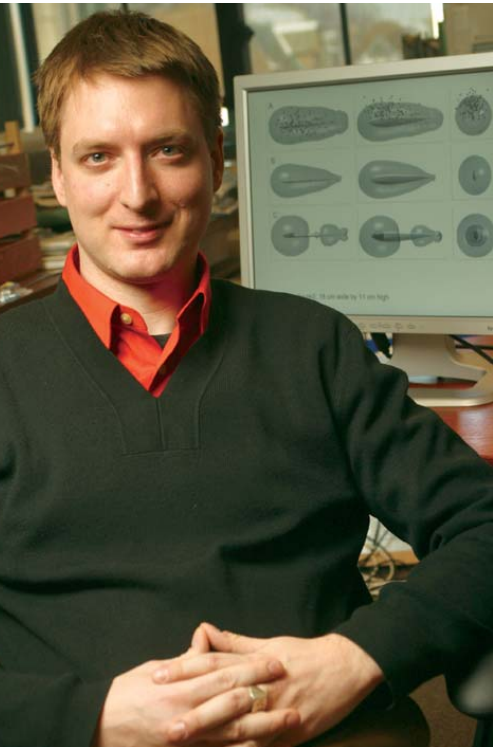


New program in neural engineering may lead to breakthroughs in rehabilitation medicine



Neural engineer Malcolm MacIver grew up in northern Ontario but spends much of his time studying a small fish native to the rivers of the Amazon basin. Why *Apteronotus albifrons*, commonly known as the black ghost knife fish? For much the same reason that MacIver's colleague, Mitra Hartmann, studies rats' whiskers. By exploring the relationship between the sensory and motor systems of these animals, MacIver and Hartmann hope to spark discoveries in rehabilitation medicine, robotics,

and the development of artificial limbs.

MacIver and Hartmann became members of McCormick's faculty in September, both hired jointly as assistant professors by two departments, biomedical engineering and mechanical engineering. Their appointments are part of Northwestern's effort to establish an interdepartmental graduate program in neural engineering, with the help of a \$1 million Whitaker Foundation Special Opportunity Award (*By Design*, spring 2003). McCormick is developing the interdisciplinary program in collaboration with the Rehabilitation Institute of Chicago, with a primary focus on restoring function in neurologically impaired people.

"The joint appointments of Mitra Hartmann and Malcolm MacIver build on a long history of interdisciplinary work at McCormick but also mark the beginning of a major commitment to neural engineering," says Matthew Glucksberg, professor and chair of biomedical engineering. "These two young professors are leading both departments in exciting new directions, and their interactions with scientists at the Rehabilitation Institute have already strengthened our ties to the Chicago campus."

The interdisciplinary reach of neural engineering is apparent in the training of these faculty members. MacIver earned a bachelor's

degree in computer science and a master's degree in philosophy from the University of Toronto, followed by a PhD in neuroscience from the University of Illinois at Urbana-Champaign. In two years of postdoctoral work at the California Institute of Technology, MacIver continued his PhD research and delved more deeply into mechanical engineering. Hartmann's training displays a similar breadth, with an undergraduate degree from Cornell University in applied physics followed by a PhD in integrative neurobiology from Caltech and three years of postdoctoral work at NASA's Jet Propulsion Laboratory.

Exploring complex connections

To facilitate collaboration and take advantage of their overlapping areas of research, MacIver and Hartmann will soon be working in adjacent labs. "We're both interested in the connection between movement and sensory inflow," explains MacIver. "We both make models to explore those complex connections." Those models include biological, computer, and robotic representations.

MacIver's lab will contain tanks of the 15-centimeter-long black ghost knife fish, which have become important models for studying sensory systems. The self-generated weak electric signals that the fish use to sense their surroundings in the dark — like the rat whiskers that Hartmann studies — constitute an active sensing system, found in animals like bats, dolphins, and whales. By generating signals, MacIver explains, animals with active sensing systems "see the world like a miner directing a headlamp."

Much of MacIver's research involves quantifying the signals emitted by knife fish, including using computer modeling to reconstruct activity of the nervous system from motion-capture data. In



Malcolm MacIver (top left) studies *Apteronotus albifrons*, the black ghost knife fish (above). Photo from Dr. Axelrod's *Atlas of Freshwater Fishes*.

one recent result, MacIver showed that knife fish are able to detect objects placed anywhere in a cylinder of space around the body. When he quantified the space into which the knife fish could quickly move — a long, ribbonlike fin along the bottom edge of the fish's body gives it unusual agility and the ability to swim in all directions — he found it to be a similar shape. The point at which these sensing and movement spaces overlap the most is a function of how much space it takes the fish to come to a halt and may offer insights into how sensing, locomotion, and the cost of sensory information interact for active sensing systems.

Such research could yield broad applications. For example, it might suggest strategies for bringing these two spaces back into alignment in cases in humans where they become disjointed, such as stroke. Other applications of his research may derive from a better understanding of how knife fish process sensory signals. This might one day help people with sensory input disorders, common to conditions that include attention deficit disorder and autism. Even the fish's omnidirectional swimming ability might be worth emulating in the design of underwater vehicles, says MacIver. That's an idea he is exploring with colleagues in mechanical engineering.

Opening doors to collaboration

Hartmann's research is equally likely to yield far-reaching applications. In her lab she concentrates on the sensory modulation of behaviors involving rhythmic movement, studying two model systems that use sensory feedback to modulate motor patterns: rat whisking behavior and bipedal locomotion. To gain an understanding of how rat whiskers interact with objects, Hartmann uses high-speed videography of rats as well as computer and hardware models of rats' heads and whiskers. The goal, says Hartmann, is to develop an active tactile sensing system that can accurately extract information about an object's spatial properties. Such information should provide insights into the underlying organization of the nervous system and the algorithms with which it encodes sensory information.

Creating a home for the kind of interdisciplinary research undertaken by Hartmann and MacIver meant breaking through traditional departmental boundaries. L. Catherine Brinson, Jerome B. Cohen Professor of Engineering and professor and associate chair of mechanical engineering, says the joint appointments will benefit both mechanical engineering and biomedical engineering. "The wonderful thing about joint hires," she says, "is that they open doors to collaboration and new directions for research. In the neural engineering program, Mitra and Malcolm have overlapping interests with the robotics and control faculty in our department. While faculty from

biomedical engineering and mechanical engineering have had collaborative research projects in the past, with the new faculty the collaborative activities in this area are being invigorated."

For their part, Hartmann and MacIver have found the University to be an ideal place for their work. "Mitra and I are using engineering approaches to understand fundamental issues in neuroscience and movement," says MacIver. "Where does work like that find a home? At Northwestern we can combine principles of mechanical and biomedical engineering and find applications for our research at the Rehabilitation Institute of Chicago. We can study nervous systems and build robotic models. I was attracted to Northwest-

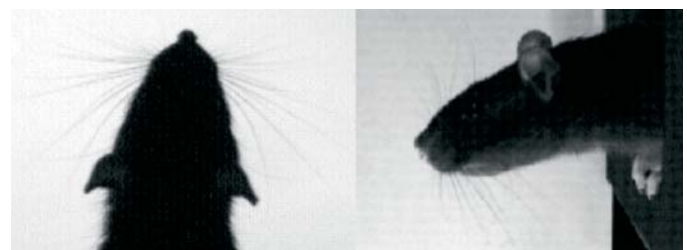
"The joint appointments of Mitra Hartmann and Malcolm MacIver build on a long history of interdisciplinary work at McCormick but also mark the beginning of a major commitment to neural engineering." — Matthew Glucksberg

ern because of its interdisciplinary programs and the opportunity to work with three different groups of people with common goals."

A further attraction was the strong neuroscience community at Northwestern, exemplified by the Northwestern Institute for Neuroscience, to which MacIver and Hartmann belong.

Brinson echoes MacIver's enthusiasm. "The value of work that extends beyond a single department," she says, "is that it is by its very nature interdisciplinary: In the collaborations that develop, we devise new ways to look at problems, new methods of solution, and revolutionary progress. And what more exciting area for progress than neural engineering — concepts of sensing, locomotion, biomechanics, biomaterials, and control — we all can see how the research will immediately help people to have better lives."

—Leanne Star



Mitra Hartmann (top right) does research on how rat whiskers interact with objects (above).