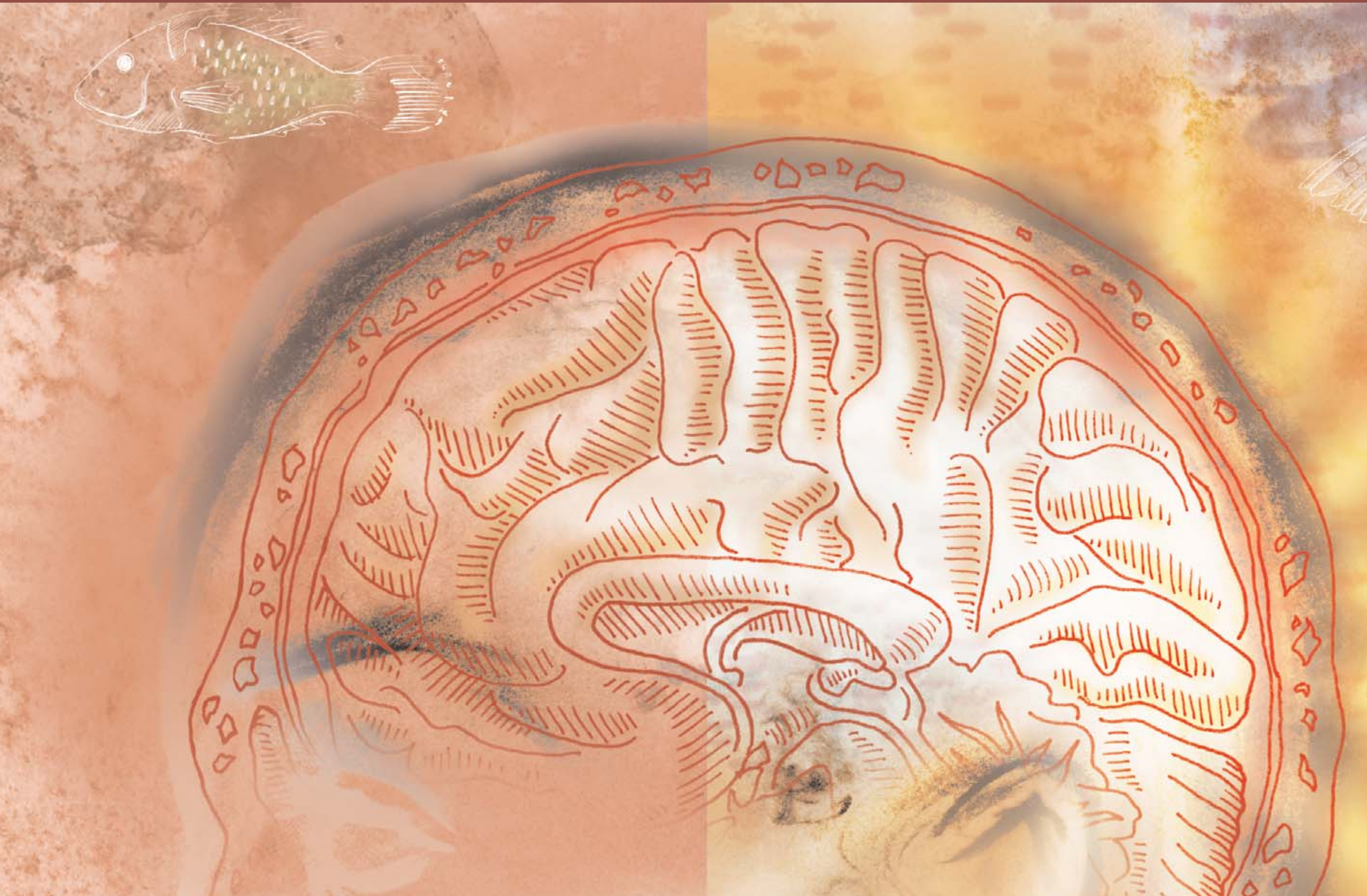
Center for Behavioral Neuroscience | *A National Leader in Brain Research*



A Model for Accomplishing ‘Big Science’

In 1999, eight metro Atlanta colleges and universities began an experiment to test the power of multi institutional, interdisciplinary collaboration to accomplish “big science.” The idea behind the fledgling Center for Behavioral Neuroscience was that by bringing together scientists to share ideas and resources, much more could be accomplished than by a single laboratory working alone.

What began as an experiment has succeeded beyond anyone’s expectations. CBN’s collaborative research programs are recognized today as a model for the execution of science that can be applied to other areas of bioscience—from behavioral ecology to biomedical research. Because of CBN, scientists today have a much deeper understanding of the neurobiology of social behavior. Among other discoveries, CBN researchers have identified a genetic basis for social bonding between animals and mapped the neurocircuitry for the brain’s fear mechanisms. These findings are leading to new discoveries about a range of disorders from anxiety to autism.

In addition to scientific discovery, CBN has built a comprehensive education program to train the next generation of neuroscientists and increase science literacy. Initiatives from elementary school through the post-doctoral level capture and retain students in neuroscience education programs and prepare them for scientific careers. CBN also works with its community partners, Zoo Atlanta, the Fernbank Museum of Natural History, the Georgia Aquarium and the Georgia Biomedical Partnership, to develop education programs that promote science literacy among the general public.

We encourage you to learn more about our programs in this viewbook.

H. Elliott Albers

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CBN Director

National Science Foundation Science and Technology Center Program

The National Science Foundation (NSF) established the Science and Technology Center (STC) Program to enhance the nation's economic competitiveness by fostering collaborations in the research community. NSF currently funds 17 STCs pursuing research in a variety of specialized disciplines. These partnerships are charged with developing high-risk research programs to yield scientific discoveries and new technologies. STCs also explore more effective ways to educate students about science and facilitate the exchange of knowledge among academia, industry and national laboratories.

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History

In 1999, CBN was launched with $19.9 million in initial funding from NSF and $7.5 million in infrastructure support from the Georgia Research Alliance (GRA). In 2004, NSF awarded CBN a $17.3 million grant renewal, ensuring funding through November 2009. GRA also committed an additional $8.5 million over the same period.

An Emerging Player in the Life Science Industry

Georgia is ranked among the top eight biotech states and has been identified as a new hub of biotechnology development in the southeast United States. In the field of behavioral neuroscience, experts have identified CBN as a strong player in the region's biotech industry.*

JACK KEARSE, EMORY HEALTH SCIENCES COMMUNICATIONS

* Source: "From Lab to Market: A Strategic Framework to Make Georgia a Leader in the Biosciences," Technology Partnership Practice, Battelle Memorial Institute, January 2002.

About CBN

Atlanta skyline

CBN is a consortium of eight metro Atlanta colleges and universities, including lead institution Georgia State University, Emory University, Georgia Institute of Technology and the five schools comprising the Atlanta University Center (Clark Atlanta University, Morehouse College, Morehouse School of Medicine, Morris Brown College and Spelman College).

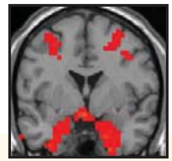
CBN consists of interdisciplinary programs integrating research, education and knowledge transfer. More than 100 neuroscientists lead the research program, along with a cadre of more than 50 graduate students and 25 postdoctoral researchers, to study the basic neurobiology of social behaviors. CBN also directs a comprehensive education program designed to train the next generation of neuroscientists and improve science literacy.

Research, education and knowledge transfer

Capabilities and Facilities

Five service cores support research in CBN collaboratories:

- Behavioral Technology Core develops tools for capturing and quantifying behavioral data;
- Cellular Core develops techniques, such as viral vectors, to study the roles of specific receptor proteins in complex social behaviors;
- Imaging Core develops new and improved imaging technology, including positron emission tomography (PET) and functional magnetic resonance imaging (fMRI), to visualize and interpret brain activity;



An fMRI cross-sectional slice of the human brain.

- Molecular Core profiles gene expression in areas of the brain or individual neurons using DNA microarray technology;
- Tract Tracer Core uses attenuated viruses to map entire neural circuits involved in complex behaviors.

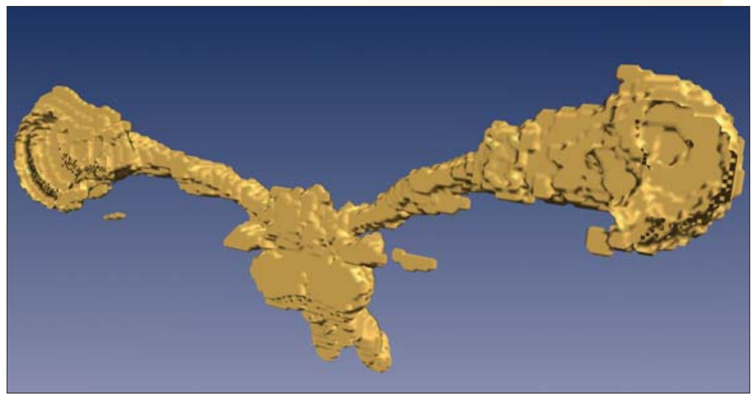
CBN researchers conduct studies in state-of-the-art laboratories throughout the consortium. Among the facilities are a 92,000-square-foot neuroscience building at the Yerkes National Primate Research Center at Emory University, which contains PET and MRI equipment. By the end of the decade, CBN also will benefit from the construction of two new science facilities at Georgia State University.

The new neuroscience building at the Yerkes National Primate Research Center.

Technology Development

CBN has developed an array of new technologies to enhance neuroscience research. They include:

- Magnetic resonance imaging (MRI) that employs manganese to study brain structures in animals as small as crayfish;
- Visual- and radio-frequency-based tracking systems to study spatial cognition and behavior in non-human primates;
- Three-dimensional multielectrode array that allows studies of living disembodied rat brain tissue connected to robotic or computer-simulated bodies;
- High-speed cameras to image the actual firing of individual neurons;
- A molecular technique combining gene knockout mice and gene transfer enables researchers to determine how genes acting in specific brain regions control a variety of social behaviors;
- A post-traumatic stress disorder testing system enables clinicians to objectively measure impairment in the brain's fear control mechanisms.



A three-dimensional view of the crayfish brain yielded through manganese-enhanced MRI.

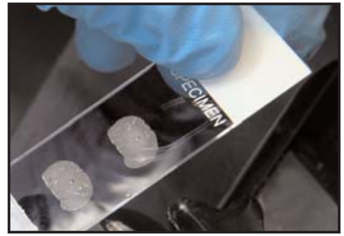
Experimental Model Systems

Animals and humans share many of the same genes and biological processes. As models, experimental animals are an indispensable part of the study of behavioral neuroscience. CBN researchers employ a variety of animal models, including nematodes, crustaceans, birds, frogs, lizards, mice, rats, birds, primates and humans. Findings from CBN animal studies have already led to clinical applications, including a new treatment for anxiety-related disorders.

Research Teams

CBN investigators are organized into interdisciplinary teams called collaboratories that build synergies among laboratories using different models, technologies and approaches. They include the following groups:

- Affiliation Collaboratory examines the neural mechanisms underlying affiliative behaviors, including pair bonding, approach, recognition and parental care;
- Aggression Collaboratory studies the common biological processes involved in fear and aggression and means to control them;
- Fear Collaboratory focuses on the neural mechanisms of fear learning and ways to control them;
- Reproduction Collaboratory investigates sexual behavior from the molecular to the system level using different animal models.
- Reward and Reinforcement Collaboratory focuses on identifying common brain areas, circuit architecture, and neurochemicals involved in reward mechanisms for various behaviors.
- Memory and Cognition Collaboratory addresses broad questions about memory and cognition, particularly as they relate to social behavior.



Collaboratories are designed to build synergies among many laboratories using different models, technologies and approaches.

Affiliation Collaboratory

At A Glance

Affiliation Collaboratory research focuses on social recognition, social attachment, attractant pheromones and maternal influences on behavior. The collaboratory has discovered:

- The genes for vasopressin (AVP) and oxytocin (OT) regulate social recognition;
- AVP acts on the brain's reward circuitry to regulate the formation of social attachments between animals; transferring a receptor gene for AVP into the brain increases social or pair-bonding behavior in male prairie voles and makes promiscuous male meadow voles monogamous; differences in the length of seemingly non-functional "junk DNA" in the AVP receptor gene affect the degree of pair-bonding behavior of male prairie voles;
- Genetically identical animals placed in different pre- and post-natal environments will differ dramatically as adults in their tendencies to form social attachments depending on the behavior of the rearing mother towards her offspring.

Findings from the Affiliation Collaboratory have potential relevance to understanding autism and drug addiction.

CBN researchers made promiscuous male meadow voles monogamous by manipulating a single gene.

Aggression Collaboratory

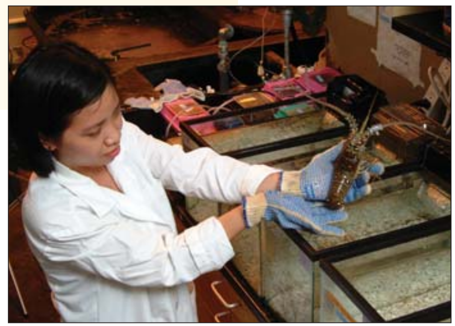
At A Glance

The Aggression Collaboratory focuses on the neural and behavioral mechanisms governing social hierarchies. Discoveries include:

- Oxytocin (OT) regulates behaviors involved in the formation of social hierarchies in animals; social experience and social context affect OT's release in the brain;
- Social subordinance results in the release of neurochemicals associated with chronic stress and adversely affects digestive function in some animals;
- Termites, one of the few non-human species that engage in organized warfare, fight more intensely when deprived of and competing for food;
- The defensive secretion of the *Aplysia* sea slug contains an antimicrobial protein with potential industrial applications;
- Food competition between male rats alters vasopressin V1a receptor binding density in the lateral septum;
- The brain regulates the initial stages of sex change in the bluebanded goby.

The bluebanded goby is used in studies of aggression and reproduction.

The spiny-tailed lobster is a model for studies of aggression.



Termites, one of the few non-human species that engage in organized warfare

Fear Collaboratory

At A Glance

The Fear Collaboratory focuses on understanding the neural processes underlying fear and anxiety-related disorders. Investigators examine the brain's fear mechanisms, specifically the role of the amygdala, from molecular, cellular, behavioral and electrophysiological perspectives. Their discoveries include:

- The medial amygdala plays a key role in fear learning and extinction in certain environments;
- Virtual reality technology used in combination with a cognitive enhancer, d-cycloserine, improves the effectiveness of psychotherapy in treating phobias, such as fear of heights;
- Rhesus macaque monkeys show greater fear-related responses to startle stimuli when reared by their natural mothers than when reared by a peer group of monkeys;
- Brain-derived neurotrophic factor, a neurochemical involved in learning and memory, and its receptor are both highly activated in the amygdala of rats after they learn to fear a light paired with a mild electric foot shock.

The Fear Collaboratory studies ways to control phobias and anxiety-related disorders.

CBN researchers have developed a post-traumatic stress disorder testing system to objectively measure impairment in the brain's fear mechanisms.

Rearing conditions affect fear response development in rhesus macaques.

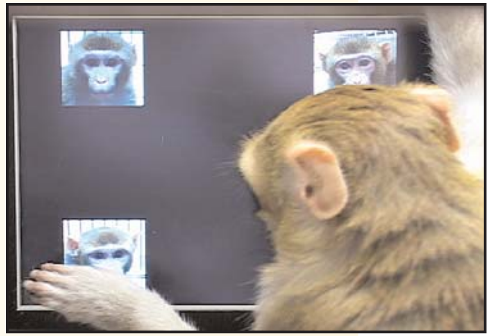
Memory and Cognition Collaboratory

At A Glance

The Memory and Cognition Collaboratory addresses broad questions about memory and cognition, particularly as they relate to social behavior. Areas of focus include, but are not limited to:

- Individual recognition;
- Processing of social signals;
- Comparative cognition;
- Social dimension of mental dysfunction.

A rhesus monkey makes his choice in an individual recognition experiment.



Current projects involving Memory and Cognition members include:

- Functional imaging of the brain processes underlying perception and memory of emotional stimuli in awake monkeys;
- Automated cognitive testing of apes at Zoo Atlanta;
- Studies of the role of the amygdala in social behavior in semi-free ranging monkeys.

Reproduction Collaboratory
At A Glance

The Reproduction Collaboratory has made significant discoveries about sexual behavior in five major areas: the medial amygdala, estrogens, energetics, steroid responsiveness and sex differences. Discoveries include:

- Phytoestrogen supplements, an increasingly popular soy-derived alternative to estrogen replacement therapy, make male rats anxious, but calm females; dietary soy supplements also do not produce the same molecular and behavioral effects on the brain as endogenous estrogen and can actually have anti-estrogenic effects on female sexual behavior;
- Medroxyprogesterone acetate, a synthetic form of the naturally occurring steroid hormone progesterone widely used in contraceptives and hormone replacement therapy, increases aggression and anxiety and reduces sexual activity in female monkeys;
- *Caenorhabditis elegans*, a hermaphroditic self-fertilizing nematode, produces a pheromone that appears to regulate the male sex drive;
- Food restriction significantly suppresses both reproductive and maternal behaviors in rodents;
- Visual sexual stimuli produce much higher levels of activation in the amygdala of the male brain than the female brain.

CBN scientists have found a commonly sold phytoestrogen supplement interferes with the normal estrogenic processes in the female brain.

Studies of zebra finches are examining sex differentiation in the song system.

Reward and Reinforcement Collaboratory

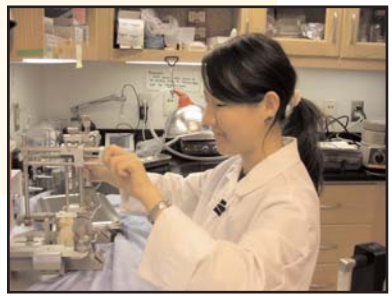
At A Glance

The Reward and Reinforcement Collaboratory focuses on identifying common brain areas, circuit architecture, and neurochemicals involved in reward mechanisms for various behaviors. Areas of interest include, but are not limited to:

- How concepts of brain reward and reinforcement systems apply to studies of pair bonding, mother-offspring dyads, reproduction, and food intake;
- Commonality vs. specificity of reward and reinforcement circuitry across stimulus modalities;
- The role of neuroeconomics in determining behavioral output.

Current projects include:

- Defining molecular mechanisms involved in assigning positive vs. negative valence to environmental stimuli in rat reward and fear models;
- Comparing nucleus accumbens efferents in processing articifical rewards (drubs or intracranial electrical stimulation) and natural rewards (food) in rat operant models.



Understanding the specific neurochemistry and neurocircuitry underlying "reward" and "reinforcement" are primary goals of the Reward and Reinforcement Collaboratory.

Undergraduate, Graduate and Postdoctoral Programs

CBN's undergraduate and graduate programs focus on recruiting and retaining women and underrepresented minorities in neuroscience education programs. The programs also introduce students to an array of science career pathways.

- **Behavioral Research Advancements in Neuroscience (BRAIN)** — This 10-week summer undergraduate program, which targets women and underrepresented minorities, consists of an introduction to neuroscience and research immersions in CBN laboratories;
- **CBN Graduate Scholars Program** — The non-degree granting program, which includes a stipend, provides research opportunities in CBN laboratories for graduate students enrolled in neuroscience programs within the consortium;
- **CBN Postdoctoral Fellows Program** — CBN provides full salary support and training to postdoctoral fellows who collaborate with two or more CBN faculty members.

The programs introduce students to myriad science career pathways.

Building an Education Pipeline

CBN has developed an education pipeline beginning at the elementary school level designed to improve science literacy and spark students' interest in neuroscience. K-12 education programs include:

A Brain Camp student builds an imaginary brain out of Play-Doh.

- **Atlanta Brain Bee** —This annual competition tests high school students' knowledge of neuroscience;
- **Institute on Neuroscience (ION)** — The eight-week summer program for metro Atlanta high school students consists of lectures, laboratory tours and independent research projects with CBN scientists;
- **Brain Camps** — Summer brain camps targeting African-American middle school students in Atlanta feature brain dissections and instructional units on sensory systems and drugs of abuse;
- **Neuroscience Exposition** —This annual two-day program at Zoo Atlanta consists of neuroscience educational activities for middle school students.
- **Lending Library** — A collection of neuroscience resources, including brain specimens and models, is available for loan to K-12 science teachers;

The education pipeline is designed to spark students' interest in neuroscience.

Professional Development for Science Teachers

CBN professional development initiatives provide K-12 educators with the knowledge and tools to teach neuroscience effectively. Teachers learn about behavioral neuroscience research methods and are guided in the development of their own neuroscience lesson plans. Programs include:

- **Teacher Workshops** — Annual summer workshops for middle and high school teachers explore behavioral neuroscience and other scientific disciplines. Teachers demonstrate their command of the material through lesson plans they develop based on content presented during the workshops;
- **Conferences** — National conferences involving teachers, scientists and students examine best practices in science education with the goal of developing better teaching methods;

Teacher workshops provide K-12 educators with the knowledge and tools to teach neuroscience effectively.

CBN educator Laura Carruth (left) shows a metro Atlanta public school teacher how to read a DNA gel.

Community Partnerships

Community partnerships are a central component of CBN's efforts to improve science literacy and attract more women and underrepresented minorities to neuroscience. In Atlanta, CBN has forged alliances with Zoo Atlanta, the Fernbank Museum of Natural History, the new Georgia Aquarium and the Georgia Biomedical Partnership. The center works closely with these organizations to develop neuroscience-related educational exhibits and activities including:

- Exhibits on fish behaviors, gorilla and orangutan learning and cognition and panda bear reproduction;
- An annual neuroscience exposition at Zoo Atlanta consisting of educational activities about the brain;
- Professional development workshops for Georgia science teachers at Zoo Atlanta;
- Development of new course linking bioscience and business.

FERNBANK MUSEUM OF NATURAL HISTORY

GEORGIA BIOMEDICAL PARTNERSHIP, INC.

GEORGIA AQUARIUM

ZOO ATLANTA

The Dana Alliance for Brain Initiatives

INSTITUTE FOR BIOMEDICAL PHILOSOPHY

Taz, a maile silverback gorilla at Zoo Atlanta, is trained on a variety of tasks with the new training panel in the Willie B. Conservation Center.