Graph theory helps biologists study homeostasis

March 3 2021, by Laura Arenschield

Credit: Pixabay/CC0 Public Domain

Healthy human bodies are good at regulating: Our temperatures remain around 98.6 degrees Fahrenheit, no matter how hot or cold the temperature around us. The sugar levels in our blood remain fairly constant, even when we down a glass of juice. We keep the right amount of calcium in our bones and out of the rest of our bodies.

We couldn't survive without that regulation, called homeostasis. And when the systems break down, the results can cause illness or, sometimes, death.

In presentations at the American Association for the Advancement of Science's annual meeting, researchers argued that mathematics can help explain and predict those breakdowns, potentially offering new ways of treating the systems to prevent or fix them when things go wrong. The meeting was held virtually earlier this year because of the COVID-19 pandemic.

Homeostasis "is a biological phenomenon and biological systems wouldn't work without it," said Marty Golubitsky, one of the presenters and a distinguished professor of natural and mathematical sciences at The Ohio State University. "And if you had detailed, accurate mathematical models, you could numerically explore those systems, find places where this control really happens, and then you could estimate how things go wrong and how you might be able to correct it."

Scientists have a good handle on the biological reasons why that regulation happens: Certain systems in our bodies have to remain constant in order to function and keep our bodies alive. The math behind it, though, is less certain.

But understanding homeostasis—including predicting changes to it and calculating ways to keep the body regulated despite breakdowns in the body's systems that manage those regulations—could be a way to provide targeted medical care to people who need it, said Janet Best, co-author of some of the research behind the presentations and professor of mathematics at Ohio State.

"This is part of precision medicine," said Best, who is also co-director of Ohio State's Mathematical Biosciences Institute. "People are different, and you need a model that can work on different people. And we think that's what we've developed here."

Researchers at the MBI and at other institutions who study how math and biology intersect have built models to explain how the body maintains homeostasis in a variety of systems. At the heart of those models is a graph, a mathematical concept that seeks to explain how objects relate to one another. (If you took algebra or geometry in high school, you likely learned some of the basics of graph theory.)

Golubitsky and Best said that graph theory can help explain and predict changes to homeostasis in the body. That explanation, they say, could be useful for biologists and others looking for ways to intervene when homeostasis breaks down. That breakdown causes a number of problems—too much glucose in a person's blood, for example, or not enough calcium in their bones.

The AAAS presentations focused both on a graph that models how the body regulates dopamine levels through homeostasis and how graph theory helps identify properties of graphs that can help predict homeostasis. Golubitsky and Best described how dopamine and the enzymes that break it down can be represented as a mathematical formula associated with a graph.

They showed that, by calculating changes in the nodes, it might be possible to calculate or predict changes in dopamine levels. That approach could be expanded to other systems, Golubitsky said, though future study is needed to know for sure. That study is already underway, he said.

"Homeostasis is an important enough area in biology that if mathematics can contribute anything, it's a success," he said.

Provided by The Ohio State University