# The Physics of Living Systems

## Jaan Mannik's Work on Cellular Organization Earns an NSF CAREER Award

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Physics and bacteria may not seem the most likely match, but Assistant Professor Jaan Mannik uses one to study the other, and his efforts have resulted in the department's second CAREER award from the National Science Foundation in two years.

Mannik's research combines physics, biology, and nanotechnology to understand how bacteria (specifically *E. coli*) are organized at the cellular level and how robust this organization is relative to perturbations. What molecular mechanisms maintain cellular organization in bacteria against perturbations of bacterial shapes? To what extent can scientists perturb the cellular organization without affecting an organism's viability? To what degree do basic cellular processes, such as cell division and chromosome replication, depend on cell shape?

The NSF funded Mannik's proposal—"Understanding robustness of cellular organization in Escherichia coli through nanofabricated environments"—to answer fundamental questions such as these. The award comes through the prestigious Faculty Early Career Development (CAREER) Program, whose goal is to encourage junior faculty who have demonstrated exceptional research, teaching, and the ability to integrate the two. Mannik's grant is renewable over five years and brings with it a total of $635,000 in support.

To see just how robust a bacteria's cellular structure is, Mannik develops a kind of obstacle course for *E. coli*: nanoscale mazes that challenge these tiny organisms to show how they handle the unexpected. He starts with a silicon wafer. On top of that is a polymer layer that's sensitive to light or electron beams. Using computer-generated designs, he etches the silicon with channels for the bacteria to navigate—some more narrow than the organisms themselves and some much larger. The wafer is then separated into individual chips about the size of a penny, each one a sort of nano-laboratory where Mannik controls various physical and chemical stimuli to coax bacteria into revealing their properties. These micro and nano-engineering methods create an environment where he and his students observe how bacteria assume different shapes as they negotiate the channels in which they're placed. Of keen interest is how those adaptations effect the way chromosomes are organized, as accurate chromosome positioning is critical in cell division if the daughter cells are to inherit the complete genetic code from the parent cell. Mannik uses fluorescence microscopy to image the bacterial cells and what's going on inside them and then builds on this experimental work with quantitative analysis. These studies bring with them a number of possible applications. Locating vulnerabilities in cell organization, for example, could help define new targets for antibiotics. Other labs involved with live cell imaging of bacteria or yeast cells could benefit from the development of micro- and nano-engineered chips that will be carried out during this project.

"What I want to do is very physics-related," Mannik explained. "(It's) answering biological questions using physics methods and concepts. Indeed biological systems organize themselves according to the laws of physics but how this happens is yet poorly understood."

The CAREER Award will advance this work, primarily by supporting the addition of new graduate students. At present, Mannik's research group includes physics graduate student Matthew Bailey, undergraduates Boyd Warren (microbiology) and Clayton Greer (mechanical engineering), and Oak Ridge High School student Liam Schramm. He would like to add more graduate students from physics to these interdisciplinary endeavors, which he pursues in his lab in the Science and Engineering Research Facility. Motivating students to go into science is a primary goal of the CAREER program, and Mannik's proposal includes integrating his research into the undergraduate curriculum and supervising VolsTeach students (undergraduates in science, math, and engineering majors who will also be certified teachers). He will also offer summer internships to minority students from the Tennessee Louis Stokes Alliance for Minority Participation program.

Mannik, who earned a Ph.D. in physics at SUNY Stony Brook, joined the UT Physics Department as an assistant professor in September 2011. His CAREER Award is the second for the department in two years: in 2012 Dr. Norman Mannella won a CAREER grant for his work in condensed matter physics.