Pendulum swings back on 350-year-old mathematical mystery

June 10 2013, by B. Rose Huber

(Phys.org) —A 350-year-old mathematical mystery could lead toward a better understanding of medical conditions like epilepsy or even the behavior of predator-prey systems in the wild, University of Pittsburgh researchers report.

The mystery dates back to 1665, when Dutch mathematician, astronomer, and physicist Christiaan Huygens, inventor of the pendulum clock, first observed that two pendulum clocks mounted together could swing in opposite directions. The cause was tiny vibrations in the beam caused by both clocks, affecting their motions.

The effect, now referred to by scientists as "indirect coupling," was not mathematically analyzed until nearly 350 years later, and deriving a formula that explains it remains a challenge to mathematicians still. Now, Pitt professors apply this principle to measure the interaction of "units"—such as neurons, for example—that turn "off" and "on" repeatedly. Their findings are highlighted in the latest issue of *Physical Review Letters*.

"We have developed a mathematical approach to better understanding the 'ingredients' in a system that affect synchrony in a number of medical and ecological conditions," said Jonathan E. Rubin, coauthor of the study and professor in Pitt's Department of Mathematics within the Kenneth P. Dietrich School of Arts and Sciences. "Researchers can use our ideas to generate predictions that can be tested through experiments."

More specifically, the researchers believe the formula could lead toward a better understanding of conditions like epilepsy, in which neurons become overly active and fail to turn off, ultimately leading to seizures. Likewise, it could have applications in other areas of biology, such as understanding how bacteria use external cues to synchronize growth.

Together with G. Bard Ermentrout, University Professor of Computational Biology and professor in Pitt's Department of Mathematics, and Jonathan J. Rubin, an undergraduate mathematics major, Jonathan E. Rubin examined these forms of indirect communication that are not typically included in most mathematical studies owing to their complicated elements. In addition to studying neurons, the Pitt researchers applied their methods to a model of artificial gene networks in bacteria, which are used by experimentalists to better understand how genes function.

"In the model we studied, the genes turn off and on rhythmically. While on, they lead to production of proteins and a substance called an autoinducer, which promotes the genes turning on," said Jonathan E. Rubin. "Past research claimed that this rhythm would occur simultaneously in all the cells. But we show that, depending on the speed of communication, the cells will either go together or become completely out of synch with each another."

To apply their formula to an epilepsy model, the team assumed that neurons oscillate, or turn off and on in a regular fashion. Ermentrout compares this to Southeast Asian fireflies that flash rhythmically, encouraging synchronization.

"For neurons, we have shown that the slow nature of these interactions encouraged 'asynchrony,' or firing at different parts of the cycle," Ermentrout said. "In these seizure-like states, the slow dynamics that couple the neurons together are such that they encourage the neurons to fire all out of phase with each other."

The Pitt researchers believe this approach may extend beyond medical applications into ecology—for example, a situation in which two independent animal groups in a common environment communicate indirectly. Jonathan E. Rubin illustrates the idea by using a predator-prey system, such as rabbits and foxes.

"With an increase in rabbits will come an increase in foxes, as they'll have plenty of prey," said Jonathan E. Rubin. "More rabbits will get eaten, but eventually the foxes won't have enough to eat and will die off, allowing the rabbit numbers to surge again. Voila, it's an oscillation. So, if we have a fox-rabbit oscillation and a wolf-sheep oscillation in the same field, the two oscillations could affect each other indirectly because now rabbits and sheep are both competing for the same grass to eat."

More information: The paper, "Analysis of synchronization in a slowly changing environment: how slow coupling becomes fast weak coupling," was first published online May 13 in *Physical Review Letters*.

Provided by University of Pittsburgh

Citation: Pendulum swings back on 350-year-old mathematical mystery (2013, June 10) retrieved 6 May 2024 from https://phys.org/news/2013-06-pendulum-year-old-mathematical-mystery.html