Chiang, D.T. Chang, P.A. Beachy, M. Tessier-Lavigne

**Long-range sclerotome induction by sonic hedgehog: Direct role of the amino-terminal cleavage product and modulation by the cyclic AMP signaling pathway**

Cell, 81 (1995), pp. 457-465

[Article](#)  [PDF \(4MB\)](#)

Fan and Tessier-Lavigne, 1994 C.M. Fan, M. Tessier-Lavigne

**Patterning of mammalian somites by surface ectoderm and notochord: Evidence for sclerotome induction by a hedgehog homolog**

Cell, 79 (1994), pp. 1175-1186

[Article](#)  [PDF \(20MB\)](#)

Ferrara, 1999 N. Ferrara

**Role of vascular endothelial growth factor in the regulation of angiogenesis**

Kidney Int., 56 (1999), pp. 794-814

[Article](#)  [PDF \(465KB\)](#)

Ferrara et al., 1996 N. Ferrara, K. Carver-Moore, H. Chen, M. Dowd, L. Lu, K.S. O'Shea, L. Powell-Braxton, K.J. Hillan, M.W. Moore

**Heterozygous embryonic lethality induced by targeted inactivation of the VEGF gene**

Nature, 380 (1996), pp. 439-442

Fouquet et al., 1997 B. Fouquet, B.M. Weinstein, F.C. Serca, M.C. Fishman

**Vessel patterning in the embryo of the zebrafish: Guidance by notochord**

Dev. Biol., 183 (1997), pp. 37-48

[Article](#)  [PDF \(978KB\)](#)

Goodrich, 1930 E.S. Goodrich

Studies on the Structure and Development of Vertebrates, Macmillan, London (1930)

Halpern et al., 1995 M.E. Halpern, C. Thisse, R.K. Ho, B. Thisse, B. Riggleman, B. Trevarrow, E.S. Weinberg, J.H. Postlethwait, C.B. Kimmel

**Cell-autonomous shift from axial to paraxial mesodermal development in zebrafish floating head mutants**

Development, 121 (1995), pp. 4257-4264

Hebrok et al., 1998 M. Hebrok, S.K. Kim, D.A. Melton




**Notochord repression of endodermal Sonic hedgehog permits pancreas development**

Genes Dev., 12 (1998), pp. 1705-1713

Humphrey and Pittman, 1974 C. Humphrey, F. Pittman

**A simple methylene blueazure II-basic fuchsin stain for epoxy-embedded tissue sections**

Stain Technol., 49 (1974), pp. 9-14

- Hyink et al., 1996 D.P. Hyink, D.C. Tucker, P.L. St John, V. Leardkamolkam, M.A. Accavitti, C.K. Abrass, D.R. Abrahamson  
**Endogenous origin of glomerular endothelial and mesangial cells in grafts of embryonic kidneys**  
Am. J. Physiol., 270 (1996), pp. F886-F899
- Karlstrom et al., 1999 R.O. Karlstrom, W.S. Talbot, A.F. Schier  
**Comparative syntenic cloning of zebrafish you-too: Mutations in the Hedgehog target gli2 affect ventral forebrain patterning**  
Genes Dev., 13 (1999), pp. 388-393
- Kim et al., 1997 S.K. Kim, M. Hebrok, D.A. Melton  
**Notochord to endoderm signaling is required for pancreas development**  
Development, 124 (1997), pp. 4243-4252
- Kitamoto et al., 1997 Y. Kitamoto, H. Tokunaga, K. Tomita  
**Vascular endothelial growth factor is an essential molecule for mouse kidney development: Glomerulogenesis and nephrogenesis**  
J. Clin. Invest., 99 (1997), pp. 2351-2357
- Koster et al., 1997 R. Koster, R. Stick, F. Loosli, J. Wittbrodt  
**Medaka spalt acts as a target gene of hedgehog signaling**  
Development, 124 (1997), pp. 3147-3156
- Krauss et al., 1993 S. Krauss, J.P. Concordet, P.W. Ingham  
**A functionally conserved homolog of the Drosophila segment polarity gene hh is expressed in tissues with polarizing activity in zebrafish embryos**  
Cell, 75 (1993), pp. 1431-1444  
Article  PDF (13MB)
- Lewis et al., 1999 K.E. Lewis, J.P. Concordet, P.W. Ingham  
**Characterization of a second patched gene in the zebrafish danio rerio and the differential response of patched genes to hedgehog signaling**  
Dev. Biol., 208 (1999), pp. 14-29  
Article  PDF (935KB)
- Liang et al., 1998 D. Liang, X. Xu, A.J. Chin, N.V. Balasubramanian, M.A. Teo, T.J. Lam, E.S. Weinberg, R. Ge  
**Cloning and characterization of vascular endothelial growth factor (VECF) from zebrafish, Danio rerio**  
Biochim. Biophys. Acta, 1397 (1998), p. 1420
- Liao et al., 1997 W. Liao, B.W. Bisgrove, H. Sawyer, B. Hug, B. Bell, K. Peters, D.J. Grunwald, D.Y. Stainier  
**The zebrafish gene cloche acts upstream of a flk-1 homologue to regulate endothelial cell differentiation**  
Development, 124 (1997), pp. 381-389
- Lindahl et al., 1998 P. Lindahl, M. Hellstrom, M. Kalen, L. Karlsson, M. Pekny, M. Pekna, P. Soriano, C. Bersholtz  
**Paracrine PDGFB/PDGF-Rbeta signaling controls mesangial cell development in kidney glomeruli**  
Development, 125 (1998), pp. 3313-3322
- Lyons et al., 1998 M.S. Lyons, B. Bell, D. Stainier, K.G. Peters  
**Isolation of the zebrafish homologues for the tie-1 and tic-2 endotheliumspecific receptor tyrosine kinases**  
Dev. Dyn., 212 (1998), pp. 133-140
- Majumdar and Drummond, 1999 A. Majumdar, I.A. Drummond  
**Podocyte differentiation in the absence of endothelial cells as revealed in the zebrafish mutant, cloche**  
Dev. Genet., 24 (1999), pp. 220-229
- Melby et al., 1996 A.E. Melby, R.M. Warga, C.B. Kimmel  
**Specification of cell fates at the dorsal margin of the zebrafish gastrula**  
Development, 122 (1996), pp. 2225-2237
- Millauer et al., 1993 B. Millauer, S. Witzmann-Voos, H. Schnurch, R. Martinez, N.P. Moller, W. Risau, A. Ullrich  
**High affinity VECF binding and developmental expression suggest Flk-1 as a major regulator of vasculogenesis and angiogenesis**  
Cell, 72 (1993), pp. 835-846  
Article  PDF (2MB)
- Moja-Kociński and Eisen, 1997 E.M. Moja-Kociński, J.S. Eisen

**Sclerotome development and peripheral nervous system segmentation in embryonic zebrafish**

Development, 124 (1997), pp. 159-167

Neufeld et al., 1999 G. Neufeld, T. Cohen, S. Gengrinovitch, Z. Poltorak

**Vascular endothelial growth factor (VEGF) and its receptors**

FASEB J., 13 (1999), pp. 9-22

Normes et al., 1996 S. Normes, I. Mikkola, S. Krauss, M. Delghandi, M. Perander, T. Johansen

**Zebrafish Pax9 encodes two proteins with distinct C-terminal transactivating domains of different potency negatively regulated by adjacent N-terminal sequences**

J. Biol. Chem., 271 (26) (1996), pp. 914-926

J. Biol. Chem., 271 (26) (1996), p. 923

Oxtoby and Jewett, 1993 E. Oxtoby, T. Jewett

**Cloning of the zebrafish krox-20 gene (krx-20) and its expression during hindbrain development**

Nucleic Acids Res., 21 (1993), pp. 1087-1095

Palade et al., 1979 G.E. Palade, M. Simionescu, N. Simionescu

**Structural aspects of the permeability of the microvascular endothelium**

Acta Physiol. Scand. Suppl., 463 (1979), pp. 11-32

Palade et al., 1979 G.E. Palade, M. Simionescu, N. Simionescu

**Structural aspects of the permeability of the microvascular endothelium**

Acta Physiol., Scand. Suppl., 463 (1979), pp. 11-32

Placzek, 1995 M. Placzek

**The role of the notochord and floor plate in inductive, interactions**

Curr. Opin. Genet. Dev., 5 (1995), pp. 499-506

[Article](#)  [PDF \(801KB\)](#)

Risau, 1998 W. Risau

**Development and differentiation of endothelium**

Kidney Int. Suppl., 67 (1998), pp. S3-S6

[Article](#)  [PDF \(142KB\)](#)

Robert et al., 1996 B. Robert, P.L. St. John, D.P. Hyink, D.R. Abrahamson

**Evidence that embryonic kidney cells expressing flk-1 are intrinsic, vasculogenic angioblasts**

Am. J. Physiol., 271 (1996), pp. F744-F753

Roberts and Palade, 1995 W.G. Roberts, G.E. Palade

**Increased microvascular permeability and endothelial fenestration induced by vascular endothelial growth factor**

J. Cell Sci., 108 (1995), pp. 2369-2379

Sariola et al., 1983 H. Sariola, P. Ekblom, E. Lehtonen, L. Saxen

**Differentiation and vascularization of the metanephric kidney grafted on the chorioallantoic membrane**

Dev. Biol., 96 (1983), pp. 427-435

[Article](#)  [PDF \(15MB\)](#)

Sariola et al., 1984 H. Sariola, R. Timpl, K. von der Mark, R. Mayne, J.M. Fitch, T.F. Linsenmayer, P. Ekblom

**Dual origin of glomerular basement membrane**

Dev. Biol., 101 (1984), pp. 86-96

[Article](#)  [PDF \(17MB\)](#)

Schauerte et al., 1998 H.E. Schauerte, F.J. van Eeden, C. Fricke, J. Odenthal, U. Strahle, P. Haffter

**Sonic hedgehog is not required for the induction of medial floor plate cells in the zebrafish**

Development, 125 (1998), pp. 2983-2993

Shalaby et al., 1997 F. Shalaby, J. Ho, W.L. Stanford, K.D. Fischer, A.C. Schuh, L. Schwartz, A. Bernstein, J. Rossant

**A requirement for Hkl in primitive and definitive hematopoiesis and vasculogenesis**

Cell, 89 (1997), pp. 981-990

[Article](#)  [PDF \(418KB\)](#)

Shalaby et al., 1995 R. Shalaby, J. Rossant, T.P. Yamauchi, M. Gertsenstein, X.F. Wit, M.L. Breitman, A.C. Schuh

**Failure of blood-island formation and vasculogenesis in Flk-1-deficient ice**

Nature, 376 (1995), pp. 62-66

Simon et al., 1995 M. Simon, H.J. Grone, O. Johren, L. Kullmer, K.H. Plate, W. Risau, E. Fuchs

**Expression of vascular endothelial growth factor and its receptors in human renal ontogenesis and in adult kidney**

Am. J. Physiol., 268 (1995), pp. F240-F250

Sumoy et al., 1997 L. Sumoy, J.B. Kency, T.D. Dittman, D. Kimelman

**A role for notochord in axial vascular development revealed by analysis of phenotype and the expression of VEGF-2 in zebrafish flh and ntl mutant embryos**

Mech. Dev., 63 (1997), pp. 15-27

Article  PDF (557KB)

Takahashi et al., 1998 T. Takahashi, U. Hunyih-Do, T.O. Daniel

**Renal microvascular assembly and repair: Power and promise of microvascular definition**

Kidney Int., 53 (1998), pp. 826-835

Article  PDF (395KB)

Talbot et al., 1995 W.S. Talbot, B. Trevarrow, M.E. Halpern, A.E. Melby, G. Farr, J.H. Postlethwait, T. Jewett, C.B. Kimmel, D. Kimelman

**A homeobox gene essential for zebrafish notochord development**

Nature, 378 (1995), pp. 150-157

van Eeden et al., 1996 F.J. van Eeden, M. Granato, U. Schach, M. Brand, M. Furutani-Seiki, R. Haffter, M. Hammerschmidt, C.P. Heisenberg, Y.J.

Jung, D.A. Katie, R.N. Kelsh, M.C. Mullins, J. Odenthal, R.M. Warga, M.L. Allende, E.S. Weinberg, C. Nusslein-Volhard

**Mutations affecting somite formation and patterning in the zebrafish, *Danio rerio***

Development, 123 (1996), pp. 153-164

Vize et al., 1997 P.D. Vize, D.W. Seufert, T.J. Carroll, J.B. Wallingford

**Model systems for the study of kidney development: Use of the pronephros in the analysis of organ induction and patterning**

Dev. Biol., 188 (1997), pp. 189-204

Article  PDF (4MB)

Westerfield, 1993 M. Westerfield

The Zebrafish Book: A Guide for the Laboratory Use of Zebrafish (*Brachydanio Rerio*), Westerfield, Eugene OR (1993)

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