

# References

- Adler, I. (1974). A model of contact pressure in phyllotaxis. *J. theor. Biol.* 45, 1–79.
- Ataullakhanov, F.I. and Guriya, G.T. (1994). Spatial aspects of the dynamics of blood clotting - I. Hypothesis. *Biophysics* 39, 91–97.
- Bär, M., Eiswirth, M., Rotermund, H.H. and Ertl, G. (1992). Solitary-wave phenomena in an excitable surface-reaction. *Phys. Rev. Lett.* 69, 945–948.
- Baier, H. and Bonhoeffer, F. (1992). Axon guidance by gradients of a target-derived component. *Science* 255, 472–475.
- Bellwinkel, H.W. (1992). Naturwissenschaftliche Themen im Werk von Thomas Mann. *Naturw. Rundsch.* 45, 174–183.
- Bernasconi, G.P. (1994). Reaction-diffusion model for phyllotaxis. *Physica D* 70, 90–99.
- Bode, H.R. (2003). Head regeneration in hydra. *Dev. Dyn.* 226, 225–236.
- Bode, P.M., Awad, T.A., Koizumi, O., Nakashima, Y., Grimmelikhuijzen, C.J.P. and Bode, H.R. (1988). Development of the two-part pattern during regeneration of the head in hydra. *Development* 102, 223–235.
- Bretschneider, T., Siegert, F. and Weijer, C.J. (1995). 3-dimensional scroll waves of cAMP could direct cell-movement and gene-expression in *Dictyostelium* slugs. *Proc. Natl. Acad. Sci. USA* 92, 4387–4391.
- Bronsvoort, W. and Klok, F. (1985). Ray tracing generalized cylinders. *ACM Transactions on Graphics* 4, 291–303 .
- Broun, M., Gee, L., Reinhardt, B. and Bode, H.R. (2005). Formation of the head organizer in hydra involves the canonical wnt pathway. *Development* 132, 2907–2916.
- Browne, E.N. (1909). The production of new hydrants in Hydra by insertion of small grafts. *J. Exp. Zool.* 7, 1–23.
- Buikema, W.J. and Haselkorn, R. (2001). Expression of the *Anabaena* *hetR* gene from a copper-regulated promoter leads to heterocyst differentiation under repressing conditions. *PNAS* 98, 2729–2734.
- Butty, A.C., Perrinjaquet, N., Petit, A., Jaquenoud, M., Segall, J.E., Hofmann, K., Zwahlen, C., Peter, M. (2002). A positive feedback loop stabilizes the guanine-

- nucleotide exchange factor Cdc24 at sites of polarization. *EMBO J.* 21, 1565–1576.
- Canales, C., Grigg, S. and Tsiantis, M. (2005). The formation and patterning of leaves: recent advances. *Planta* 221, 752–756.
- Chant, J. (1999). Cell polarity in yeast. *Annu. Rev. Cell Dev. Biol.* 15, 365–391.
- Charest, P.G. and Firtel, R.A. (2006). Feedback signaling controls leading-edge formation during chemotaxis. *Cur. Op. Gen. Dev* 16, 339–347.
- Cohn, M.J. and Tickle, C. (1996). Limbs - a model for pattern-formation within the vertebrate body plan. *Trends in Genetics* 12, 253–257.
- Comfort, A. (1951). The pigmentation of molluscan shells. *Biological Review* 26, 285–301
- Cook, T.A. (1914). *Curves of Life*. Constable and Company, London, reprinted 1979 by Dover Publications, New York.
- Cortie, M.B. (1989). Models for mollusc shell shape. *South African Journal of Science* 85, 454–460.
- Coultas, L., Chawengsaksophak, K. and Rossant, J. (2005). Endothelial cells and VEGF in vascular development. *Nature* 438, 937–945.
- Coxeter, H.S.M. (1961). *Introduction to Geometry*. J. Wiley and Sons, New York
- Crick, F. (1970). Diffusion in embryogenesis. *Nature* 225, 420–422.
- DeRobertis, E.M. (1995). Dismanteling the organizer. *Nature* 374, 407–408.
- Devreotes, P.N. (1989). *Dictyostelium discoideum*: A model system for cell-cell interactions in Development. *Science* 245, 1054–1058.
- Diaz-Benjumea, J., Gonzales Gaitan, M.A.F. and Garcia-Bellido, A. (1989). Developmental genetics of the wing vein pattern of *Drosophila*. *Genome* 31, 612–619.
- Diaz-Benjumea, J., Gonzales-Gaitan, M.A.F. and Garcia-Bellido, A. (1989). Developmental genetics of the wing vein pattern of *Drosophila*. *Genome* 31, 612–619.
- do Carmo, M. (1976). *Differential Geometry of Curves and Surfaces*. Prentice Hall, Englewood Cliffs
- Ermentrout, B., Campbell, J. and Oster, G. (1986). A model for shell patterns based on neural activity. *The Veliger* 28, 369–338.
- Farrar, N.R. and Spencer, G.E. (2008). Pursuing a 'turning point' in growth cone research. *Dev. Biol.*, 318, 102–111.
- Fassler, P.E. and Sander, K. (1996). Mangold, Hilde (1898-1924) and Spemanns organizer - achievement and tragedy. *Roux's Archives Dev. Biol.* 205, 323–332.
- Feininger, A. and Emerson, W.K. (1972). *Shells*. The Viking Press
- Foley, J.D., van Dam, A., Feiner, S. and Hughes, J. (1990). *Computer graphics: Principles and practice*. Addison-Wesley, Reading.
- Folkman, J. (1976). The vascularization of a tumor. *Sci. American* 234, May, 58–73.
- Fowler, D.R., Meinhardt, H. and Prusinkiewicz, P. (1992). Modeling seashells. Proceedings of SIGGRAPH '92. *Computer Graphics* 26, 379–387.
- Gasseling, MT and Saunders, JWJr (1964). Effect of the "Posterior Necrotic Zone" on the early chick wing bud on the pattern and symmetry of limb outgrowth. *Amer. Zool.* 4, 303–304.

- Gerisch, G. (1968). Cell aggregation and differentiation in *Dictyostelium*. *Curr. Top. Dev. Biol.* 3, 157–232.
- Gierer, A. (1977). Biological features and physical concepts of pattern formation exemplified by hydra. *Curr. Top. Dev. Biol.* 11, 17–59.
- Gierer, A. (1981). Generation of biological patterns and form: Some physical, mathematical, and logical aspects. *Prog. Biophys. molec. Biol.* 37, 1–47.
- Gierer, A. and Meinhardt, H. (1972). A theory of biological pattern formation. *Kybernetik* 12, 30–39.
- Gierer, A., Berking, S., Bode, H., David, C.N., Flick, K., Hansmann, G., Schaller, H. and Trenkner, E. (1972). Regeneration of hydra from reaggregated cells. *Nature New Biology* 239, 98–101.
- Giulini, A., Wang, J. and Jackson, D. (2004). Control of phyllotaxy by the cytokinin-inducible response regulator homologue ABPHYL1 1031. *Nature* 430, 1031–1034.
- Glass, L. and Mackey, M.C. (1988). From clocks to chaos. Princeton University Press
- Goldbeter, A. (1996). Biochemical oscillations and the cellular rhythm: The molecular bases of periodic and chaotic behaviour. Cambridge University Press.
- Gordon, N.R. (1990). Seashells: A Photographic Celebration. Friedman group, New York
- Gould, A., Itasaki, N. and Krumlauf, R. (1998). Initiation of rhombomeric HoxB4 expression requires induction by somites and a retinoic acid pathway. *Neuron* 21, 39–51.
- Grüneberg, H. (1976). Population studies on a polymorphic prosobranch snail (*Clithon (Pictoneritina) oualaniensis* Lesson). *Phil. Transactions Royal Soc. London B* 275, 385–437.
- Granero, M.I., Porati, A. and Zanacca, D. (1977). A bifurcation analysis of pattern formation in a diffusion governed morphogenetic field. *J. Math. Biology* 4, 21–27.
- Grapin-Botton, A., Bonnin, M.A., Sieweke, M. and Le Douarin, N.M. (1998). Defined concentrations of a posteriorizing signal are critical for MadB/Kreisler segmental expression in the hindbrain. *Development* 125, 1173–1181.
- Grieshammer, U., Minowada, G., Pisenti, J.M., Abbott, U.K. and Martin, G.R. (1996). The chick *limbless* mutation causes abnormalities in limb bud dorsal-ventral patterning: implication for apical ridge formation. *Development* 122, 3851–3861.
- Gurdon, J.B., Mitchell, A. and Mahony, D. (1995). Direct and continuous assessment by cells of their position in a morphogen gradient. *Nature* 376, 520–521.
- Hörstadius, S. (1939). The mechanics of sea-urchin development studied by operative methods. *Biol. Rev.* 14, 132–179.
- Hale, C.A., Meinhardt, H. and de Boer, P.A.J. (2001). Dynamic localization cycle of the cell division regulator MinE in *Escherichia coli*. *Embo J.* 20, 1563–1572.
- Hammer, O. and Bucher, E. (1999). Reaction-diffusion processes: application to the morphogenesis of ammonid ornamentation. *GeoBios*, 32, 841–852

- Harfe, B.D., Scherz, P.J., Nissim, S., Tian, F. and McMahon, A.P. (2004). Evidence for an expansion-based temporal Shh gradient in specifying vertebrate digit identities. *CELL* 4, 517–528.
- Harris, M.P., Williamson, S., Fallon, J.F., Meinhardt, H. and Prum, R.O. (2005). Molecular evidence for an activator-inhibitor mechanism in development of embryonic feather branching. *PNAS* 102, 11734–11739.
- Harrison, R.G. (1918). Experiments on the development of the fore-limb of *Amblystoma*, a self-differentiating equipotential system. *J. exp. Zool.* 25:413–46.
- Hellström, M., Phng, L.K., Hofmann, J.J., Wallgard, E., Coultas, L., Lindblom, P., Alva, J., Nilsson, A.K., Karlsson, L., Gaiano, N., Yoon, K., Rossant, J., Iruela-Arispe, M.L., Kalen, M., Gerhardt, H. and Betsholtz, C. (2007). Dll4 signalling through notch1 regulates formation of tip cells during angiogenesis. *Nature* 445, 776–780.
- Herman, G.T. and Liu, W.H. (1973). The daughter of Celia, the french flag and the firing quad: Progress report on a cellular linear iterative-array simulator. *Simulation* 21, 33–41.
- Hobmayer, B., Rentzsch, F., Kuhn, K., Happel, CM, Cramer von Laue, C, Snyder, P, Rothbacher, U and Holstein, TW (2000). Wnt signalling molecules act in axis formation in the diploblastic metazoan hydra. *Nature* 407, 186–189.
- Hopfield, J.J. and Herz, A.V.M. (1995). Rapid local synchronization of action potentials: Toward computation with coupled integrate-and-fire neurons. *Proc. Natl. Acad. Sci. USA* 92, 6655–6622.
- Hu, Z., and Lutkenhaus, J. (1999). Topological regulation of cell division in *Escherichia coli* involves rapid pole to pole oscillation of the division inhibitor MinC under the control of MinD and MinE. *Mol Microbiol.* 34, 82–90.
- Huang, X., Dong, Y. and Zhao, J. (2004). HetR homodimer is a DNA-binding protein required for heterocyst differentiation, and the DNA-binding activity is inhibited by PatS. *PNAS* 2004 101, 4848–4853.
- Illert, C. (1989). Formulation and solution of the classical seashell problem. *Il Nuovo Cimento* 11 D, 761–780 .
- Izpisua-Belmonte, J.C., De Robertis, E.M., Storey, K.G., Stern, C., (1993). The homeobox gene *gooseoid* and the origin of organizer cells in the early chick blastoderm. *Cell*, 74, 645–659.
- Jones, C.M., Arnes, N. and Smith, J.C. (1996). Short-range signalling by Xnr-2 and BMP-4 contrasts with the long-range effects of activin *Current Biology* 6, 1468–1475.
- Jung, H.S., Francis-West, P.H., Widelitz, R.B., Jiang, T.X., Ting-Berreth, S., Tickle, C., Wolpert, L. and Chuong, C.M. (1998). Local inhibitory action of BMPs and their relationships with activators in feather formation: implications for periodic patterning. *Dev. Biol.* 196, 11–23.
- Kaandorp, J. (1994). *Fractal modelling: Growth and form in biology*. Springer-Verlag, Heidelberg

- Kawaguchi, Y. (1982). A morphological study of the form of nature. *Computer Graphics* 16, 223–232.
- Kay, R.R., Langridge, P., Traynor, D. and Hoeller, O. (2008). Changing directions in the study of chemotaxis. *Nat. Rev. Mol. Cell Biol.*, 9455–4, 3.
- Khaner, O. and Eyal-Giladi, H. (1989). The chick's marginal zone and primitive streak formation. I. Coordinative effect of induction and inhibition. *Dev. Biol.* 134, 206–214.
- Kiecker, C. and Lumsden, A. (2005). Compartments and their boundaries in vertebrate brain development. *Nature Rev. Neurosci.* 6, 553–564.
- Koch, A.J. and Meinhardt, H. (1994). Biological pattern-formation - from basic mechanisms to complex structures. *Rev. Modern Physics* 66, 1481–1507.
- Kuhlemeier, C. (2007). Phyllotaxis. *Trends Plant Sci* 12, 143–150.
- Kusch, I. and Markus, M. (1996). Mollusc shell pigmentation: Cellular automaton simulations and evidence for undecidability. *J. theor. Biol.* 178, 333–340.
- Ladher, R., Mohun, T.J., Smith, J.C. and Snape, A.M. (1996). Xom - a *Xenopus* homeobox gene that mediates the early effects of BMP-4. *Development* 122, 2385–2394.
- Lawrence, P.A., (1992). The making of a fly: The genetics of animal design Blackwell Scientific Publications, Oxford
- Lemaire, L., Roeser, T., Izpisua-Belmonte, J.C. and Kessel, M. (1997). Segregating expression domains of two *goosecoid* genes during the transition from gastrulation to neurulation in chick embryos. (Development, in press)
- Lenhoff, H. (1991). Ethel Browne, Hans Spemann, and the discovery of the organizer phenomenon. *Biol. Bull.* 181, 72–80.
- Leptin, M. (1991). *twist* and *snail* as positive and negative regulators during *Drosophila* mesoderm development. *Genes Dev.* 5, 1568–1576.
- Lindsay, D.T. (1982). A new programmatic basis for shell pigment patterns in the bivalve mollusc *Lioconcha castrensis* L. *Differentiation* 21, 32–36.
- Lovtrup, S. and Lovtrup, M. (1988). The morphogenesis of molluscan shells: A mathematical account using biological parameters. *J. Morph.* 197, 53–62.
- Lutz, H. (1949). Sur la production experimentale de la polyembryonie et de la monstruosite double chez les oiseaux. *Arch. d'Anat. Micro. et de Morph.*, 38, 79–144.
- Martin, G.R. (1995). Why thumbs are up. *Nature* 374, 410–411.
- Meinhardt, H. (1976). Morphogenesis of lines and nets. *Differentiation* 6, 117–123.
- Meinhardt, H. (1978). Space-dependent cell determination under the control of a morphogen gradient. *J. theor. Biol.* 74, 307–321.
- Meinhardt, H. (1982). Models of Biological Pattern Formation. Academic Press, London (freely available from our website, <http://www.eb.tuebingen.mpg.de/meinhardt> )
- Meinhardt, H. (1983a). A boundary model for pattern formation in vertebrate limbs. *J. Embryol exp. Morphol.* 76, 115–137.

- Meinhardt, H. (1983b). Cell determination boundaries as organizing regions for secondary embryonic fields. *Devl. Biol* 96, 375–385.
- Meinhardt, H. (1984). Models for positional signalling, the threefold subdivision of segments and the pigmentation pattern of molluscs. *J. Embryol. exp. Morph.* 83, (Supplement) 289–311.
- Meinhardt, H. (1993). A model for pattern-formation of hypostome, tentacles, and foot in hydra: how to form structures close to each other, how to form them at a distance. *Dev. Biol.* 157, 321–333.
- Meinhardt, H. (1999). Orientation of chemotactic cells and growth cones: Models and mechanisms. *J. Cell Sci.* 112, 2867–2874.
- Meinhardt, H. (2002). The radial-symmetric hydra and the evolution of the bilateral body plan: an old body became a young brain. *Bioessays* 24, 185–191.
- Meinhardt, H. (2004). Different strategies for midline formation in bilaterians. *Nat Rev Neurosci* 5, 502–510.
- Meinhardt, H. (2006). Primary body axes of vertebrates: generation of a near-Cartesian coordinate system and the role of Spemann-type organizer. *Dev Dyn.* 235, 2907–2919.
- Meinhardt, H. (2008). Models of biological pattern formation: from elementary steps to the organization of embryonic axes. *Curr. Top. Dev. Biol.* 81, 1–63.
- Meinhardt, H. and de Boer, P.A.J. (2001). Pattern formation in *E.coli*: a model for the pole-to-pole oscillations of Min proteins and the localization of the division site. *PNAS* 98, 14202–14207.
- Meinhardt, H. and Gierer, A. (1980). Generation and regeneration of sequences of structures during morphogenesis. *J. theor. Biol.* 85, 429–450.
- Meinhardt, H. and Klingler, M. (1987). A model for pattern formation on the shells of molluscs. *J. theor. Biol* 126, 63–69.
- Mirollo, R.E. and Strogatz, S.H. (1990). Synchronization of pulse-coupled biological oscillators. *SIAM J. On Applied Mathematics* 50, 1645–1662.
- Moos, M., Wang, S.W. and Krinks, M. (1995). Anti-dorsalizing morphogenetic protein is a novel TGF- $\beta$  homolog expressed in the spemann organizer. *Development* 121, 4293–4301.
- Murray, J.D. (1989). Mathematical biology. Springer, Heidelberg, New York
- Nüsslein-Volhard, C. (1991). Determination of embryonic body axes in the *Drosophila* embryo. *Development Supplement* 1, 1–10.
- Nüsslein-Volhard, C. (1996). Gradienten als Organisatoren der Embryonalentwicklung. *Spektrum der Wissenschaften* Oktober 10/1996, pp 38–46.
- Nüsslein-Volhard, C. and Wieschaus, E. (1980). Mutations affecting segment number and polarity in *Drosophila*. *Nature* 287, 795–801.
- Nellen, D., Burke, R., Struhl, G. and Basler, K. (1996). Direct and long-range action of a dpp morphogen gradient. *Cell* 85, 357–368.
- Neumann, D. (1959). Experimentelle Untersuchungen des Farbmusters auf der Schale von *Theodoxus fluviatilis* L. In: Verh. Deutsch. Zoolog. Gesellsch. Münster/Westph. pp.152–156 (Akademische Verlagsgesellschaft Leipzig)

- Neumann, D. (1959). Morphologische und experimentelle Untersuchungen über die Variabilität der Farbmuster auf der Schale von *Theodoxus fluviatilis* L. *Z. Morph. Ökol. Tiere* 48, 349–411.
- Neumann, D. (1959). Musterumschlag auf der Molluskenschale. *Experienta* 15, 178.
- Niehrs, C., Steinbeisser, H. and DeRobertis, E.M. (1994). Mesodermal patterning by a gradient of the vertebrate homeobox gene *gooseoid*. *Science* 263, 817–820.
- Oliver, G, Sidell, N, Fiske, W, Heinzmann, C, Mohandas, T, Sparkes, RS and De Robertis, ED (1989). Complementary homeo protein gradients in developing limb buds. *Genes Dev.* 3, 641–650.
- Oppenheimer, P. (1986). Real time design and animation of fractal plants and trees. *Computer Graphics* 20, 55–64.
- Ozbudak, E.M., Becskei, A. and van Oudenaarden, A. (2005). A System of Counteracting Feedback Loops Regulates Cdc42p Activity during Spontaneous Cell Polarization. *Dev. Cell* 9, 565–571.
- Parr, B.A. and McMahon, A.P. (1995). Dorsalizing signal *Wnt-7a* required for normal polarity of D-V and A-P axes of the mouse limb. *Nature* 374, 350–353.
- Pickover, C.A. (1989). A short recipe for seashell synthesis. *IEEE Computer Graphics and Applications* 9, 8–11 .
- Pickover, C.A. (1991). Computers and the Imagination. St. Martin's Press
- Plath, P.J, Schwietering, J. (1992). Improbable event in deterministically growing patterns. In: *Fractal Geometry and Computer. Graphics* (J. L. Encarnuao, H. O. Peitgen, Skas, G. Englert, Eds.) Springer Verlag.
- Prigogine, I. and Lefever, R. (1968). Symmetry breaking instabilities in dissipative systems. II. *J. chem. Phys.* 48, 1695–1700.
- Prum, R.O. and Williamson, S. (2002). Reaction-diffusion models of within-feather pigmentation patterning. *Proc. R. Soc. London B* 269, 781–792.
- Prusinkiewicz, P. (1994). Visual models of morphogenesis. *Artificial Life* 1, 61–74.
- Prusinkiewicz, P. and Streibel, D. (1986). Constraint-based modeling of three-dimensional shapes. In *Proceedings of Graphics Interface '86 - Vision Interface '86*, pp. 158–163.
- Psychoyos, D. and Stern, C.D. (1996). Restoration of the organizer after radical ablation of Hensen's node and the anterior primitive streak an the chick embryo. *Development* 122, 3263–3273.
- Ptashne, M., Jeffrey, A., Johnson, A.D., Maurer, R., Meyer, B.J., Pabo, C.O., Roberts, T.M. and Sauer, R.T. (1980). How the lambda repressor and Cro work. *Cell* 19, 1–11.
- Raskin, D.M. and de Boer, P.A.J. (1999). Rapid pole-to-pole oscillation of a protein required for directing division to the middle of *Escherichia coli*. *PNAS* 96, 4971–4976.
- Raup, D.M. (1962). Computer as aid in describing form in gastropod shells. *Science* 138, 150–152 .
- Raup, D.M. (1969). Modeling and simulation of morphology by computer. *Proceedings of the North American Paleontology Convention*

- Raup, D.M. and Michelson, A. (1965). Theoretical morphology of the coiled shell. *Science* 147, 1294–1295.
- Regulski, M., Dessain, S., McGinnis, N. and McGinnis, W. (1991). High-affinity binding-sites for the deformed protein are required for the function of an autoregulatory enhancer of the deformed gene. *Genes & Development* 5, 278–286.
- Risau, W. and Flamme, I. (1995). Vasculogenesis. *Annu. Rev. Cell Dev. Biol.*, 11, 73–91.
- Sabelli, B. (1979). Guide to Shells. Simon and Schuster
- Sachs, T. (1991). Cell polarity and tissue patterning in plants. *Development Supplement* 1, 83–93.
- Saunders, B.W. (1984). *Nautilus* growth and longevity: Evidence from marked and recaptured animals. *Science* 224, 990–992.
- Schoute, J.C. (1913). Beiträge zur Blattstellung. *Rec. trav. bot. Neerl.* 10, 153–325.
- Segel, L.A. (1984). Modelling dynamic phenomena in molecular and cellular biology. Cambridge University Press, Cambridge
- Segel, L.A. and Jackson, J.L. (1972). Dissipative structure: an explanation and an ecological example. *J. theor. Biol.* 37, 545–549.
- Seilacher, A. (1972). Divaricate patterns in pelecypod shells. *Lethaia* 5, 325–343.
- Seilacher, A. (1973). Fabricational noise in adaptive morphology. *Systematic Zool.* 22, 451–465.
- Shapiro, L. and Losick, R. (2000). Dynamic spatial regulation in the bacterial cell. *Cell* 100, 89–98.
- Shimizu, H. and Fujisawa, T. (2003). Peduncle of Hydra and the heart of higher organisms share a common ancestral origin. *Genesis* 36, 182–186.
- Siebert, F. and Weijer, C.J. (1992). 3-dimensional scroll waves organize *Dictyostelium* slugs. *Proc. Natl. Acad. Sci. USA* 89, 6433–6437.
- Simpson-Brose, M., Treisman, J and Desplan, C (1994). Synergy between the *hunchback* and *bicoid* morphogens is required for anterior patterning in *Drosophila*. *Cell* 78, 855–865.
- Smith, R.S., Guyomarc'h, S., Mandel, T., Reinhardt, D., Kuhlemeier, C. and Prusinkiewicz, P. (2006). A plausible model of phyllotaxis. *PNAS* 103, 1301–1306.
- Spemann, H. and Mangold, H. (1924). Über Induktion von Embryonalanlagen durch Implantation artfremder Organisatoren. *Wilhelm Roux' Arch. Entw. mech. Org.* 100, 599–638.
- Starz-Gaiano, M., Melani, M., Wang, X., Meinhardt, H. and Montell, D.J. (2008). Feedback Inhibition of JAK/STAT signaling by apontic is required to limit an invasive cell population. *Dev. Cell* 14, 726–738.
- Stewart, I. (1991). All together now. *Nature* 350, 557–557.
- Suchting, S., Freitas, C., le Noble, F., Benedito, R., Breant, C., Duarte, A. and Eichmann, A. (2007). The notch ligand delta-like 4 negatively regulates endothelial tip cell formation and vessel branching. *PNAS* 104, 3225–3230.



- Technau, U. and Holstein, T.W. (1995). Head formation in hydra is different at apical and basal levels. *Development* 121, 1273–1282.
- Thompson, d'Arcy, W. (1952). On Growth and Form. Cambridge
- Thompson, d'Arcy, W. (1961). On Growth and Form (Abridged Edition). Cambridge University Press, Cambridge
- Tickle, C., Summerbell, D. and Wolpert, L. (1975). Positional signalling and specification of digits in chick limb morphogenesis. *Nature* 254, 199–202.
- Trembley, A. (1744). Memoires pour servir a l'histoire d'un genre de polypes d'eau douce. *J. u. H. Verbeek, Leiden.* , .
- Turing, A. (1952). The chemical basis of morphogenesis. *Phil. Trans. B.* 237, 37–72.
- Udolf, G., Lüer, K., Bossing, T. and Technau, G.M. (1995). Commitment of the CNS progenitors along the dorsoventral axis of *Drosophila* neuroectoderm. *Science* 269, 1278–1281.
- van Iterson, G. (1907). Mathematische und mikroskopisch-anatomische Studien über Blattstellungen. *Fischer, Jena.* , .
- Vincent, J.P. and Lawrence, P.A. (1994). It takes three to distalize. *Nature* 372, 132–133.
- von Rosenhof, R. (1755). Historie der Polypen und anderer kleiner Wasserinsecten. Insektenbelustigung. Vol. III. Nürnberg
- Wacker, S.A., Jansen, H.J., McNulty, C.L., Houtzager, E. and Durston, A.J. (2004a). Timed interactions between the Hox expressing non-organiser mesoderm and the Spemann organiser generate positional information during vertebrate gastrulation. *Dev. Biol.* 268.207–21, .
- Waddington, C. and Cowe, R. (1969). Computer simulation of a molluscan pigmentation pattern. *J. Theor. Biol.* 25, 219–225.
- Wanscher, J.H. (1971). Considerations on phase-change and decorations in snail shells. *Hereditas* 71, 75–94.
- Ward, P.D. and Chamberlain, J. (1983). Radiographic observation of chamber formation in *Nautilus pompilius*. *Nature* 304, 57–59.
- Wilcox, M., Mitchison, G.J. and Smith, R.J. (1973). Pattern formation in the blue-green alga, *Anabaena*. I. Basic mechanisms. *J. Cell Sci.* 12, 707–723.
- Willmann, R. (1983). Die Schnecken von Koos. *Spektrum der Wissenschaft (Februar)* pp. 64–76.
- Winfree, A.T. (1980). The geometry of biological time. Springer Verlag, New York, Heidelberg, Berlin.
- Wolfram, S. (1984). Cellular automata as models of complexity. *Nature* 341, 419–424.
- Wolpert, L. (1969). Positional information and the spatial pattern of cellular differentiation. *J. theor. Biol.* 25, 1–47.
- Yoon, H.S. and Golden, J.W. (1998). Heterocyst pattern-formation controlled by a diffusible peptide. *Science* 282, 935–938.
- Zigmond, S.H. (1977). Ability of polymorphonuclear leukocytes to orient in gradients of chemotactic factors. *J Cell Biol.* 75, 606–617.

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