AN OPEN MIND

UO neuroscience—an area of research excellence and a popular new major—**promises to unlock how the brain works**

BY JASON STONE

In the 21st century, one of the most thrilling frontiers of human thought is the instrument of inquiry itself.

"Perhaps the greatest discovery of humankind is the realization that the mind—its thoughts, emotions, memories, and aspirations—is the result of patterns of activity bouncing around inside the most complex structure in the known universe," says David McCormick, a biologist and neuroscientist at the University of Oregon.

That sounds grandiose, but it's no exaggeration. When you start looking into the human brain, even the basic numbers are mind-boggling. You have about 86 billion neurons, each with around 1,000 connections to other cells. Neural impulses speed through your head at around 260 miles per hour. You've doubtless heard the brain compared to a computer. Well, check out these tech specs: your 100 trillion synapses and 100,000 miles of axons perform, on average, 10 quadrillion operations per second, and your head contains 2.5 million gigabytes of storage space.

If absorbing all this data makes your brain

hurt, that's an illusion. While the body's sensation of pain occurs inside the brain, your gray matter itself has zero pain receptors.

At the UO, smart people have had brains on their minds for decades. From innovative beginnings half a century ago, neuroscience has grown into an academic endeavor that connects scholars across disciplines, advances the university's international reputation, and drives important research breakthroughs.

AN INTELLECTUAL HOME

While many institutions labored to find an intellectual home for this emerging discipline, at the UO a culture of research collaboration provided a solid foundation. A multidisciplinary faculty group established the Institute of Neuroscience (ION) in 1979, to build, as its website states, "a highly collaborative, integrated group where biologists and psychologists work together to dissect the development and function of the nervous system."

Administered through ION, a graduate program in neuroscience soon developed, offering robust training to students across disciplines. The Center for Translational Neuroscience (CTN) was founded in 2015 to promote transformative science for social change and train graduate researchers. And in the fall of 2020, neuroscience debuted as one of the UO's newest undergraduate majors.

In laboratories and classrooms across campus and beyond, UO researchers are tackling questions that will help shape our future understanding of the brain and its peripheral nervous system.

What mechanisms generate the brain's large diversity of neurons? How do these neurons "wire up" into functional circuits, and how do the circuits produce behavior? What are the circuits of reward, addiction, memory, and cognitive flexibility?

Such questions are more than just academic. Centered as it is on the essence of what makes us human, neuroscience is being used with life-changing impact. While medical applications of neuroscience may be the first use that comes to mind, neuroscience research findings are also widely used in fields including business, technology, law, mental wellness, government, and education.

Professor and Philip H. Knight Chair Phil Fisher, director of the Center for Translational Neuroscience, is an expert in child development who studies the effects of early, traumatic experiences, such as child abuse and neglect, and strives to address them.

"At CTN we are conducting world-class research using our state-of-the-science facilities to understand the basic brain mechanisms that underlie both mental health difficulties and well-being across the lifespan," he says.

"We employ these discoveries to craft innovative intervention and prevention programs that can be implemented at scale, in settings around the United States and globally. We also focus intensively on effective science communications in order to impact social policy."

Fisher's lab houses a research program that helps children and families facing economic and social adversity. The center also includes researchers campus-wide whose work runs the gamut of stages of human development, addressing everything from academic achievement and adolescent risk-taking to smoking cessation and cancer prevention.

"CTN's pipeline from basic science to programs to policy is unique to the UO and has evolved in the strongly collaborative and entrepreneurial culture of this university," Fisher says. "I'm not sure it could have happened anywhere else."

WIDE-RANGING BENEFITS

McCormick, Presidential Chair and director of ION, says the institute is similarly engaged in research that benefits humanity. Discoveries made at the UO are enabling progress in diagnosing Parkinson's disease, detecting infant hearing problems, fine-tuning motor disorders, and improving short-term memory.

"I'm particularly excited about a $5 million grant we've recently received from the National Institutes of Health," he says. "Along with five of my colleagues spanning a

FACULTY RESEARCH HIGHLIGHTS

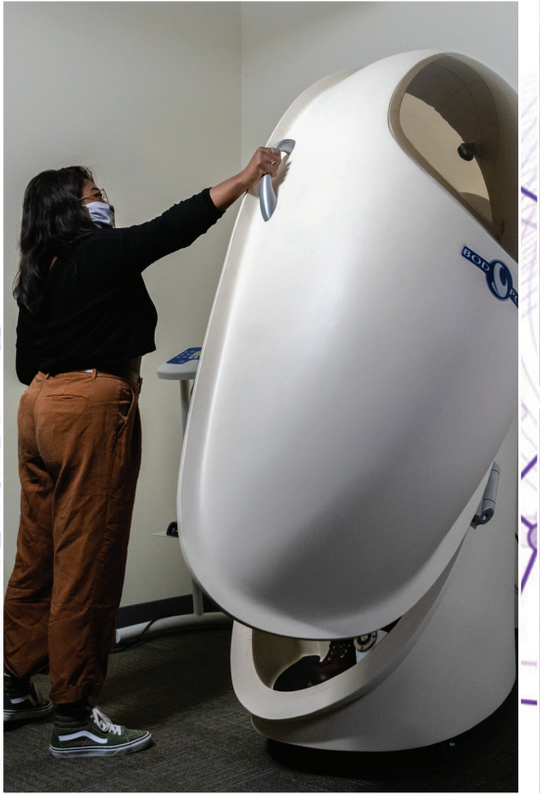
Biologist **Judith Eisen**, whose research on early development focuses on individually identified neurons, was elected to the American Academy of Arts and Sciences in 2018.

At the Phil and Penny Knight Campus for Accelerating Scientific Impact, neuroengineer **Tim Gardner** is unlocking clues to the workings of short-term memory by studying birdsong.

In EEG data, **Nicole Swann**, an assistant professor in human physiology, found markers that can aid the diagnosis of Parkinson's disease and fine-tune therapeutic treatments for motor disorders.

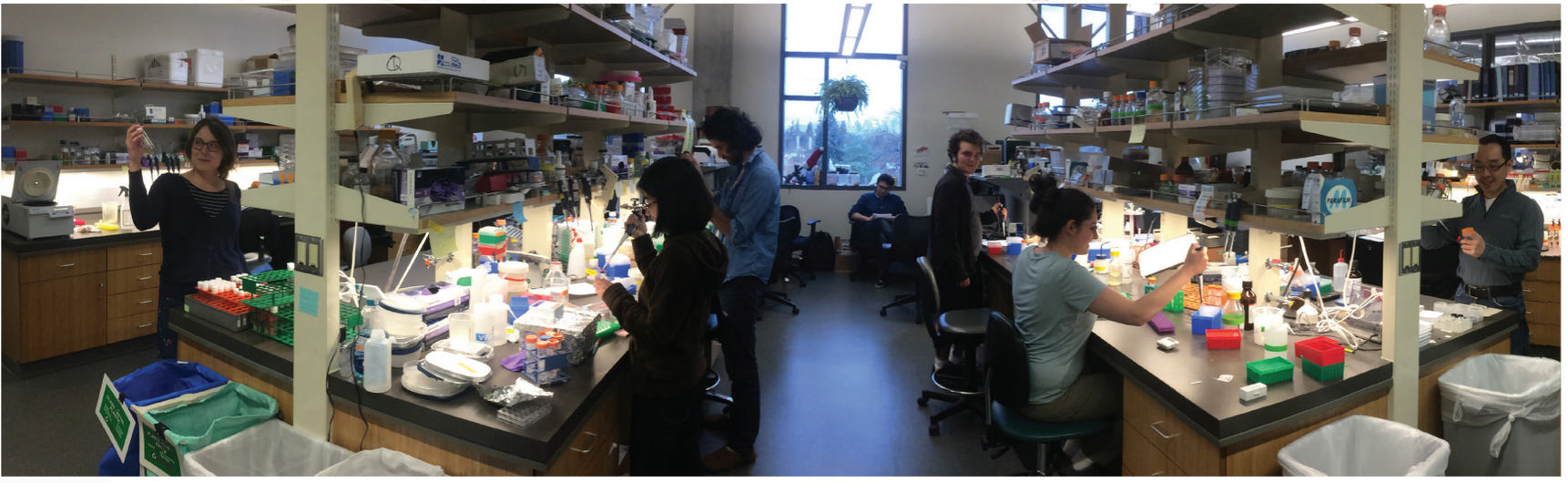
Jennifer Pfeifer, of the Center for Translational Neuroscience, addresses adolescent anxiety and mood disorders by using neuroimaging to study brain development and structure.

Biology professor **Shawn Lockery**'s research on the neuronal basis of behavior led to major innovations in the use of roundworms (*C. elegans*) for lab work and drug discovery.



CLOCKWISE FROM TOP RIGHT CORNER: Philip Fisher, of the Center for Translational Neuroscience; the UO pioneered the use of zebrafish now used internationally for research; Breyaundra Woods, class of 2022, works in the Social and Affective Neuroscience (SAN) Laboratory, which studies human goals and motivation.

BELOW: In the lab of biology professor Chris Doe, of the Institute of Neuroscience, research focuses on ***Drosophila***—the common fruit fly—and the development of stem cells into neural circuits. Lab students (left to right) Kate Walsh, Keiko Hirono, Mubarak Syed, Aref Zarin (sitting), Casey Doe (Chris's son), Emily Sales, and Sen-Lin Lai in Room 303 of the Lewis Integrative Sciences Building in 2019.



number of disciplines, I'm part of a team that will investigate cognitive flexibility—the neural mechanisms behind our ability to quickly shift our attention among differing tasks. This project is just the kind of collaborative research challenge that attracted me to Oregon in the first place. Outside of the UO, there are only a couple of other places in the world that have the number of people and skill sets and a critical mass like we do for this particular type of research."

Ultimately, the researchers hope to address conditions such as attention deficit disorder, schizophrenia, and other psychiatric diseases. But the potential outcomes could also help everyone focus on the competing tasks of learning, work, and daily life.

Biologist Cris Niell, a coprincipal investigator on the grant, notes that the project has particular resonance in the current era.

"So many of us are facing additional responsibilities and distractions," Niell says. "We have kids at home doing schoolwork and we're trying to avoid scrolling on our phones to figure out who won the election and things like that. This research is especially relevant now, when we are in this world where there's often just too many things going on for us."

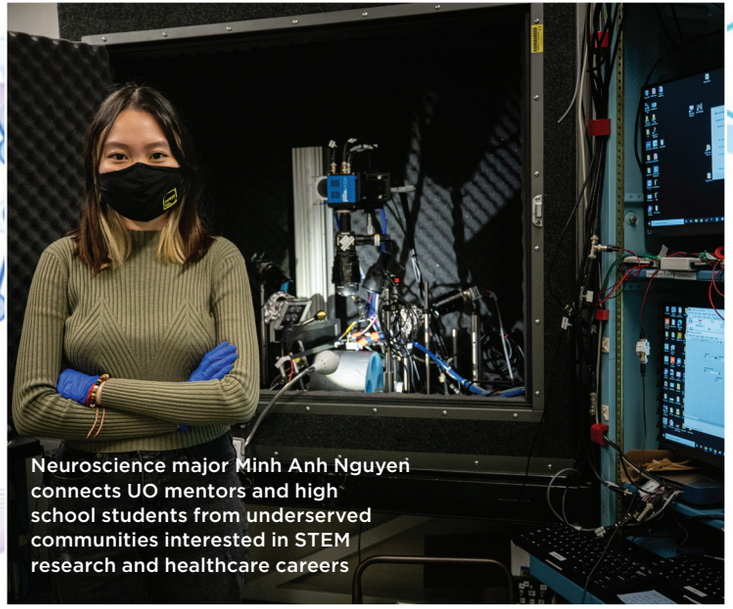
MODELING THE BRAIN'S BUILDING BLOCKS

While some neuroscientists concentrate on biology and anatomy and others focus on patterns of behavior, still others specialize in theoretical and computational methods.

Luca Mazzucato, an assistant professor in biology and mathematics and a coprincipal investigator on the NIH grant, explores human behavior through statistical physics, information theory, and machine learning. He notes that the "knowledge experts" from various fields bring more than their own research methods to UO neuroscience—each discipline also contributes a different lens of understanding.

"The theoretical part of neuroscience is based on neural networks—these are the most fascinating objects to me," Mazzucato says. "While a colleague trained in biology

NIC WALCOTT, UNIVERSITY COMMUNICATIONS (SAN LAB AND NGUYEN, OPPOSITE PAGE); CHRIS DOE (ION LAB); CHARLIE LITCHFIELD, UNIVERSITY COMMUNICATIONS (FISHER, ZEBRAFISH)



Neuroscience major Minh Anh Nguyen connects UO mentors and high school students from underserved communities interested in STEM research and healthcare careers

will tend to picture them as an organic system and a computer scientist will think of them more algorithmically, as programs—with my training in physics, I tend to picture something more like a spin glass, a physical substrate."

Cognitive functions emerge from the collective actions of many, many neurons, he explains, and experimental research now furnishes massive data sets of these neural impulses. Theoretical physics, in turn, is used to interpret all that data.

"My research takes experimental data on animal behavior, and neural data, and puts them together to build a model that hopefully can explain the computation that occurs in a certain brain area to produce a behavior, our sense of vision or taste, or even how we make decisions," Mazzucato says.

While neuroscientists are making breakthroughs in training artificial neural networks to learn and perform tasks, Mazzucato says his work is more connected to foundational biology.

"I want to have a model that not only explains the cognitive function we study but also reproduces the building blocks of the brain—the neurons and chemical processes," he says. "The work my lab is doing with computational models is performed in constant dialogue with my colleagues' labs, where they work with living brains. A lot of our work at ION is done in this way, as a close collaboration between theorists and experimental researchers."

The future of neuroscience looks expansive, reaching far beyond the lab and clinic. The Society for Neuroscience predicts the next 50 years will be a golden era of neurotherapeutics, filled with leading-edge research driving major advances in human health, wellness, economies, and societies.

At the UO, there's a palpable, positive energy as the new major ramps up and neuroscientists grow increasingly confident their discipline is at the verge of new breakthroughs and tantalizingly close to solving the human mind's whole, monumental puzzle—one with countless pieces.

"There is literally a neural circuit of anything human," McCormick reflects. "Art, love, music, economics, friendship—even fascination with the brain."

Jason Stone is a staff writer for University Communications.

Visit **around.uoregon.edu/neuroscience** for more.

NEW MAJOR IN NEUROSCIENCE

Nicole Dudukovic, a senior instructor of psychology and faculty member with the Robert D. Clark Honors College, is fascinated by memories, how they change over time, and why two people may remember the same event differently. Asked to recall her inspiration for helping to create a neuroscience major at the UO, she says the reason was obvious.

"Given the existing faculty excellence in neuroscience at the UO, it seemed like a no-brainer—pun intended—to create a neuroscience major," says Dudukovic, who directs the new undergraduate program. "There's a lot of dynamic energy and trending awareness surrounding this field, and I think this is a great example of the UO building further in an area of strength."

The first of its kind at a public university in Oregon, the major is already popular, especially among students interested in careers in research or healthcare. Since the program debuted last fall, 88 students have signed up to pursue a bachelor of science or arts in neuroscience.

Breyaundra Woods, a junior from San Diego, says she wanted to sign up on the same day she learned that the new major became official.

"Neuroscience pools knowledge from many different programs, and I think of the major as a bridge that will help undergraduates identify and connect with their specific areas of research interest," Woods says. "Everyone is very excited about the potential to pull people together from different parts of campus and form something like a family."

Isabelle Cullen, a senior from Dover, New Hampshire, has always been motivated to understand autism spectrum disorder. The new major is the one she's been waiting for.

"This is a great major specifically for students who want to get directly involved in research as undergraduates," says Cullen, who is planning to apply for PhD and MD/PhD programs.

"There are so many different types of research you can do—from molecular, cellular, behavioral, anatomical, and computational, to more exploratory types of research—and UO students have the opportunity to get connected with some of the top people in the field."

Neuroscience majors are encouraged to get hands-on experience in a lab and can also hone science communications, computational, and programming skills. It's all part of the rigorous preparation necessary for advanced studies and rewarding careers in this dynamic field.

"In creating this major," Dudukovic says, "we thought about the kinds of qualities that our faculty look for in prospective graduate students, and we designed the major so that it provides this kind of training."