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Embryonic Cleavage Modeling as a computational approach to Sphere Packing Problem.

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Embryonic cleavage depends on the distribution in the cytosol of molecular signals that influence mitotic spindle positioning. By implementing the New Kind of Science (NKS) theory in which a simple rule can evolve with a complex overall behavior, here we propose a new theoretical approach that is capable of modeling the mechanisms of early embryonic cleavage dynamics. The model shows that the same spindle pole orientation rule governs the first three embryonic cleavages, which progressively allow the transition from one to eight daughter cells. However, likely due to the establishment of an apical-basal cell polarity, the fourth cleavage that allows the transition from eight to sixteen cells needs a change of spindle pole orientation and position. Finally, we present evidence of a strong similarity between Kepler's *Sphere Packing Problem* and embryonic cleavage, which thus represents a prominent example of natural computing.

References

1. Ahringer, J. (2003) Control of cell polarity and mitotic spindle positioning in animal cells. *Curr Opin Cell Biol.*, **15**, 73-81.
2. Gerhart, J., Wu, M. and Kirschner, M. (1984) Cell cycle dynamics of an M-phasespecific cytoplasmic factor in Xenopus laevis oocytes and eggs. *J Cell Biol*, **98**, 1247-1255.
3. Gilbert, S.F. (2000) *Developmental Biology*. Sinauer Associates, Inc.

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4. Gumbiner, B.M. (2005) Regulation of cadherin-mediated adhesion in morphogenesis. *Nat Rev Mol Cell Biol*, **6**, 622-634.
5. Hayashi T, C.R. (2004) Surface mechanics mediate pattern formation in the developing retina. *Nature.*, **2004 Oct 7;431(7009):647-52**, 647-652.
6. Hynes, R.O. and Zhao, Q. (2000) The evolution of cell adhesion. *J Cell Biol*, **150**, F89-96.
7. Kaltschmidt, J.A., Davidson, C.M., Brown, N.H. and Brand, A.H. (2000) Rotation and asymmetry of the mitotic spindle direct asymmetric cell division in the developing central nervous system. *Nat Cell Biol*, **2**, 7-12.
8. Laure L, O.M., Hirchenhain J, Kemler R. (1994) E-cadherin null mutant embryos fail to form a trophectoderm epithelium. *Proc. Natl. Acad. Sci.*, **91**, 8263-8267.
9. Newport, J.W. and Kirschner, M.W. (1984) Regulation of the cell cycle during early Xenopus development. *Cell*, **37**, 731-742.
10. Odlyzko, A.M., Sloane, N. J. A. (1979) New bounds on the number of unit spheres that can touch a unit sphere in n dimensions. *J. Combin. Theory Ser.*, **A 26**, 210—214.
11. Ou, Y., Zhang, M. and Rattner, J.B. (2004) The centrosome: The centriole-PCM coalition. *Cell Motil Cytoskeleton*, **57**, 1-7.
12. Pearson, C.G. and Bloom, K. (2004) Dynamic microtubules lead the way for spindle positioning. *Nat Rev Mol Cell Biol*, **5**, 481-492.
13. Weisstein, E.W. (2005a) Rotation Matrix. *From MathWorld--A Wolfram Web Resource. http://mathworld.wolfram.com/RotationMatrix.html*.
14. Weisstein, E.W. (2005b) Kepler Problem. *From MathWorld--A Wolfram Web Resource. http://mathworld.wolfram.com/KeplerConjecture.html*.
15. Wolfram, S. (1984) Cellular Automata as Models of Complexity. *Nature*, **311**, 419-424. Wolfram, S. (2002) *A New Kind of Science*. Wolfram Media, Champaign, Illinois.
16. Wolfram, S. (2003) *Th Mathematical Book*. Wolfram Media, Champaign, Illinois.
17. Zernicka-Goetz, M. (2005) Developmental cell biology: cleavage pattern and emerging asymmetry of the mouse embryo. *Nat Rev Mol Cell Biol*, **6**, 919-928.