

Patterns found in laboratory spark insight into nature and society

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(PhysOrg.com) -- Irv Epstein's research is proving that patterns found in mathematical formulas and chemical reactions may be used to understand economics, how an epidemic might spread and the way animal populations survive in the natural world.

Irv Epstein is fascinated with patterns — how they show up in economics, in the coats of animals and within social systems.

“If you look for patterns in social systems, you see them in housing, segregation or in how an epidemic might spread,” says Epstein, the Henry F. Fischbach Professor of Chemistry. “In general, changes don’t occur smoothly, but in patterns that often have some regularity to them.”

While his research is done in the lab, it is proving that [chemical reactions](#) and mathematical formulas may also be used to understand how organisms move and the way animal populations survive in the natural world.

Epstein’s group studies oscillatory chemical reactions (systems in which concentrations of various chemical increase and decrease over time); cross-diffusion, spatial pattern formation, transformation of chemical into mechanical energy, dynamical systems and neurobiology. He is the former dean of arts and sciences and provost at Brandeis. He’s also a founder of the Science Posse, which brings underrepresented and economically disadvantaged students to Brandeis to study science.

Hired in 1971 to teach quantum mechanics, Epstein says his interest in oscillating reactions came about while working with some eager undergraduates who were looking for a summer project. Feeling that quantum mechanics would be a bit too complex for students who had just finished their freshman year, he recalled an article in the *Journal of Chemical Education* about oscillating chemical reactions and suggested the topic.

Little did he know the project would reroute his career.

“One of the students discovered something that contradicted a statement in the classic literature and figured out what was going on,” says Epstein. “We published a paper and I became more interested in this stuff, eventually changing fields completely.”

Epstein says non-linear dynamics and exotic reactions like oscillating chemical reactions are quite rare in chemistry but very important in biology, because every living system is full of reactions in which concentrations increase and decrease, typically on a daily cycle. Unraveling this phenomenon in chemistry is offering insights into pattern formation in other systems, such as human and animal populations. To better understand diffusion, cross-diffusion and oscillatory chemical reactions, Epstein revisits a science demo popular with the elementary school set: The glass of water and drop of food coloring.

Diffusion is the phenomenon by which a species spreads out from a concentrated region to a less concentrated region. When a drop of red food coloring is placed in a glass of water, the food coloring disperses over time, resulting in a uniform pink glass of colored water. The process by which the color spreads is diffusion.

Cross-diffusion is a process in which two species are spreading- for example, if you have both a red drop and a blue drop of food coloring;

the “cross” aspect means that the distribution of one color affects the diffusion of the other.

“Chemists and physicists have largely ignored cross-diffusion,” says Epstein. “When you study diffusion in an introductory chemistry or physics course, the standard treatment completely ignores the possibility that if there are two different chemicals present one might influence the diffusion of the other.”

Using his theories, Epstein is creating mathematical models to use in the context of biological, ecological and social systems.

“Instead of having blue molecules and red molecules, maybe you have populations of two different ethnic groups that either like to be near each other or prefer to avoid each other,” says Epstein. “This might affect population patterns in a city or region.”

While he’s not expecting urban planners to track him down this year, his research is gaining momentum.

In ecology, Epstein says, one can create models to describe a predator-prey system.

“Suppose I have foxes and rabbits,” says Epstein. “If the rabbits are by themselves, they’ll distribute evenly, assuming that the food supply is evenly distributed. But if I introduce foxes into the system, then the foxes will eat the rabbits and the rabbits will tend to move away from high concentrations of foxes.” You can actually [design] a mathematical model that describes the processes by which rabbits eat grass and multiply, foxes eat rabbits and multiply and the two species move around.”

While many of the exotic reactions that Epstein examines touch on

oscillation and transience, Epstein himself is an example of steadfastness.

Epstein has spent this year at Harvard as Radcliffe Institute Fellow, but he has literally spent his adult life at Brandeis. He arrived in 1971 during the bitter end of the Vietnam War, experienced the '80s with the explosion of the space shuttle Challenger and the discovery of AIDS, the '90s with the release of Nelson Mandela, the end of the Cold War and the dawn of the 21st century, where smart phones and social media have changed the way people live their lives.

As Epstein points out, the lab facilities at Brandeis have evolved as well.

“When I started at Brandeis,” he says, “ I had only a small office and no labs. As I shifted my efforts from theory to experiment, generous colleagues offered to share lab space with me, and I eventually inherited labs of my own when they retired, but the space was less than ideal.”

Two years ago his research team moved to the newly constructed Shapiro Science Center, where, for the first time, Epstein says, they can control key variables such as room temperature and lighting levels without having to resort to Rube Goldberg-like “fixes.”

A native of Queens, N.Y., Epstein was an only child. His father was a locksmith born in Russia, his mother a school librarian. He earned a B.A. in chemistry and physics, an M.A. in chemistry and a Ph.D. in chemical physics from Harvard University and a diploma in advanced mathematics as a Marshall Scholar at the University of Oxford. After a NATO post-doctoral fellowship at the University of Cambridge, he moved from England to New England, accepting a position at Brandeis.

Twenty-one years later, Epstein was made dean of arts and sciences, moving up to provost in 1994 when the incumbent provost, Jehuda Reinharz, became Brandeis' seventh president.

Robin Feuer Miller, professor of Russian literature who served as dean of arts and sciences from 1994-2000, worked closely with Epstein during his seven- year term as provost.

“He is, quite simply, one of the smartest people I know,” says Miller. “But what I perhaps valued most about working with him was his ability to change his mind” after making an effort to understand another side. On the occasions when they disagreed, Miller said, they were always able to talk things through and come to an amicable decision.

Perhaps it’s this passion for people and progress that played into Epstein’s success in garnering a million-dollar grant in 2006 from the Howard Hughes Medical Institute (HHMI), the nation’s largest private funder of science education, to start the first Science Posse, a program at Brandeis created to attract and retain talented, underrepresented students in college-level science.

“If you look at the statistics, the state of American science, we are falling behind, says Epstein. “More than half of the graduate students in chemistry, math and physics are from other countries. And if you look even more closely, underrepresented minorities are even more underrepresented in the sciences.”

In 2010, the foundation awarded an additional \$600,000 to further develop the program. The Science Posse is an extension of the successful Posse Foundation, a liberal arts program founded in 1989 by Brandeis alum Deborah Bial ‘87, which carefully selects and trains a group or “posse” of students who act as a support system for each other.

Though the students don’t know each other when they’re chosen, between the time that they’re selected in December and when they arrive on campus in September, they will have spent 3-4 hours a week together, bonding and learning skills from time management to persuasive writing.

“Irv has vision,” says assistant biology professor Melissa Kosinski-Collins who runs the academic side of the Science Posse as well as the summer boot camp. “He genuinely cares about our scholars and makes it his goal to be there when they need him.”

Jerry Saunders II ‘11 is a member of the Science Posse. He said that working in Epstein’s lab was one of the highlights of his undergraduate career.

“Dr. Epstein is a real-time celebrity whose example constantly challenges me to always strive for more,” says Saunders. “Despite his many successes he remains interested in the work you are doing and what you hope to accomplish. Furthermore, he is more than willing to assist you in that path. He is never too busy to lend guidance.”

Eve Marder, head of division of science and the Victor and Gwendolyn Beinfeld Professor of Neuroscience, got to know Epstein in the late 1980s when the pair collaborated on building a semi-realistic model of a neuro-oscillator; in other words, they developed mathematical models used to research several kinds of neurons that are studied in Marder’s lab.

“He was doing the theory and we went back and forth discussing the biology,” says Marder. The two also wrote a grant together.

“Irv has got to be the fastest writer and fastest and best editor that I’ve ever worked with,” says Marder. “He’s astronomically quick. I think that’s part of the reason that he’s been so successful and productive.”

More information: pubs.acs.org/toc/jceda8/current

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