

Calculating life

McMaster biomathematician applies numbers to the analysis of life

by Graham Jansz, SPARK Writer
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Galileo Galilei once said, "Measure what is measurable, and make measurable what is not so". Recent trends in experimentation and technology certainly seem to suggest that scientists and mathematicians have taken Galileo's words to heart.

Measurements have been made of things as small as atoms and as big as galaxies.

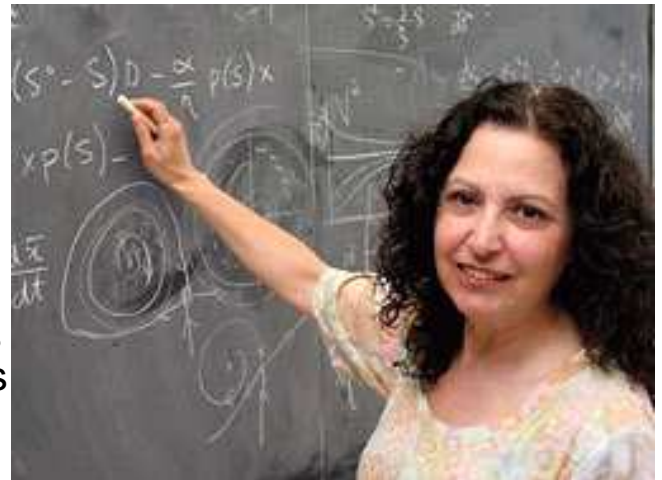
Indeed, numbers and measurements are the backbone of a great deal of innovative scientific discoveries.

However, there are times when Galileo's advice isn't easy to follow. As science continues to progress, the measurements that provide the fundamental basis for discovery often become increasingly complex. In many cases, accurate measurements are not easily or ethically obtained -counting tens of thousands of bacteria in a colony is definitely tedious and infecting a person with a disease to measure the effects is certainly wrong.

To help "make measurable what is not so" mathematicians have developed models that can predict the outcomes of certain scenarios, thereby decreasing the need for experimentation. McMaster University's Gail Wolkowicz, a professor in the Department of Mathematics & Statistics, focuses on developing such models. Wolkowicz specifically designs her models for use with biological systems that can be as minute as bacteria and as vast as ecosystems. As a biomathematician, Wolkowicz works towards calculating life.

Rather than perform calculations to generate specific numbers, Wolkowicz uses math to prove that certain factors, called bifurcation parameters, are critical in the behavior of a system. This has applications in biology because living systems are often governed by very specific factors, and changes to these factors can lead to things like extinction. For example, Wolkowicz doesn't use her models to say how many bacteria will grow - she uses them to figure out what factors, such as food or temperature, are crucial for the bacteria's survival, and which factors don't matter at all.

Wolkowicz observes, "Knowing which parameters play a crucial role is important, since these are the parameters that experimental scientists need to measure most accurately. Taking such measurements is often very expensive



Gail Wolkowicz. Photo credit: Graham Jansz

and time consuming, and so knowing which parameters to focus on could save a lot of time and money."

"Mathematical modeling is an art," Wolkowicz notes. As with any art different mathematical artists generate unique and different models. Many mathematicians develop complex, large-scale models that require a lot of data to make very specific predictions about what would actually happen. Wolkowicz observes, "These models have a very important role today, especially because of the advances with computers and the ability we now have to simulate these large-scale models."

For example, these types of models are used to forecast the weather around the world - a remarkable feat. The problem, however, is that a huge amount of detailed information must be fed into the models, thus making them applicable only to very specific situations.

Wolkowicz's models are somewhat different than these complex models. She says, "My models are smaller in scale and the techniques used are analytical (based on theories and basic principals) rather than numerical (based on numbers); hence, their predictions are much more general. For example, one model I developed determines which species would prevail when two different species are competing for the same nutrient. This model requires the measurement of only a single parameter. Based on this one piece of information, the model can predict which species will survive and which species will be driven to extinction."

Understanding the factors that explain biological phenomena has myriad applications. If conservationists understand the determining factors of an ecosystem they can help endangered species to thrive. If exterminators know the critical needs of termite colonies they can help to remove them from houses. Wolkowicz's work, which is funded by the Natural Sciences and Engineering Research Council (NSERC), allows tests to be run mathematically to determine the conditions that are just right for the desired outcome - a huge convenience, given that trial and error with an ecosystem is not a good idea.

Wolkowicz has applied mathematical modeling to many biological and ecological questions observed in nature. For example, in some cases stronger organisms exclude weaker organisms through competition for resources and the weaker are often driven to extinction. On the other hand, in some cases competition leads to ecosystems filled with diverse creatures. Wolkowicz has been able to develop robust models to show when each scenario prevails - a task that would be very unwieldy through typical observation and measurement.

Ecologists also often deal with the question of how species will interact when they are introduced to the same environment. For biologists, this sort of information is vital in maintaining balanced ecosystems and environments. For

the everyday person, wouldn't it be nice to know in advance that the goldfish in our fish tank will die the day after we add the algae eater?

Wolkowicz has also done significant work on the math behind a device called a chemostat, which is essentially a biochemical reactor, or as Wolkowicz says, 'a lake in a lab'. Chemostats have many applications. For example, they are used to grow cells for experiments, to raise organisms that produce antibiotics, to purify water and to breakdown wastes. Wolkowicz's models can help to ensure that these valuable tools operate with maximum efficiency and success.

Although Wolkowicz often applies her models in specific situations, their usefulness is extremely extensive. Wolkowicz notes that, "As a mathematician, I like to try to make the model as general as possible to cover as many different scenarios as possible."

Wolkowicz notes that one of the major aims of her work is to "build and develop the mathematics of general frameworks so biologists can then look at particular sets of models and say 'Okay, my particular system fits into this framework' - and the mathematics of the model is already understood."

Wolkowicz's models can allow scientists to increase their efficiency and accuracy as they venture towards discovery. Her work has the potential to greatly alleviate the often tedious or impossible measurements associated with biology.

Hundreds of years ago Galileo recognized the importance of being able to make measurements. Today, the complexity of scientific innovations continues to increase and numbers continue to be necessary for much of this work. For this reason, mathematicians like Gail Wolkowicz strive to "calculate what is calculable, and make calculable what is not so'.

(The Natural Sciences and Engineering Research Council SPARK (Students Promoting Awareness of Research Knowledge) program was launched in 1999 at 10 universities across Canada. Through SPARK, students with an aptitude for communications are recruited, trained and paid to write stories based on the NSERC supported research at participating universities.)