# THE SCIENCE OF CONSCIOUSNESS

A new center within the U-M Medical School takes a multidisciplinary approach to reveal what it means to be conscious.

*By Jennifer Xu, '13*

EVERY MORNING when we awake, an entire world of images, textures, sounds, and smells emerges around us. We smell coffee, hear a chorus of birds, and squint at the sun filtering through the curtains. We also experience a series of internal sensations: a stream of jumbled thoughts, awareness of ourselves, hunger, pain, happiness. All of this perceptual experience isn't the natural world; it's our subjective representation of it. This is the mysterious, impalpable quality we call consciousness.

The essential properties of consciousness have been matters of philosophical debate since the 1600s, when French philosopher René Descartes proclaimed that the mind and brain consisted of different substances. But recently, scientists and doctors have started asking new, compelling questions about how we construct and experience reality. For instance, what does consciousness look like mechanistically in the brain? Is it located in a specific region, or is it a general process? Can it be measured?

At the U-M Medical School, an official center devoted to the topic opened its doors in August: the Center for Consciousness Science. This collaboration of anesthesiologists, physicists, neurobiologists, biomedical engineers, psychiatrists, and philosophers seeks to find scientific measures of subjective phenomena. The humanities have batted around theories of consciousness for centuries. Now the question remains: can science develop a theory that objectively describes human consciousness?

THE CENTER FOR CONSCIOUSNESS SCIENCE is the brainchild of George Mashour, an anesthesiologist and professor of neuroscience in the Medical School. He envisioned a collaborative endeavor that could advance multidisciplinary research in consciousness studies while simultaneously capturing the imagination and interest of the public.

"People on the street have these fundamental questions about their existence," Mashour says. "You don't have to be a scientist to ask, 'Why am I here? Why am I aware? How is it that I know the world?'"

The center uses anesthesiology as a cornerstone of its investigations. Intuitively, this makes sense: Every day, approximately 60,000 patients in the United States are shuttled in and out of unconsciousness under the watchful eyes of anesthesiologists. But for a long time, physicians didn't understand how these anesthetics worked or what, exactly, consciousness was. Research focused more on how to administer drugs safely than on their exact mechanism on the brain.

The tide shifted in the early 1990s, when scientists started seeing anesthesiology as a tool for investigating the human brain. Anesthesiologists had been safely manipulating consciousness for more than 200 years. These established techniques offered an ideal substrate on which to test scientific hypotheses.

A typical experiment involves the electroencephalogram, a machine attached to a tentacled mesh net that is snugly fit on the subject's scalp, like something out of a science fiction movie. Subjects lie in a bed until drugs slowly extinguish their ability to respond to commands. Meanwhile, the machine records the brain's electrical activity, a code that represents the billions of neurons in the brain firing signals to each other. Somewhere, within those oscillating signals, is where scientists believe the key to consciousness resides.

Mashour says the Center for Consciousness Science is searching for both the "neural correlates and neural causes of consciousness"—signatures in the brain's electrical activity that are distinct to particular states of consciousness. He hopes to better understand the neural mechanisms underlying changes in brain state and fold those findings into current philosophical and religious theories of consciousness—objective measures of subjective experiences.

MASHOUR'S EDUCATIONAL BACKGROUND has influenced his multidisciplinary approach to these consciousness studies. "I was a mathematical and scientific moron until the age of 20," he says of his undergraduate years. Before entering medical and graduate schools at Georgetown University, he majored in philosophy. And it wasn't until he engaged in that rigorous liberal arts education did he even start to think scientifically, he says.

When he came to Michigan in 2007 with the intention of investigating the neural correlates of consciousness, the first person he collaborated with wasn't a physician or neurobiologist. It was a young complex systems physicist, UnCheol Lee, who is currently associate director of the Center for Consciousness Science.

"At the time, the mechanisms of general anesthesia had not really been thought about extensively in cognitive terms," Mashour says. He was convinced that the key to consciousness lay not in the physical properties of individual neurons, but in the connections between them. The study of complex systems offered a way to quantify such connections.

The study of complex systems is rooted in describing the ebb and flow of networks, how a simple collection of points joined by lines can self-organize into something patterned and dynamic. Discoveries in this field have been able to predict changes in the stock market, reveal the underlying structure of traffic jams, and define relationships in social networks. Network physicists view the brain as just one network out of many, according to Joon-Young Moon, a physicist who works in Mashour's lab.

Over the years, Mashour has made many striking discoveries with his collaborators. Importantly, he has found that highly diverse anesthetics—which are distinct at the molecular and neurophysiological levels—behave in a similar way when it comes to networks. Although different, these drugs all cause a breakdown in how the brain communicates with itself. Mashour's lab was the first to bring all major classes of anesthetics under one unifying framework. These findings help answer a question that has persisted since the birth of anesthesiology in the mid-19th century: How do these structurally and pharmacologically diverse drugs all cause unconsciousness?

One of Mashour's most notable findings was a study on the electrical activity in the brains of dying rats. The researchers observed a "transient surge" of highly synchronized brain activity in the 30 seconds after rats underwent cardiac arrest. This surge had a magnitude that exceeded brain activity when the rat was awake. What this means is that the 20 percent of cardiac arrest survivors who report near-death experiences might in fact be grounded in scientific fact.

His collaborators come from diverse backgrounds. In addition to network physicists, Mashour's team has included experimental neuroscientists examining mechanisms of sleep in rats, an engineer interested in augmenting communication with people with profound multiple disabilities, and a philosopher investigating how recent scientific discoveries in consciousness parallel philosophical theories. In lab meetings, conversations rapidly switch from the physical properties of networks to the evolution of animal consciousness to the psychedelic effects of magic mushrooms. These conversations make one realize how colossal the question of consciousness is and how far we are from reaching an answer.

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SCIENTISTS ARE BEGINNING TO REACH A CONSENSUS on what happens to the brain as it loses and reconstructs consciousness. Many agree that the best determinant of consciousness is the consolidation of information across different parts of the brain. Conscious people have brains that coordinate information flow both locally and across regions. When a person becomes unconscious, the local networks remain connected, but the communication across regions dies out. "The neighborhood's lights are on, in other words, but the Internet and phone lines have all been cut," writes Maggie Koerth-Baker in the New York Times. But is this information flow across regions really consciousness?

"Philosopher Joseph Levine's basic idea is that no amount of scientific evidence can entirely remove the mystery of consciousness," says Neil Mehta, a professor of philosophy at Yale-NUS who collaborated with Mashour as a doctoral student. This is because science still struggles to capture what's known as the "hard problem" of consciousness: why all this information flow in the brain happens to culminate into a subjective experience. We all live in the same world and, presumably, use the same mechanisms to process information, yet the realities we experience are vividly different. The green experienced by one person is not the green of anyone else; the same goes for the smell of coffee, the warmth of the sun, or the feeling of pain. Philosophers call this subjective experience "qualia." The main challenge of science is elucidating how a physical brain made of cells and tissues can give rise to qualia—"how imagination emerges from matter," says UnCheol Lee.

"I still don't have a good conception of consciousness in a scientific way," says Mashour. "I know how it is as I experience it. How to capture that subjectivity and describe it in quantitative, scientific terms that actually meaningfully explain the phenomenology is an enormous challenge."

Though Mashour has some idea of how the pieces might fit together, he knows that it will a take a coordinated effort from various disciplines to unite emerging neuroscientific discoveries with ancient theories of philosophy and religion. He hopes the Center for Consciousness Science will pave the way for future collaborative endeavors.

"Consciousness really has not only the ability but maybe even the requirement for this multidisciplinary approach." M

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