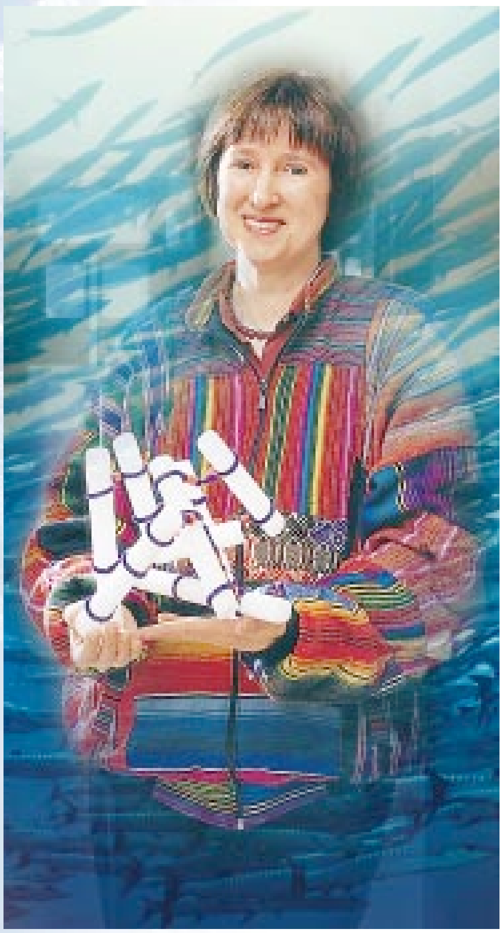
Understanding Complex Systems

Mathematical biologist Leah Keshet is one of a growing number of interdisciplinary researchers who use mathematical modelling to help solve some of science's most puzzling questions.

WHAT KEEPS A SCHOOL OF FISH OR A SWARM OF BEES together? What forms or breaks up a string of molecules? What controls the shape and movement of a cell? Why do nerve cells degenerate and die in diseases such as Alzheimer's and ALS. The common link in these questions is that they all involve highly complex systems. Leah Keshet uses mathematical tools such as differential equations and computer modelling rather than in vitro experiments to try to answer them. Keshet says her binary love for both math and biology is inherited. "My mother was a biologist and my father is a mathematician. I was fascinated with both areas and eventually wound up in the middle."

Her initial research involved modelling the way that actin filaments—components of the cytoskeleton or the structural scaffolding of cells—interact to form different kinds of structures, such as bundles, loose networks, or gels, and what role this plays in disease. In cancerous cells, the actin cytoskeleton is one of the cellular components that can be severely affected, resulting in the abnormal motion of these cells. In cystic fibrosis, cells spill out very long actin filaments that produce a heavy mucus in the lungs. "Polymer chemistry has traditionally been dominated by physical chemistry and thermodynamic techniques." Keshet notes. "I look at these problems from a kinetic and differential equations perspective."



MITACS team leader, Mathematics Professor Leah Keshet holds a model of an actin filament network.

Keshet's research is not confined to the microscopic aspect of biology. She and associates Alex Mogliner and Danny Grunbaum have also been looking at a much larger picture—the complexity of swarming behaviour in animals and insects. They use mathematical models to shed light on what keeps a swarm or flock together, what governs its shape, and why it can travel for long distances without losing individuals. This research has implications for behavioural ecology, conservation of natural resources such as fish, management strategies for bee farming, and pest control.

In addition to her research and teaching, Keshet is actively involved in curriculum development. She is helping to develop calculus courses for life sciences students, and she is one of the creators of Calculus OnLine. Keshet also designed and co-taught courses in Science One, UBC's innovative multi-disciplinary program for first-year science students.

When not teaching, developing courses or solving complex mathematical problems, Keshet says she enjoys spending time with her two young sons. "They both have wonderful energy and ideas." This obviously influences her approach to life and work—interactive, curious, and open to possibilities.

MITACS—Using Mathematics to Fight Disease

An exciting development for Leah Keshet and her math-bio colleagues Robert Miura and Yx Li was the announcement of major funding by the federal government for The Mathematics of Information Technology and Complex Systems (MITACS), a new Network Centres of Excellence (NCE). This initiative, of more than $14.5 million over four years, will bring together 175 researchers at 22 Canadian universities to develop new mathematical tools for Canadian industry. Keshet heads one of the biomedical MITACS teams.

In one of the recently funded MITACS projects, Keshet is studying signal transduction, the process of converting hormonal signals to cellular response which involves a complex biochemical cascade. Leah Keshet is trying to determine what happens when this complex interaction goes awry. She is working with Kinetek, a Vancouver-based pharmaceutical company, to model the architecture of these cascades in order to analyze the effects of hormonal signals and try to understand their role in diseases such as diabetes and cancer.

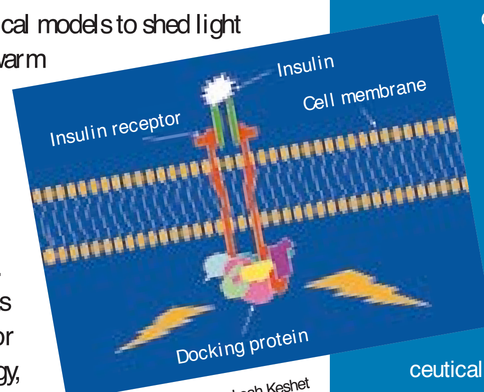


Diagram: Leah Keshet

Another MITACS project is her work with associate Chris Shaw, student Magdalena Luca, and post-doctoral fellow Alexandra Chavez-Ross on neurodegenerative diseases such as Alzheimer's and ALS. In collaboration with industry partner In Silico (Boston), they are trying to discover how microglia (the brain's "immune cells") affect the balance between healthy and stressed neurons, and how excitotoxins (molecules that mimic some neurotransmitters) cause neural stress and degeneration.