

**Name:** Carl-Henrik Heldin

**Present appointment:** Director, Ludwig Institute for Cancer Research in Uppsala and Professor in Molecular Cell Biology at Uppsala University Biomedical Center, Box 595  
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**Home address:** Rättarvägen 12  
S-756 45 Uppsala, Sweden  
Phone: +46-18-300844

**Date and place of birth:** August 9, 1952, Växjö, Sweden

**Nationality:** Swedish

**Marital status:** Married, two children, born 1982 and 1988

### University education

1971-1975 First four years of Medical School completed (University of Uppsala).  
1972-1981 Bachelor of Science (Mathematics 1 1/2 year, Numeric analysis 1/2 year, Psychology 1/2 year, Greek 1/2 year) completed July 28, 1981 (Univ. of Uppsala).  
1975-1980 Thesis work at Dept. of Medical and Physiological Chemistry (Univ. of Uppsala). Dissertation May 10, 1980. "Studies on growth factors for human cultured cells".

### Academic positions

1972-1974 Part time teaching positions at Depts. of Anatomy, Medical and Physiological Chemistry, and Physiology (in total 200 hours).  
750701-800331 Graduate student scholarship at Dept of Medical and Physiological Chemistry combined with a part time teaching position (in total 1100 hours).  
800401-801031 Research Assistant at Dept of Medical and Physiological Chemistry.  
810101-810331 Lecturer at Dept of Medical and Physiological Chemistry.  
810701-831231 Cancer Research Scholarship from the Swedish Cancer Society.  
840101-851231 Senior Scientist of the Swedish Cancer Society.  
860101-- Director, Ludwig Institute for Cancer Research (Uppsala Branch).  
920801-- Professor in Molecular Cell Biology at the Medical Faculty of Uppsala Univ.

### Positions as physician

750623-750816 Geriatric Clinic at Härnösand's Hospital.  
790625-790801 Clinical Chemistry at Sundsvall's Hospital.

## **Academic honors**

### **Elected member of learned societies**

- 1989 European Molecular Biology Organization.
- 1991 Royal Swedish Academy of Sciences, Med. Class.
- 1995 Royal Scientific Society (Uppsala).
- 1999 Academia Europea.
- 2002 Japanese Association for Cancer Research.
- 2006 Finnish Scientific Society.
- 2006 Scan Balt Academy.
- 2007 Hellenic Biochemical Society
- 2009 Norwegian Academy of Sciences and Letters
- 2009 European Academy of Cancer Sciences

### **Doctor honoris causa**

- 2009 University of Patras, Greece.
- 2010 University of Helsinki, Finland.
- 2011 University of Turku, Finland.
- 2011 University of Heidelberg, Germany.

### **Awards**

- 1984 The The Svedberg Prize, the Swedish Biochemical Society.
- 1984 King Oscar II:s Prize, Univ. of Uppsala (shared with K. Söderhäll).
- 1984 The Alvarenga Prize, Swedish Medical Society (shared with B. Westermark).
- 1984 The Thureus Prize, Royal Society of Sciences (Uppsala).
- 1986 Anders Jahre's Medical Prize for Younger Scientists, Univ. of Oslo (with B. Gustafsson).
- 1989 Prix Antoine Lacassagne, French Nat. Org. against Cancer (shared with D. Gospodarowicz).
- 1989 K. Fernström's Medical Prize for Young Swedish Scientists, Med. Faculty of Uppsala Univ.
- 1990 The Jubilee Prize, Swedish Medical Society (shared with B. Westermark).
- 1992 The EMBO Medal, EMBO Council.
- 1993 K. Fernström's Large Medical Prize for Nordic Scientists, Lund Univ. (with B. Westermark).
- 1999 Meyenburg Prize, German Cancer Center, Heidelberg.
- 2002 Pezcoller-AACR Award, Pezcoller Foundation and American Ass. for Cancer Research.
- 2003 Rudbeck Award, Medical Society in Uppsala.
- 2006 K.-J. Öbrink Lecture, Uppsala Univ.
- 2011 The Rudbeck Medal, Uppsala Univ.
- 2011 The Berzelius Medal, Swedish Medical Society.
- 2012 Honorary Medal of the Signal Transduction Society.

### **Other academic honors**

- 1981 Appointed docent in Medical and Physiological Chemistry at Uppsala Univ.
- 1986 Appointed adjunct professor in Medical and Physiol. Chemistry at Uppsala Univ.
- 2010 Honorary member, Norrland's student association.

## **Thesis adviser**

Thesis adviser for 14 graduate students:

Bo Ek (dissertation 1985), Ann Johnsson (1986), Lars Rönstrand (1989), Annet Hammacher (1989), Arne Östman (1990), Kensuke Usuki (1992), Maria Andersson (1994), Flemming Vassbotn (1994), Anders Olofsson (1995), Peter Blume-Jensen (1995), Klaus Hansen (1996), Jan Saras (1997), Roya Hooshmand-Rad (1999), Anders Kallin (2003).

Assistant thesis adviser for 31 graduate students:

Christer Betsholtz (1986), Monica Nistér (1987), Karin Mellström (1988), Ylva Paulsson (1988), Anders Tingström (1991), Anders Eriksson (1992), Anja Smits (1992), Monica Hermanson (1993), Petra Franzén (1995), Koutaro Yokote (1996), Sigrídur Valgeirsdóttir (1998), Simon Ekman (2000), Greger Brodin (2002), Kristian Pietras (2002), Tobias Sjöblom (2002), Camilla Persson (2003), Sofia Edlund (2003), Fumiko Itoh (2003), Gudrun Valdimarsdóttir (2004), Katarzyna Kowanetz (2004), Marcin Kowanetz (2005), Katerina Pardali (2005), Rosita Bergström (2008), Susann Karlsson (2009), Agnieszka Kłosowska-Wardęga (2010), Piotr Wardęga (2010), Peter Lönn (2010), Michael Vanlandewyck (2011), Maria Ekman (2011), Markus Dahl (2012), Erna Raja (2012).

### **Thesis examiner (faculty opponent)**

Ylva Engström, Karolinska Institute, Stockholm, December 17, 1985.  
Eva Dafgård, Karolinska Institute, Stockholm, February 1, 1991.  
Kristian Helin, University of Copenhagen, June 25, 1991.  
Eva Jacobson, University of Stockholm, May 9, 1994.  
Pia Ljungquist-Höddelius, University of Linköping, Sept. 30, 1994.  
Tim Wood, Karolinska Institute, Stockholm, December 19, 1996.  
Martin Ridderstråle, University of Lund, February 28, 1997.  
Mikael Rydén, Karolinska Institute, Stockholm, April 25, 1997.  
Lone Rønnov-Jessen, University of Copenhagen, May 16, 1997.  
Panu Jaakkola, University of Turku, May 20, 1998.  
Stephen Miller, University of Uppsala, October 2, 1998.  
Michael Jeltsch, University of Helsinki, November 29, 2002.  
Alexandra Mandic, Karolinska Institute, Stockholm, February 28, 2003.  
Sailaja Paruchuri, University of Lund, June 4, 2004.  
Johanna Lahdenranta, University of Helsinki, June 23, 2004.  
Lotta Gustafsson, University of Lund, May 20, 2005.  
Anders Bratt, Karolinska Institute, Stockholm, September 16, 2005.  
Anna-Lotta Hallbeck, University of Linköping, November 23, 2007.  
Daniel Wetterskog, University of Gothenburg, October 17, 2008.  
Magdalena Laska, University of Århus, March 6, 2009.  
Sofia Halin, University of Umeå, January 22, 2010.  
Federica Toffalini, University of Brussels, March 1, 2010.  
Kanutte Huse, University of Oslo, June 29, 2011.  
Toril Holien, University of Trondheim, February 16, 2012.

### **Referee for professorships**

Professor in Medical Biochemistry, Oulu University, Finland, 1989.  
Professor in Cell Biology, Linköping University, Sweden, 1992.  
Professor in Cell Biology/Physiology, Linköping University, Sweden, 1992.  
Professor in Molecular Cell Biology, Helsinki University, Finland, 1993.  
Professor in Molecular Cell Biology, Lund University, Sweden, 1995.  
Professor in Cell Biology, Oulu University, Finland, 1999.  
Professor in Tissue Biology, Karolinska Institute, Stockholm, Sweden, 1999.  
Professor of the Academy of Finland, 2000.  
Lecturer/Professor in Molecular Developmental Biology, Karolinska Inst., 2000.  
Professor in Medical Technology and Biotechnology, Tampere, 2002.  
Professor in Molecular Cell Biology, Copenhagen University, 2002.  
Professor in Vascular Biology, Karolinska Institute, 2004.  
Professor in Cancer Genetics, Tampere University, 2004.  
Professor in Functional Genomics in Biomedicine, Copenhagen University, 2005.  
Professor in Medical Technology and Biotechnology, Tampere University, 2006.

Professor in Medical Biochemistry, Oslo University, 2008.  
Professor in Genetics, Helsinki University, 2009.

### **Scientific conferences**

Participated in 257 conferences outside Sweden between 1977 and 2011 (in 246 as an invited lecturer).

Co-organized 28 international meetings or courses between 1987 and 2009.

Elected chairman for the Gordon Conference on Peptide Growth Factors 2000 (vice chair 1998).

### **Scientific advisory committees for academic institutes**

- 1988-1995 Heinrich-Pette-Institut für Virologie, Hamburg (member).
- 1989-1991 European Science Foundation Network on Developmental Biology (member).
- 1989-1991 European Organization for Research and Treatment of Cancer (member).
- 1990-1995 Danish Biotechnology Program (member).
- 1994-1996 Medical Bioscience, Foundation for Strategic Research, Sweden (member).
- 1996-2010 Division of Cancer Biology, Danish Cancer Society, Copenhagen (chair).
- 1998-2000 LICR/Oxford GlycoSciences collaboration (member).
- 1998-2004 EMBL, Heidelberg (member; 2001-2004 chair).
- 1998- European Institute for Oncology, Milan (member).
- 1998-2010 Max-Planck Institut für Biochemie, Martinsried (member).
- 2000-2005 Progr. in Cancer Biol. Growth Control and Angiogenesis, Helsinki Univ. (member).
- 2000-2006 Karolinska Institute – BMS effort in oncogenomics (member).
- 2001-2004 Swegene effort in Functional Genomics (chair).
- 2001- Institute of Medical Technology, Tampere (chair).
- 2002-2010 German Cancer Center, Heidelberg (member; 2006-2010 chair).
- 2003-2009 Bio-City, Turku (chair).
- 2004-2010 Bio-X, Uppsala (member).
- 2004 Institute of Molecular Biology, University of Copenhagen (member).
- 2004-2005 Research and Training in Parasitic Diseases at the S. Cone of Latin Am. (member).
- 2004-2007 International Affairs Committee, American Association for Cancer Res. (member).
- 2005- Biotechnology Center, Oslo (member).
- 2005-2008 Membership Committee, EMBO (member; 2008 chair).
- 2005- Structural Genomics Consortium, Oxford, Toronto and Stockholm (member).
- 2005-2006 Ensemble, EBI, Hinxton (member).
- 2006 FUGE effort in Functional Genomics, Norwegian Research Council (member).
- 2007- Cluster of Excellence, Frankfurt (member).
- 2007- FIMM, Helsinki (member).
- 2008- Center for Molecular Medicine, Vienna (member).
- 2009- Biocenter Finland (chair).
- 2009- VIB11, Leuven (member).
- 2010- External Expert Group, FET Flagships Science Forum (member).
- 2010- Interdisciplinary Cancer Center, Turino (member).

### **Scientific advisory committees for companies**

- 1998-2001 Nycomed-Amersham, Amersham (member).
- 2000-2007 Innoventus AB, Uppsala (member).
- 2001-2005 Actar AB, Stockholm (member).
- 2007- Mol Med, Milan (member).

- 2009- Kolltan, New Haven (member).  
 2009- ModPro, Uppsala (member).

### **Grant review committees**

- 1989-2001 Priority Committee A, Swedish Cancer Society (member; 1997-2001 chair).  
 1993-1994 Priority Committee Chemistry I, Swedish Medical Research Council (member).  
 1999-2004 Review Committee, Program on Angiogenesis, Deutsche Forschungsgem. (member).  
 1998 Grant Review Committee, Italian Association of Cancer Research (external member).  
 2000 Grant Review Committee, Norwegian Research Council (chair).  
 2001 Evaluation of applications for Centers of Excellence, Academy of Finland (chair).  
 2001-2002 Evaluation of appl. for Centers of Excellence, Norwegian Res. Council (member).  
 2002 Grant Review Committee, Fortis Insurance Cancer Foundation, Belgium (member).  
 2003 Grant Review Committee, FUGENE Program, Norwegian Res. Council (member).  
 2003 Grant Review Committee, Biocentrum Helsinki (member).  
 2003-2004 Selection of Future Research Leaders, Foundation for Strategic Res. (member).  
 2003 Biocenter funding, Helsinki University (member).  
 2004 Grant Review Committee, Norwegian Research Council (chair).  
 2004 Evaluation of appl. for Centers in Oncogenomics, Italian Ass. for Cancer Res. (member).  
 2004 Program for Outstanding Young Investigators, Norwegian Res. Council (chair).  
 2004-2005 Evaluation of appl. for Centers of Excellence, Foundation for Strategic Res. (member).  
 2005 Grant Review Committee, ALF funding, Karolinska Institute (member).  
 2006 Evaluation of appl. for Centers of Excellence, Norwegian Res. Council (chair).  
 2008 Grant Review Committee, molecular biology, Norwegian Res. Council (chair).  
 2009 Grant Review Committee, cancer, Norwegian Res. Council (chair).  
 2009 Grant Review Committee, molecular biology, Norwegian Res. Council (chair).  
 2009 BioCenter Finland, Infrastructure funds (chair).  
 2011 BioCenter Finland, Infrastructure funds (chair).  
 2012 Grant Review Committee, Outstanding Young Scientists in Medicine, Ragnar Söderberg's Foundation (chair).  
 2012 Grant Review Committee, Portuguese Government (chair).  
 2012 Grant Review Committee, WELBIO, Belgium (member).

### **Scientific review committee visits**

- 1991 Differentiation Programme, EMBL, Heidelberg (member).  
 1993 CRC Growth Factor Research Group, Oxford (member).  
 1994 ICRF Laboratories, Inst. of Mol. Med. and Clinical Oncology Unit, Oxford (member).  
 1995 Differentiation Programme, EMBL, Heidelberg (member).  
 1996 Biocenter, Oulu (member).  
 1997 CRC Growth Factor Research Group, Birmingham (member).  
 1998 Max-Delbrück-Center, Berlin (member).  
 1999 Developmental Biology Programme, EMBL, Heidelberg (member).  
 1999 ICRF Laboratories, Inst. of Mol. Med. and Clinical Oncology Unit, Oxford (member).  
 1999 Evaluation of Biology at Helsinki University (member).  
 1999 Max Planck Institute for Biochemistry, Martinsried (member).  
 2000 Evaluation of Biomedical Research in Norway (member).  
 2001 Cell Biology and Biophysics Programme, EMBL, Heidelberg (chair).  
 2002 CRC Growth Factor Research Group, Birmingham (member).  
 2002 Grad. Progr. on Signal Transd. and Cell Regul., Austrian Res. Council (member).  
 2002 Cancer Research UK unit at Lincoln's Inns Field, London (member).

2002 Max Planck Institute for Biochemistry, Martinsried (member).  
 2003 Developmental Biology Programme, EMBL, Heidelberg (chair).  
 2003 Inst. for Biochem. and Biophys. and Nenski Inst., Polish Acad. Sci., Warsaw (member).  
 2003 Structural and Functional Genomics Program, DKFZ, Heidelberg (member).  
 2004 Cancer Research UK unit at Hammersmith Hospital, London (member).  
 2005 Biotechnology Center, Oslo (member).  
 2005 Max Planck Institute for Biochemistry, Martinsried (member).  
 2005 Center of Biotechnology, Madrid (member).  
 2005 Cell and Tumor Biology Program, DKFZ, Heidelberg (member).  
 2006 Biotechnology Center, Oslo (member).  
 2006 Swegene, Gothenburg and Lund (chair).  
 2006 IMT, Tampere (chair).  
 2007 Biotechnology Center, Oslo (member).  
 2007 Max Planck Institute for Biochemistry, Martinsried (member).  
 2008 Biotechnology Center, Oslo (member).  
 2008 Structural and Functional Genomics Program, DKFZ, Heidelberg (member).  
 2008 Center for Molecular Medicine, Vienna (member).  
 2008 EPFL, Lausanne (chair).  
 2009 SCIBLU Center, Lund (chair).  
 2009 ICRSET, Dublin (member).  
 2009 Biotechnology Center, Oslo (member).  
 2009 VIB11, Leuven (member).  
 2009 Center for Molecular Medicine, Vienna (member).  
 2010 Center of Excellence in Integrative Life Science, Tokyo University (chair).  
 2011 IMT, Tampere (chair).  
 2011 Biotechnology Center, Oslo (member).  
 2011 FIMM, Helsinki (member).  
 2011 Center for Molecular Medicine, Vienna (member).  
 2011 Department of Biomedicine, University of Bergen (member).  
 2012 Leiden University Medical School (member).  
 2012 University of Debrecen (member).  
 2012 Center for Molecular Medicine, Vienna (member).

### Scientific award committees

1988-1990 Sloan Prize Selection Committee, General Motors Cancer Res. Awards (member).  
 1992-1995 Prix Antoine Lacassagne Selection Committee, French Nat. Org. Cancer (member).  
 1997-1998 Pezcoller-AACR Cancer Research Award Committee (member).  
 1999- Crafoord Prize in Polyarthritis Selection Committee (member; since 2011 chair).  
 2000 Interbrew-Baillet Latour Health Prize Committee (member).  
 2000 Van Gysel Prize for Biomedical Research Committee (member).  
 2003-2005 Pezcoller-AACR Cancer Research Award Committee (member; 2004-2005 chair).  
 2005-2006 Landon-AACR Prize for Basic Cancer Research Selection Committee (member).

### Boards

1978-1980 Board of the Faculty of Medicine, Uppsala University (member).  
 1993-1999 Board of the Faculty of Medicine, Uppsala Univ. and subcommittees (member).  
 2001-2006 Board of the Swedish Research Council (member).  
 2004-2005 Board of the WCN consortium in Functional Genomics (member).  
 2005- Scientific Council, ERC (coordinator for Life Sciences; since 2011 Vice President).  
 2006-2010 Board of Trustees, German Cancer Center, Heidelberg (member).  
 2008-2010 EMBO Council (member; 2010 chair).  
 2009- EMBL node Molecular Infection Medicine Sweden, Umeå (chair).

### **Other committees**

- 2004 Search Committee for Director General at EMBL (member).
- 2007-2008 Search Committee for EMBO Director (member).
- 2012 Search Committee for Head of Swedish Cancer Society (member).

### **Senior editor**

- 2003-2009 Cancer Research.

### **Associate editor**

- 1988- Growth Factors.
- 1989- Molecular Biology of the Cell.
- 1993-2000 Cancer Research.
- 1995- Genes to Cells.

### **Editorial boards**

- 1987-1992 European Journal of Biochemistry.
- 1988- In Vitro Cellular and Developmental Biology.
- 1988-1995 Progress in Growth Factor Research.
- 1989-1992 Biochemistry.
- 1989-1998 Journal of Vascular Medicine and Biology.
- 1989- International Journal of Cancer.
- 1989-1996 Oncogenes and Growth Factors Abstracts.
- 1990-1992 EMBO Journal.
- 1990-2000 European Journal of Cancer.
- 1990- Trends in Biological Sciences.
- 1991- Journal of Vascular Research.
- 1996-2001 Pathobiology.
- 1996- Journal of Cellular Physiology.
- 1996- Cytokine and Growth Factor Reviews.
- 1996- Journal of Cell Science.
- 1999-2004 EMBO Journal.
- 1999-2006 Matrix Biology.
- 1999-2002 IUBMB Life.
- 2000-2004 EMBO Reports.
- 2001- Signal Transduction - Receptors, Mediators and Genes.
- 2004- International Journal of Cancer Prevention.
- 2004- Cancer Science.
- 2005- Current Cancer Therapy Reviews.
- 2006- Molecular Oncology.
- 2007- Cancer Genomics and Proteomics.
- 2007- Journal of Molecular Signaling
- 2007- The Open Cell and Developmental Biology Journal
- 2007- The Open Cancer Journal
- 2008- EMBO Molecular Medicine
- 2008- Chinese Journal of Cancer
- 2010- DNA and Cell Biology
- 2010- Cancers

## **Publications**

391 research papers published in peer-reviewed journals, and 193 review articles.  
26 patents approved. Cited >54,000 times, H-index 126.



**RESEARCH ARTICLES**

2012-11-14

1. Heldin, C.-H., Wasteson, Å., and Westermark, B. (1977). Partial purification and characterization of platelet factors stimulating the multiplication of normal human glial cells. *Exp. Cell Res.* 109, 429-437.
2. Wasteson, Å., Glimelius, B., Busch, C., Westermark, B., Heldin, C.-H., and Norling, B. (1977). Effect of a platelet endoglycosidase on cell surface associated heparan sulphate of human cultured endothelial and glial cells. *Thrombosis Res.* 11, 309-321.
3. Heldin, C.-H., Westermark, B., and Wasteson, Å. (1979). Platelet-derived growth factor: Purification and partial characterization. *Proc. Natl. Acad. Sci. USA* 76, 3722-3726.
4. Heldin, C.-H., Westermark, B., and Wasteson, Å. (1979). Desensitisation of cultured glial cells to epidermal growth factor by receptor down-regulation. *Nature* 282, 419-420.
5. Heldin, C.-H., Westermark, B., and Wasteson, Å. (1980). Chemical and biological properties of a growth factor from human-cultured osteosarcoma cells: Resemblance with platelet-derived growth factor. *J. Cell. Physiol.* 105, 235-246.
6. Oldberg, Å., Heldin, C.-H., Wasteson, Å., Busch, C., and Höök, M. (1980). Characterization of a platelet endoglycosidase degrading heparin-like polysaccharides. *Biochemistry* 19, 5755-5762.
7. Heldin, C.-H., Wasteson, Å., and Westermark, B. (1980). Growth of normal human glial cells in a defined medium containing platelet-derived growth factor. *Proc. Natl. Acad. Sci. USA* 77, 6611-6615.
8. Heldin, C.-H., Westermark, B., and Wasteson, Å. (1981). Platelet-derived growth factor: Isolation by a large-scale procedure and analysis of subunit composition. *Biochem. J.* 193, 907-913.
9. Heldin, C.-H., Wasteson, Å., Fryklund, L., and Westermark, B. (1981). Somatomedin B: Mitogenic activity derived from contaminant epidermal growth factor. *Science* 213, 1122-1123.
10. Heldin, C.-H., Westermark, B., and Wasteson, Å. (1981). Demonstration of an antibody against platelet-derived growth factor. *Exp. Cell Res.* 136, 255-261.
11. Heldin, C.-H., Westermark, B., and Wasteson, Å. (1981). Specific receptors for platelet-derived growth factor on cells derived from connective tissue and glia. *Proc. Natl. Acad. Sci. USA* 78, 3664-3668.
12. Ek, B., Westermark, B., Wasteson, Å., and Heldin, C.-H. (1982). Stimulation of tyrosine-specific phosphorylation by platelet-derived growth factor. *Nature* 295, 419-420.
13. Heldin, C.-H., Wasteson, Å., and Westermark, B. (1982). Interaction of platelet-derived growth factor with its fibroblast receptor. Demonstration of ligand degradation and receptor modulation. *J. Biol. Chem.* 257, 4216-4221.

14. Johnsson, A., Heldin, C.-H., Westermark, B., and Wasteson, Å. (1982). Platelet-derived growth factor: Identification of constituent polypeptide chains. *Biochem. Biophys. Res. Commun.* 104, 66-74.
15. Ek, B., and Heldin, C.-H. (1982). Characterization of a tyrosine-specific kinase activity in human fibroblast membranes stimulated by platelet-derived growth factor. *J. Biol. Chem.* 257, 10486-10492.
16. Edlund, B., Heldin, C.-H., and Engström, L. (1982). Effect of chemical modification of a histidine and a lysine residue of pea seed nucleoside diphosphate kinase. *J. Med. Sci.* 87, 243-250.
17. Westermark, B., Magnusson, A., and Heldin, C.-H. (1982). Effect of epidermal growth factor on membrane motility and cell locomotion in cultures of human clonal glioma cells. *J. Neuroscience Res.* 8, 491-507.
18. King, G.L., Kahn, C.R., and Heldin, C.-H. (1983). Sharing of biological effect and receptors between guinea pig insulin and platelet-derived growth factor. *Proc. Natl. Acad. Sci. USA* 80, 1308-1312.
19. Nilsson, J., Ksiazek, T., Heldin, C.-H., and Thyberg, J. (1983). Demonstration of stimulatory effects of platelet-derived growth factor on cultivated rat arterial smooth muscle cells: Differences between cells from young and adult animals. *Exp. Cell Res.* 145, 231-237.
20. Mellström, K., Höglund, A.-S., Nistér, M., Heldin, C.-H., Westermark, B., and Lindberg, U. (1983). The effect of platelet-derived growth factor on morphology and motility of human glial cells. *J. Musc. Res. Cell Motility* 4, 589-609.
21. Heldin, C.-H., Ek, B., and Rönstrand, L. (1983). Characterization of the receptor for platelet-derived growth factor on human fibroblasts. Demonstration of an intimate relationship with a 185,000-dalton substrate for the platelet-derived growth factor-stimulated kinase. *J. Biol. Chem.* 258, 10054-10061.
22. Nilsson, J., Thyberg, J., Heldin, C.-H., Westermark, B., and Wasteson, Å. (1983). Surface binding and internalization of platelet-derived growth factor in human fibroblasts. *Proc. Natl. Acad. Sci. USA* 80, 5592-5596.
23. Waterfield, M.D., Scrace, G.T., Whittle, N., Stroobant, P., Johnsson, A., Wasteson, Å., Westermark, B., Heldin, C.-H., Huang, J.S., and Deuel, T.F. (1983). Platelet-derived growth factor is structurally related to the putative transforming protein p28<sup>sis</sup> of simian sarcoma virus. *Nature (London)* 304, 35-39.
24. Betsholtz, C., Heldin, C.-H., Nistér, M., Ek, B., Wasteson, Å., and Westermark, B. (1983). Synthesis of a PDGF-like growth factor in human glioma and sarcoma cells suggests the expression of the cellular homologue to the transforming protein of simian sarcoma virus. *Biochem. Biophys. Res. Commun.* 117, 176-182.
25. Nistér, M., Heldin, C.-H., Wasteson, Å., and Westermark, B. (1984). A glioma-derived analog to platelet-derived growth factor: Demonstration of receptor competing activity and immunological crossreactivity. *Proc. Natl. Acad. Sci. USA* 81, 926-930.
26. Ek, B., and Heldin, C.-H. (1984). Use of an antiserum against phosphotyrosine for the identification of phosphorylated components in human fibroblasts stimulated by platelet-derived growth factor. *J. Biol. Chem.* 259, 11145-11152.

27. Johnsson, A., Heldin, C.-H., Wasteson, Å., Westermark, B., Deuel, T.F., Huang, J.S., Seeburg, P.H., Gray, A., Ullrich, A., Scrace, G., Stroobant, P., and Waterfield, M.D. (1984). The *c-sis* gene encodes a precursor of the B chain of platelet-derived growth factor. *EMBO J.* 3, 921-928.
28. Betsholtz, C., Westermark, B., Ek, B., and Heldin, C.-H. (1984). Coexpression of a PDGF-like growth factor and PDGF receptors in a human osteosarcoma cell line: Implications for autocrine receptor activation. *Cell* 39, 447-457.
29. Johnsson, A., Betsholtz, C., von der Helm, K., Heldin, C.-H., and Westermark, B. (1985). Platelet-derived growth factor agonist activity of a secreted form of the *v-sis* oncogene product. *Proc. Natl. Acad. Sci. USA* 82, 1721-1725.
30. Westermark, B., and Heldin, C.-H. (1985). Similar action of platelet-derived growth factor and epidermal growth factor in the prereplicative phase of human fibroblasts suggests a common intracellular pathway. *J. Cell. Physiol.* 124, 43-48.
31. Goustin, A.S., Betsholtz, C., Pfeifer-Ohlsson, S., Persson, H., Rydnert, J., Bywater, M., Holmgren, G., Heldin, C.-H., Westermark, B., and Ohlsson, R. (1985). Coexpression of the *sis* and *myc* proto-oncogenes in developing human placenta suggests autocrine control of trophoblast growth. *Cell* 41, 301-312.
32. Betsholtz, C., Bywater, M., Westermark, B., Burk, R.R., and Heldin, C.-H. (1985). Expression of the *c-sis* gene and secretion of a platelet-derived growth factor-like protein by simian virus 40-transformed BHK cells. *Biochem. Biophys. Res. Commun.* 130, 753-760.
33. Nilsson, J., Sjölund, M., Palmberg, L., Thyberg, J., and Heldin, C.-H. (1985). Arterial smooth muscle cells in primary culture produce a platelet-derived growth factor-like protein. *Proc. Natl. Acad. Sci. USA* 82, 4418-4422.
34. Bauer, G., Birnbaum, U., Höfler, P., and Heldin, C.-H. (1985). EBV-inducing factor from platelets exhibits growth-promoting activity for NIH 3T3 cells. *EMBO J.* 4, 1957-1961.
35. van Zoelen, E.J.J., van de Ven, W.J.M., Franssen, H.J., van Oostwaard, T.M.J., van der Saag, P.T., Heldin, C.-H., and de Laat, S.W. (1985). Neuroblastoma cells express *c-sis* and produce a transforming growth factor antigenically related to the platelet-derived growth factor. *Mol. Cell. Biol.* 5, 2289-2297.
36. Johnsson, A., Betsholtz, C., Heldin, C.-H., and Westermark, B. (1985). Antibodies against platelet-derived growth factor inhibit acute transformation by simian sarcoma virus. *Nature* 317, 438-440.
37. Nistér, M., Heldin, C.-H., and Westermark, B. (1986). Clonal variation in the production of a platelet-derived growth factor-like protein and expression of corresponding receptors in a human malignant glioma. *Cancer Research* 46, 332-340.
38. Ek, B., and Heldin, C.-H. (1986). Specific cleavage of the fibroblast receptor for platelet-derived growth factor by an endogenous  $Ca^{2+}$ -dependent thiol protease. *Eur. J. Biochem.* 155, 409-413.
39. Heldin, C.-H., Johnsson, A., Wennergren, S., Wernstedt, C., Betsholtz, C., and Westermark, B. (1986). A human osteosarcoma cell line secretes a growth factor structurally related to a homodimer of PDGF A-chains. *Nature* 319, 511-514.

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## REVIEW ARTICLES

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