

## DEPARTMENT OF BIOMEDICAL ENGINEERING

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INSTITUTE OF TECHNOLOGY



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### Cell Growth and Division

- B.Ch.E, Chemical Eng., University of Minnesota, 1988
- M.S., Chemical & Biochemical Eng., Rutgers University, 1992
- Ph.D., Chemical & Biochemical Eng., Rutgers University, 1995

### Mitosis

The proper segregation of chromosomes is achieved by a sorting machine known as the mitotic spindle. The spindle is composed of dynamic, self-assembling microtubules and molecular motors. We are studying the dynamic interplay of these nanomachines as they sort out the chromosomes, so that each of two nascent daughter cells gets a complete genome. Our approach is to integrate computer modeling with live fluorescence microscopy, cryo-electron microscopy, and genetics. In our models we also simulate the imaging process, an approach we call "model-convolution", which facilitates hypothesis testing. Understanding the mechanochemical basis of mitosis will give us more rational approaches to interfere with mitosis, for example in cancer therapy and control of restenosis after stenting.

### Cell Growth

Each cell type has a characteristic size, ranging from a few cubic micrometers for bacteria to 1000 cubic micrometers for mammalian tissue cells. A key question is what controls cell size. We are studying how mechanical force stimulates cell growth using neurons as our model system. Interestingly, neurons can be induced to form axons de novo in response to appropriate levels of mechanical tension. In addition, we are investigating how neurons respond to the mechanical stiffness of their environment. These studies will give us a better understanding of how to promote nerve regeneration in vivo and engineer neural tissue in vitro. In addition, they will provide us with new insight on the mechanochemical basis of environmental stiffness sensing, which controls stem cell differentiation, and of cell polarization, which is required for axon growth.

### Microtubule Dynamics

The positioning of intracellular structures is determined largely by the organization of the cytoskeleton, a collection of self-assembled protein filaments inside eukaryotic cells that serve as nanometer-scale railroad tracks for molecular motors and their associated cargoes. A prime example is the movement of DNA during mitosis. When cells divide, replicated chromosomes attach specifically to the ends of cytoskeletal filaments called microtubules. Microtubules then undergo stochastic switching between rounds of assembly and disassembly, which ultimately serves to mediate the movement of one chromosome to one pole and the replicated sister chromosome to the other pole. My laboratory is interested in modelling the kinetics and thermodynamics of microtubule assembly and disassembly, the dynamics of microtubule-associated proteins, and the interplay between mechanical forces and chemical kinetics and thermodynamics. In doing so we hope to better understand and control such seemingly diverse processes as cell division and nerve regeneration, both of which require the reorganization of microtubules.

## Selected Publications

- Nahmias, Y.K., B.Z. Gao, and D.J. Odde, "Dimensionless parameters for the design of optical traps and laser guidance systems," *Applied Optics*, 43, 3999-4006 (2004).
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- Nahmias, Y.K., R. Schwartz, C.M. Verfaillie, and D.J. Odde, "Laser-guided direct writing for three-dimensional tissue engineering," *Biotechnology and Bioengineering*, 92, 129-136 (2005).
- Odde, D. J., "Mitotic Spindle: Disturbing a Subtle Balance," *Current Biology*, 15, R1-3 (2005).
- VanBuren, V., L.U. Cassimeris, and D.J. Odde, "A mechanochemical model of microtubule structure and kinetics," *Biophysical Journal*, 89, 2911-2926 (2005).
- Nahmias, Y.K., A. Arneja, T. Tower, M.J. Renn, and D.J. Odde, "Cell patterning on biological gels via cell spraying through a mask," *Tissue Engineering*, 11, 701-708 (2005).
- Fischer TM, Steinmetz PN, and D. J. Odde, "Robust micromechanical neurite elicitation in synapse-competent neurons via magnetic bead force application," *Annals of Biomedical Engineering* 9, 1229-1237 (2005).
- Pearson C\*, Gardner M\*, Paliulis L, Salmon ED, Odde DJ, Bloom K., "Measuring nanometer scale gradients in spindle microtubule dynamics using model convolution microscopy," *Molecular Biology of the Cell*, 17, 4069-4079 (2006). \*Authors contributed equally.
- Nahmias, Y. K., R. Schwartz, W.-S. Hu, C. M. Verfaillie and D. J. Odde, "Establishment of liver-like tissue in vitro via endothelium-mediated hepatocyte recruitment." *Tissue Engineering*, 12, 1627-1638 (2006).
- Meyers J\*, Craig J\*, and D. J. Odde, "Potential for control of signaling pathways via cell size and shape," *Current Biology*, 16, 1685-1693 (2006). \*denotes authors contributed equally.
- Gardner, M.K. and D. J. Odde, "Modeling kinetochore motility in mitosis," *Current Opinion in Cell Biology*, 18, 639-647 (2006).
- DeSilva MN, Paulsen J, Renn MJ, and D. J. Odde, "Two-step cell patterning on planar and complex curved surfaces by precision spraying of polymers," *Biotechnology and Bioengineering*, 93, 919-927 (2006).
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- Bicek AD, Tuzel E, Kroll DM, Odde DJ, "Analysis of microtubule curvature," *Methods in Cell Biology*, 83, 237-68 (2007).
- Schek HT, 3rd,\* Gardner MK,\* Cheng J, Odde DJ,\*\* Hunt AJ,\*\* "Microtubule assembly dynamics at the nanoscale," *Current Biology*, 17, 1445-55 (2007). \*denotes authors contributed equally. \*\* denotes authors co-directed the project equally.
- Gardner MK, Haase J, Anderson MB, Molk JN, Myhre K, O'Toole ET, Winey M, Salmon ED, Odde DJ, Bloom K. "The microtubule-based motor Kar3 and plus-end binding protein Bim1 provide structural support for the anaphase spindle," *The Journal of Cell Biology*, 180, 91-100 (2008).
- Gardner MK, Hunt AJ, Goodson HV, Odde DJ. "Microtubule Assembly Dynamics: New Insights at the Nanoscale," *Current Opinion in Cell Biology*, 20, 64-70 (2008).
- Lipkow, K, and D.J. Odde, "Model for protein concentration gradients in the cytoplasm," *Cellular and Molecular Bioengineering*, 1 (2008).
- Gardner, M.K., D.C. Bouck, L.V. Paliulis, J.B. Meehl, E.T. O'Toole, J. Haase, A. Soubry, A.P. Joglekar, M. Winey, E.D. Salmon, K. Bloom, and D.J. Odde, Chromosome congression by kinesin-5 motor-mediated disassembly of longer kinetochore microtubules. *Cell* (2008). in press.