WHERE MATH AND BIOLOGY MEET

At the new Center for Quantitative Biology, Northwestern Engineering mathematical scientists work alongside developmental biologists to study the "rules of life."

On an August morning in a Northwestern developmental biology lab, a team of researchers casts its collective eyes on thousands of roundworms culled from sites around the globe.

Using robotics to scan hundreds of roundworms each second, the lab members gather a range of measurements on the nematodes' growth—or, as Erik Andersen, an assistant professor of molecular biosciences in the Weinberg College of Arts and Sciences, succinctly puts it, "Getting a bunch of numbers about a bunch of worms."

It's important work. Studying these simple creatures can help unlock some of nature's most profound mysteries ranging from how metabolism sets development to how genetic changes spawn distinct differences. As such studies in life sciences become more reliant on data, biologists need mathematical models of these complex systems, expertise that mathematical scientists from Northwestern Engineering bring to a new partnership with University biologists to take research to higher levels.

"Mathematicians can put things into a model and then test that model quickly under different conditions," says William Kath, professor of engineering sciences and applied mathematics. "This can lead to more informed and calculated experiments and tilt the balance in favor of understanding things better and faster."

The commingling of developmental biology and mathematics—the aptly titled field of quantitative biology—is becoming increasingly commonplace. As developmental biologists, a group long reliant on qualitative descriptions, embrace more quantitative experiments, mathematicians have emerged as valuable allies helping to make sense of the numbers and reveal novel phenomena.

NORTHWESTERN LEADS THE WAY

In May, the University received a $10 million grant from the National Science Foundation (NSF) and the Simons Foundation to establish the NSF-Simons Center for Quantitative Biology (CQuB). The new center focuses on research in this burgeoning interdisciplinary field that marries mathematical models and quantitative analysis with molecular, cellular, and organismal biology to deepen understanding of the "rules of life."

Along with Kath, McCormick faculty involved in CQuB's research include Madhav Mani, assistant professor of engineering sciences and applied mathematics; Luís Amaral, professor of chemical and biological engineering; and Neda Bagheri, assistant professor of chemical and biological engineering, among others.

"With neither mathematics nor biology going away anytime soon, this new center is a way for us to collaborate better, generate critical mass, and drive discovery," says Kath, who is charged to lead CQuB alongside Richard Carthew, the Owen L. Coon Professor of Molecular Biosciences at Weinberg.

Using cutting-edge technologies, such as artificial intelligence, genomics, and microscopy, alongside hypothesis-driven mathematical modeling and data-driven analysis, the CQuB is addressing complex, fundamental questions about life and nature. The implications for science and medicine are significant.

While developmental biologists run the experiments and supply the data, McCormick scholars leverage statistical, computational, and big data techniques to guide experimentation and detect how genetic codes generate complex life. For instance, Niall Mangan, assistant professor of engineering sciences and applied mathematics, takes Andersen's numbers and builds mathematical models detailing the worms' developmental rates.

"The mathematical and computational scholars bring expertise, knowledge, and ideas to a previously qualitative discipline and push it into something it couldn't otherwise be," Andersen says.

NEXT UP, FROGS AND FLIES

Madhav Mani, meanwhile, specializes in developing quantitative image-analysis tools and mathematical models to guide new measurements and synthesize live imaging data. "Recent advances in live fluorescent imaging provide us with a dynamic and spatially resolved view of organismal development," Mani says. "But what's needed now are new mathematical tools and models that can help usher in an even deeper physical understanding of development."

Currently, Mani, who has long worked with experimental labs studying the dynamics of organismal development, has two in-process projects at CQuB: one with Carthew to understand fly development, and another with Carole LaBonne, chair and professor of molecular biosciences at Weinberg, to investigate frog development. "The upside of learning fly and frog development is the potential to reveal general principles," Mani says.

"Of course there is the potential of generality through evolutionary conservation, but there can also be generality at the level of emergent physical principles," Mani adds. "This is what drives me and focuses my work."

Also, the Center is awarding funding to two "high-risk, high-reward research" projects each year—10 over the grant's five-year run. "Think of this as early seed funding for a startup," Mani says. "These awards will help get daring ideas off the ground so researchers can gather the preliminary data they need to pursue later funding from the likes of NSF and the National Institutes of Health."

BEYOND THE RESEARCH

The Center offers an assortment of undergraduate, graduate, and postdoctoral programming designed to foster collaborations and deepen interest in quantitative biology. In addition, the Visiting Scholars Program offers researchers a six-month stay at Northwestern, while an annual conference on quantitative approaches in biology looks to stimulate the cross-fertilization of ideas through presentations, roundtable discussions, and a seminar on collaboration in team science.

The creation of the Center is "a watershed moment," Mani says. "The best science sits at the interface of what you want to do and what you can do. This funding gives us the confidence and time to pursue thoughtful research and to demonstrate what can be done."

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