McGovern Institute for Brain Research

The McGovern Institute for Brain Research at MIT is a research and teaching institute committed to advancing human understanding and communications. The goal of the McGovern Institute is to investigate and ultimately understand the biological basis of higher brain function in humans. The institute is conducting interdisciplinary research that combines and extends the results of recent breakthroughs in three major interrelated areas: systems and computational neuroscience, imaging and cognitive neuroscience, and genetic and cellular neuroscience.

Personnel

We have recently identified a new director, so Phillip Sharp has completed his last full year as director of the McGovern Institute.

There has not been a faculty search this year; thus we have no new faculty to report on for academic year 2004.

Lori Harris, administrative assistant for the office, transferred to another MIT department and was replaced in March 2004 by Emily Wilkoff. There is a search underway for a development officer for the McGovern Institute.

Activities

The McGovern Institute held its 2nd annual retreat September 10–11, 2003, at the Sea Crest Resort on Cape Cod, Falmouth, Massachusetts. There were approximately 90 participants from the labs of the McGovern investigators as well as a few visitors from other departments at MIT. Each lab put forth two members who each gave a 15, minute presentation on their current research. The evening was complete with a lobster clambake and a well, attended poster session.

The McGovern Institute cohosted a two, day symposium featuring His Holiness the Dalai Lama on the MIT campus September 13–14, 2003. The "Investigating the Mind Meeting," which was oversubscribed within two hours, created a great deal of media interest. Held at the Kresge Auditorium on the MIT campus, our cosponsorship joined leading psychologists, neuroscientists, advanced Buddhist scholar, practitioners, and

McGovern, Lore McGovern, Elizabeth McGovern, Gerald Fischbach of Columbia University, Robert Langer from MIT, Edward Scolnick from Merck and Company, Robert Silbey from MIT, Sheila Widnall from MIT, and Torsten Wiesel of Rockefeller University.

The institute is also guided by a distinguished Scientific Advisory Board composed of some of the world's most prominent neurobiologists. The board did not meet in AY2004, choosing to postpone their annual meeting until a new director has been named. Members of the board are John Duncan, Medical Research Council, England; Eric Kandel, Columbia University; Nikos Logothetis, Max Planck Institute for Biological Cybernetics; Carla Schatz, Harvard Medical School; Charles Stevens, Salk Institute; and Robert Wurtz, National Eye Institute.

Awards and Honors

Emilio Bizzi was awarded an honorary doctorate degree from the University of Genoa, Italy.

Robert Horvitz was awarded the following: honorary DSc degree, Cambridge University, Cambridge, England, 2004; honorary member, American Philosophical Society, 2004; honorary MD degree, University of Rome, Tor Vergata, 2004; honorary member, the Physiological Society (London, UK), 2004; member, Institute of Medicine (US National Academy of Sciences), 2003.

Ann Graybiel was awarded an honorary doctor of science degree from New York's Mount Sinai School of Medicine and also received the Radcliffe Alumnae Achievement Award and the National Parkinson Foundation "Women Leaders" Award.

Nancy Kanwisher was awarded the Ellen Swallows Richards professorship.

Phillip Sharp was awarded the following: honorary member, the National Academy of Sciences–Republic of Korea, 2004; the Novartis Drew Award in Biomedical Research, 2003; the University of Illinois Alumni Achievement Award, 2003.

Tomaso Poggio organized the Institute for Pure and Applied Mathematics workshop on "Mathematical Foundations of Learning (Inverse Problems)" in November 2003 and was a member of the committee for a special issue of the *Foundations of Computational Mathematics Journal* in honor of Steve Smale.

Research Accomplishments

Research in the Bizzi laboratory focuses on the study of the physiological mechanisms underlying motor learning and motor control. Emilio Bizzi's lab has designed a virtual reality system linked up to the internet that encourages patients to retrain their disabled arm by making a computer image of an arm perform various movements. The system is geared toward stroke patients who need to practice repetitive exercises to regain some arm mobility. People who have suffered a partial loss of arm and hand control after a stroke might soon be spared the arduous trip to the hospital for physiotherapy. Instead they'll be able to log on to the internet at home and run through the rehabilitation exercises designed by their doctor.

With respect to motor control, the Bizzi lab has tested the hypothesis that linear combinations of muscle synergies represent a general mechanism for the construction of motor behaviors. The Bizzi Lab was able to demonstrate that the electromyographic patterns observed during different motor behaviors in the intact frog could be described with few time,varying muscle synergies. This result represents a remarkable simplification in view of the high dimensionality of the space of all possible time,varying muscle patterns. Recently the lab has investigated the role of afferent sensory feedback in the specification of the timing and the amplitude of muscle synergies. With respect to motor learning, the Bizzi Lab has been recording from the primary motor areas of the frontal lobe of the nonhuman primate in order to investigate the way in which the motor cortical cells control the muscle synergies of the arm and the hand. The Bizzi Lab has been studying motor learning in patients with impaired mobility caused by a stroke affecting the motor areas of the central nervous system. The major goals of the project are to assess the feasibility of a remotely supervised, computer,enabled physical therapy device administered over high,speed telecommunications for patients recovering from stroke. An ongoing randomized trial has demonstrated both the feasibility and the efficacy of the approach.

James DiCarlo's lab continues to focus its work on understanding the neuronal mechanisms that enable visual object recognition to tolerate real,world changes in object position, size, and clutter. They have recently uncovered evidence from neuronal recordings in primates that strongly supports the nonintuitive hypothesis that the position tolerance of object recognition is not a fully "built,in" ability of the brain, but that it depends on visual experience. In collaboration with Tommy Poggio's group, they have begun studying the neuronal mechanisms that underlie visual recognition in real,world clutter. In collaboration with Nancy Kanwisher's group, they are exploring the effect of visual experience on the brain's representations of visual objects at the level of fMRI in both human and nonhuman primates.

Ann Graybiel's lab conducts an integrated research program to study the physiology and cellular signaling of cortico,basal ganglia circuits during the learning and the performance of behavioral sequences and habits. They discovered that large,scale changes occur in the patterns of neuronal activity in the striatum as animals learn and consolidate their learning in such tasks. Many of these plastic changes are reversed by episodes of extinction in which rewards are not available, while at least some changes can be reversed by reinstating the reward in reacquisition training. A central question addressed in their experiments is how the activity of neurons in cortico,basal ganglia loops changes during learning and what activity characterizes these neurons when animals have been trained to the point at which they carry out tasks in a highly automatic fashion.

Over the past year, Christopher Moore's lab has focused on testing a novel hypothesis of tactile perception and on developing new brain imaging techniques. The whisker sensory system is a crucial perceptual system for rodents. Because rodents are available to molecular techniques, this system is emerging as the predominant one for probing fundamental principles of sensory encoding. In a series of four publications, they put forward evidence that rodent touch perception may work through mechanisms similar to those used by the ear. In overview, the resonance properties of the whiskers on the face may provide frequency-specific tactile information that is translated into a neural code, much as the biomechanics of the ear allow mammals to discriminate pitch.

The Moore lab has also been developing novel brain imaging techniques. They developed a system for scanning monkeys in a 9.4 T MRI scanner, providing a resolution of ~500 microns for neural activity images and 125 microns for anatomical images. *These images are probably the highest resolution maps ever recorded of a functioning primate brain*. Ongoing studies in the lab also include human fMRI (at 3T) of stimuli parallel to those employed in their monkey imaging studies. They also built a novel optical imaging system using a recently developed CCD camera. With this system, they can image neural activity across several millimeters of the brain at 10–100 micron resolution. This system is an advance because it permits high-resolution imaging in both low and high light background conditions and operates at faster rates than traditional brain optical imaging systems, permitting more rapid brain map acquisition.

The Poggio lab continues to study the problem of learning, which they believe is at the core of the problem of synthesizing intelligence in machines and understanding how the brain works. Their research effort is in three main directions: theory, engineering applications, and computational neuroscience. In the theory domain, they have made a significant contribution, which is increasingly recognized to be one of the foundations of learning theory. Their engineering applications include bioinformatics with the Broad Institute and the Department of Biology, computer vision for recognition, and trainable man-machines interfaces. In the neurosciences, they have continued to work on models of visual cortex underlying object recognition and object categorization, collaborating with the Miller, Ferster, Koch, and DiCarlo labs in using the models as a powerful tool to analyze, interpret, and plan experiments. Their funding is increasingly diversified among the National Science Foundation, the National Institutes of Health, the Defense Advanced Research Projects Agency, the Office of Naval Research, and private companies.

Phillip A. Sharp
Director
Institute Professor

More information about the McGovern Institute can be found on the web at http://web.mit.edu/mcgovern/.