***Paulo Arratia***

# Fascinated by Fluid Flow

By Janelle Weaver

If you've walked down the hallways of the Towne Mezzanine in recent years, you've probably noticed colorful images and movies of flowing liquids, dancing organisms and splashing droplets. These mesmerizing displays are the visual representations of Paulo Arratia's obsession with complex fluids—everything that flows and is not water or air. It all started when Arratia was a graduate student at Rutgers University and he saw a picture of two fluids mixing together at a lab meeting. "I thought it was so beautiful. I kept asking, 'How does this happen? Why does this happen?' And it drew me in. It was love at first sight," says the associate professor of Mechanical Engineering and Applied Mechanics (MEAM).

Whether it's blood or solutions filled with polymers, Arratia is interested in studying how they flow. He uses a combination of techniques, from microfluidic devices and fluid dynamics equations to microscopy and genetic engineering, to understand fluid flow and how organisms move through complex fluids. "The hardest part is deciding what problem to work on: What is the question of the year?" Arratia notes.

One question that fascinates him is how turbulence arises as the rate of fluid flow increases. For example, when you barely turn on the faucet, water comes out smoothly, but the flow becomes turbulent as you turn the handle more. Scientists previously believed that complex fluids such as polymer solutions never became turbulent because they were too viscous and lacked inertia. But in a landmark study, Arratia discovered that turbulence actually does occur in complex fluids in the absence of inertia.

These types of breakthroughs have earned Arratia numerous honors, such as a National Science Foundation CAREER Award and his recent appointment as a Penn Fellow, as well as deep admiration from his colleagues, including John Bassani, Richard H. and S.L. Gabel Professor in MEAM. "Paulo is an incredibly creative experimentalist who is inspired to study phenomena that others say cannot possibly occur in nature," Bassani says. "There are many other examples of unusual phenomena that he has captured with exquisite photography and taught us about using elegant and often simple explanations."

## Scrutinizing Swimming

Through a collaboration with Todd Lamitina, assistant professor of Physiology in the Perelman School of Medicine at Penn, Arratia is investigating the swimming behavior of a small worm called *Caenorhabditis elegans* (*C. elegans*), an important model system in biology. The researchers have studied worms carrying a mutation that causes muscular dystrophy in humans, creating an imaging platform that could be used to screen for potential new drug treatments. By revealing how organisms swim in complex fluids such as blood, their studies could lead to the development of artificial swimmers for targeted drug delivery as well as new strategies for altering fluid environments in the human body to treat a wide variety of diseases.

Arratia and Lamitina have also developed a library of measurements related to swimming behavior to shed light on the process of aging. As organisms grow older, they move more slowly because their muscles become weaker. The genetic and molecular underpinnings of the aging process are primarily investigated in *C. elegans*. "Despite all of its advantages, tools for measuring the physiological properties of aging in *C. elegans* are extremely limited," Lamitina says. "Paulo and his group are always addressing questions in ways that we as biologists almost certainly would never have considered. So with his knowledge of fluid mechanics and our expertise in aging biology and the *C. elegans* system, we have been able to solve this problem and open up a completely new area of aging research."

## Teaching Appreciation

Before Arratia showed a penchant for science, he was a skilled athlete. Growing up in Brazil, he became a competitive tennis player by the time he was in high school and earned an athletics scholarship to compete as a college student in the United States, where he went on to play professionally for about five years and even crossed paths with Andre Agassi.

Now, Arratia finds little time for tennis, but he credits the sport for bringing him to the United States and exposing him to educational opportunities and different points of view. He attended Hampton University, a historically black university in Virginia. Putting this experience to use at Penn after earning his Ph.D. in Chemical and Biochemical Engineering at Rutgers University, Arratia has served as MEAM's Diversity Officer and co-advisor of the Penn Society of Hispanic Professional Engineers. "Paulo has been a champion for advancing diversity in engineering, and he sets an impressive example for us all," says Robert Carpick, John Henry Towne Professor and chair of MEAM.

Arratia's inclusive approach toward students is apparent in the classroom as well as the lab. "I'm always thinking about how to make the material more accessible to everyone through interactive demonstrations and movies," says Arratia, who has been recognized by the American Physical Society for the stunning images and videos of his experiments. "Even if they don't understand all of the mathematical details, students can still get an appreciation of it. Just like you don't have to be a good painter to appreciate art, you don't have to know everything about fluid mechanics to appreciate how beautiful fluid flow can be."


*Graduate students Alison Koser and David Gagnon work with Professor Arratia to research the flow of complex fluids, such as blood and liquids containing polymers and/or particles, in microfluidic devices.*