Department of Brain and Cognitive Sciences
Report to the President, year ended June 30, 2024

Introduction: Our Mission and Approach

The mission of the MIT Department of Brain and Cognitive Sciences (BCS) is to understand the mind by studying the mechanisms of the brain.

Since its founding in 1964, the department has been anchored in the idea that an understanding of how the brain gives rise to the mind requires basic science investigation at multiple empirical scales of analysis—genes, molecules, synapses, neurons, networks of neurons, brain regions, individuals, and groups of individuals—in combination with models that encapsulate our understanding by formally describing the links between each of those levels.

BCS strives to provide a collaborative environment in which the world's most talented researchers can organically pursue new ideas about the underlying mechanisms of the brain and how they give rise to the mind. Our researchers often cross the boundaries of established fields or invent new disciplines entirely. Conceptually, however, we think of our research in four broad categories:

- **Cellular and molecular neuroscience,** which strives to understand the brain at its most fundamental level by studying the mechanisms that control construction and maintenance of cellular and molecular circuits;
- **Systems neuroscience**, in which scientists examine how patterns of neuronal connections (circuits) give rise to patterns of neuronal activity, and how those patterns of neural activity give rise to overt behavioral and different internal neural states;
- **Cognitive science**, whose goal is to is to characterize the nature of human knowledge—its forms and content—and how that knowledge is used, processed, and acquired; and
- **Computational approaches**, which use the tools of mathematics and computers to develop theoretical models that test and expand our understanding of the workings of brain and behavioral processes.

In pursuit of our mission, we are guided by a set of principles:

Principle 1: Build a research community of uncompromising excellence.

We aim to be at the forefront of every research area we represent and to maintain our status as one of the top educational programs in neuroscience and cognitive science in the world. Our overarching priority is to maintain an uncompromising focus on recruiting and cultivating outstanding faculty, students, researchers and staff. We strive to identify early-career faculty who we predict will not only become international leaders in their subfield but seek to integrate results across two or more

empirical levels (see Principle 3 below), often including the use of, or collaboration with, computational models and methods.

Principle 2: Promote and maintain excellence in education and training of scientific leaders.

MIT has a tremendous opportunity to shape the world by training the next generation of leaders in brain and cognitive sciences. For both undergraduate (Course 9 and Course 6-9) and graduate students (doctoral and Course 6-9 MEng), our goal is to ensure that students are prepared for future careers, whatever path they may choose. For postdoctoral trainees, we seek to augment their ability to focus on developing and executing cutting-edge research projects.

Principle 3: Build formal bridges across empirical levels.

We believe the future of our field will depend on utilizing collected data to build predictive, mechanistic models that integrate traditionally distinct subfields into a coherent understanding of how mechanisms of the brain give rise to the mind. Thus, placing great emphasis on encouraging and facilitating collaborations across laboratory groups is critical to building bridges across empirical levels, from molecules to neurons to circuits to algorithms to cognition.

Principle 4: Proactively interface with other parts of MIT to seek out links between basic science and its applications.

Neuroscience and cognitive science have the potential to shape, and be shaped by, many elements of science, engineering, medicine, technology, economics, and the social sciences. To capitalize on advances in scientific understanding, we strive to actively reach out and link our research and teaching in new and creative ways to other communities at MIT and beyond — including academic, clinical, and industry communities.

Principle 5: Build a diverse, inclusive community

The Department of Brain and Cognitive Sciences at MIT is committed to the well-being of all members of our community. We strive to build and sustain a diverse, open, welcoming culture, dedicated to academic excellence and a shared commitment to each other's well-being. We envision a culture that fosters a true sense of belonging as we bring together diverse perspectives to explore and understand the mechanisms of the brain and mind at all levels.

The Building 46 Community

Our home is Building 46, which unites the Department of Brain and Cognitive Sciences under one roof with the McGovern Institute for Brain Research (MIBR) and The Picower Institute for Learning and Memory (PILM), each a major research enterprise in itself, and which provide immense resources and support for the research of faculty affiliated with BCS. In all, we are a community of more than 800 individuals spanning undergraduates, graduate students, postdocs, faculty, and scientific and administrative staff, led by a team of 49 highly respected professors. The cutting-edge, innovative research led by our faculty provides a stellar training ground for the next generation of scientific leaders in brain and cognitive sciences.

Strategic Planning

In 2022, the department initiated a strategic planning process and engaged the firm AltshulerStaats as a consulting partner. One-on-one meetings were held with multiple BCS faculty, and small group interviews with undergraduates, graduate students, postdocs and research scientists, administrators, and research staff were conducted, and a survey was completed by 92% of faculty, 40% of trainees, and 31% of staff. Department leadership hosted three lunches where faculty were invited to discuss emerging areas of science and how they might influence the future direction of the department. The process was managed by a core group of Department Head Michale Fee, Associate Department Heads Laura Schulz and Josh McDermott, and Director of Administration and Finance Tristan Davies. The BCS Council was periodically updated with an overview of the process, a briefing on the results of the interview and survey phases, and an opportunity to review and comment on the draft plan.

At the broadest level, several themes emerged from the data collected during the planning process. First, the process confirmed that faculty and trainees view the quality of BCS research and education as high overall, with the faculty generally viewed as outstanding. Second, the broad scope of the department is viewed by most as a strength, but was notably seen to have potential to be an even greater strength. Third, there is strong interest in having greater interaction across different areas of BCS. Fourth, there are many different ideas for research areas to target with potential hires.

These findings helped crystallize a vision for BCS and suggested a number of steps to progress towards the vision. Many of these steps are now in progress. The vision and strategic priorities identified during the process will form the backbone of a strategic plan for the department that is now under development.

Leadership

Department Head. Michale Fee, the Glen V. and Phyllis F. Dorflinger Professor of Brain and Cognitive Sciences and an Investigator in the McGovern Institute, has been Department Head since May 1, 2021.

Associate Department Heads and Officers. Fee is supported by two Associate Department Heads (ADHs): Josh McDermott and Laura Schulz, who is the ADH for diversity, equity, inclusion, and justice (DEIJ). McDermott was the Interim Department Head during Fee's medical leave in the spring of 2024. Schulz is also the Undergraduate Officer.

Other key faculty leadership includes:
• Mehrdad Jazayeri, Education Director
• Mark Harnett: Graduate Officer
• Mark Bear: Postdoc Officer
• Matt Wilson: Director of Graduate Admissions

Faculty

New Faculty: The department welcomed Assistant Professor Linlin Fan in January 2024. Dr. Fan's research seeks to understand the molecular, cellular, and systems-level mechanisms of synaptic plasticity. To probe these mechanisms, she has become a leading developer and user of tools for high precision optical electrophysiology.

Faculty Promotions: From Associate Professor with tenure to Full Professor: **Mehrdad Jazayeri** and **Josh McDermott**. From Associate Professor without tenure to Associate Professor with tenure: **Steven Flavell** and **Evelina Fedorenko.**.

Notable faculty awards in 2023-2024 include:

- Roger Levy: 2024 Guggenheim Fellow
- Elly Nedivi: 2023 Kreig Cortical Kudos Discoverer Award
- Josh Tenenbaum: Schmidt Futures AI2050 Senior Fellow, 2023
- Nancy Kanwisher: 2024 Kavli Prize in Neuroscience
- Mehrdad Jazayeri: 2024 Howard Hughes Medical Institute Investigator
- Steven Flavell: 2024 Howard Hughes Medical Institute Investigator

The department also bestows annual awards on faculty for teaching and mentorship. Recipients this year were:

- Undergraduate Advising: John Gabrieli
- Undergraduate Teaching: Josh Tenenbaum
- Graduate Teaching: Mehrdad Jazayeri
- Graduate Mentoring: Steven Flavell
- Postdoctoral Mentorship: Ed Boyden

Research Centers

BCS, the McGovern Institute, and The Picower Institute host an impressive array of research centers which support focused research into priority projects and enable broad development and use of new technologies. These include:

- **The K. Lisa Yang Center for Bionics**, established in 2022 and co-led by Ed Boyden and Hugh Herr, pioneers transformational bionic interventions across a broad range of conditions affecting the body and mind.
- **The K. Lisa Yang Brain-Body Center**, led by Polina Anikeeva, creates novel tools to explore the multidirectional, multilevel interplay between the brain and other body organ systems with the goal of advancing therapies and predictive diagnostics to achieve healthy minds in healthy bodies.
- **The K. Lisa Yang ICoN (Integrative Computational Neuroscience) Center**, led by Ila Fiete, creates mathematical models and computational tools to synthesize data across scales of neuroscience and advance our understanding of the brain.
- **The Brain Arousal State Control Innovation Center (BASCIC)**, directed by Emery Brown, a joint initiative between Mass General and MIT to create a center that uses the study of anesthesia to design novel approaches to controlling brain states.
- **Simons Center for the Social Brain**, directed by Mriganka Sur, which aims to understand the neural mechanisms underlying social cognition and behavior, and to translate this knowledge into better diagnosis and treatment of autism spectrum disorders.
- **Alana Down Syndrome Center**, directed by Li-Huei Tsai, which engages the expertise of scientists and engineers in a research effort to increase understanding of the biology and neuroscience of Down syndrome.
- **Aging Brain Initiative**, also directed by Tsai, which pulls together faculty expertise, knowledge, and technical resources from across MIT, aiming to conquer Alzheimer's disease and other forms of dementia by studying how the brain ages in health and decline.
- **Center for Neurobiological Engineering**, directed by Alan Jasanoff, which brings together engineers and scientists to create next-generation tools for comprehensive and systematic experimental investigation of the nervous system.
- **Hock E. Tan and K. Lisa Yang Center for Autism Research**, directed by Robert Desimone, to support and catalyze new research approaches and potential treatments for individuals affected by this disorder.

- **Poitras Center for Psychiatric Disorders Research**, established in 2007 and directed by Desimone, to address the root causes of psychiatric disorders such as depression and bipolar disorder.
- **MIT Quest for Intelligence**, directed by James DiCarlo, is a community of scientists, engineers, faculty, students, staff, and supporters that aim to understand intelligence – how brains produce it and how it can be replicated in artificial systems.

Diversity, Equity, Inclusion, and Justice (DEIJ)

Led by Associate Department Head Laura Schulz and DEIJ Program Officer Farrah Belizaire, Building 46 is at the forefront of efforts in the School of Science and at MIT to cultivate an inclusive working environment and develop a pipeline of promising young scientists from underserved communities.

MIT administers a survey every two years which includes questions related to the working climate and culture. Overall, the results of the 2022 Quality of Life Survey indicated a high level of satisfaction for employees and trainees across Building 46. However, a few measures did not follow this trend, and there were areas where results varied considerably depending on people's roles. These concerned us, and led the DEIJ Program Officer to conduct a listening tour in the summer of 2023 for more information and feedback directly from those involved. Upon meeting with several graduate students, a prevalent theme was a sense of social isolation within individual labs, leading to a disconnect from the broader departmental community. The Covid pandemic had exacerbated these feelings, particularly given the disruption to traditional community-building activities. The insights from this feedback led to new initiatives including:

• "Connect to Community" brunches for graduate students
• Lab-level training to promote inclusion
• Reactivation of the Building 46 Postdoc Association

BCS and the Building 46 Community actively engage in outreach aimed at making science, and scientific careers, more accessible. Current programs include:

- **The Research Scholars Program**. The BCS Research Scholars Program (RSP) is a two-year, postbaccalaureate training program for outstanding college graduates who plan to pursue a research career This program is specifically designed to provide additional research and academic training to individuals from disadvantaged backgrounds, including first-generation college students, students with disabilities, and veterans preparing to apply to PhD programs.The ultimate goal of the program is to provide fair and equitable access to

top-tier research experiences for individuals who have demonstrated exceptional academic potential in the fields of brain and cognitive science and neuroengineering despite facing significant hardships.

- **MSRP**. BCS partners with the Department of Biology and the Center for Brains, Minds, and Machines in the Bernard S. and Sophie G. Gould MIT Summer Research Program (MSRP), a ten week program which is designed to encourage first generation college students and students from economically disadvantaged backgrounds to attend graduate school and pursue a career in basic research by providing them the opportunity to conduct supervised research at a competitive research institution. Ten to 15 students are placed in Building 46 labs each summer.
- **Sagrado-MIT Neuroscience Pre-College Program.** SNPP is a summer internship and mentoring program designed for students in grades 9 to 11 who are interested in pursuing a career in science, technology, engineering and/or math with a focus in neuroscience. Students spend two weeks at the University of Sagrado Corazón in Puerto Rico and two weeks in the Cambridge area. Co-led by former McGovern Institute postdoc Hector de Jesús Cortés, SNPP participants engage with students, faculty and other community members across Building 46. BCS contributes annually to the costs associated with running this program.
- **Application Assistance Program.** Since 2019, the BCS Application Assistance Program has been striving to narrow the information gap and share social capital in STEM. The program is a volunteer-based, graduate student-run initiative that allows current students in the BCS PhD program to offer support to and share personal experiences with prospective students during the graduate application process.

DEIJ Impact Awards: This award recognizes students, staff, postdocs, and other individuals who exhibit exemplary leadership in advancing diversity, equity, and inclusion in Building 46. The recipients of this award in its second year were:

- Quilee Simeon
- Jamie Wiley
- The Building 46 Postdoctoral Association

Impact of *Students for Fair Admissions v. Harvard*

In June 2023, the U.S. Supreme Court ruled that universities could no longer take race into consideration as a specific factor in admissions decisions. A student's disadvantage, or their overcoming of hardship in which race may have been a factor, are still acceptable considerations in admission. For the 2023-24 admissions cycle, BCS implemented two major changes to decouple race from admissions decisions while still endeavoring to gather useful demographic data.

First, the application was modified to remove the “race” identification field, but also to clarify that an applicant’s statement could include the impact of race on factors that have disadvantaged them or caused hardship. This approach allows applicants to provide context about their unique backgrounds and motivations, offering a more holistic view of each candidate. Faculty who reviewed an application could assign a score based on their assessment of a student’s disadvantage and hardship.

Second, with guidance from the Office of the General Counsel, we introduced a voluntary demographic information form, inviting applicants to share additional demographic and socioeconomic information, including racial and ethnic markers. To ensure this information does not influence admissions, this data was kept behind a firewall throughout the admissions process and no faculty, staff member or trainee saw it. It was shared in aggregate form after the admissions cycle ended in order to, (a) evaluate the effectiveness of our outreach strategies and efforts to ensure equitable access to our program, and (b) assess the impact of the Supreme Court decision.

BCS remains committed to an equitable admissions process that recruits the most talented and promising young scientists.

Academics

The Department of Brain and Cognitive Sciences’ educational vision is anchored in the idea that students should acquire a fundamental knowledge of key empirical phenomena about the mind and the brain, quantitative methods for describing the mechanisms that underlie those phenomena, the procedures by which we discover new phenomena and new mechanisms, and the myriad connections of that knowledge with fields including physics, biology, engineering, mathematics, linguistics, and economics.

As part of the undergraduate and graduate curricula, BCS faculty teach an average of about 58 subjects per year; in the past academic year, BCS offered 22 undergraduate and 32 graduate-level courses. Enrollment in BCS undergraduate subjects has climbed 9% since 2015.

Undergraduate

The department offers two undergraduate programs: Course 9 (Brain and Cognitive Sciences) and Course 6-9 (Computation and Cognition).

The Course 9 undergraduate curriculum is a tiered system that builds on the expertise gained at each preceding level. It begins with a first-year introduction to neuroscience, cognitive science, and computation, with an additional emphasis on subjects that hone critical skills in

programming and statistics. Students can focus on individual areas of interest as they progress through the program. There were a total of 26 students enrolled in Course 9 in the past academic year.

Course 6-9 is a joint major in partnership with EECS, administered by BCS, leading to a Bachelor of Science in Computation and Cognition. Established in 2019, the major focuses on the emerging field of computational and engineering approaches to brain science, cognition and machine intelligence. For the first time since it was introduced, Course 6-9 saw a drop in enrollment in the 2023-24 academic year. This can likely be attributed to the establishment of a new EECS major in the fall of 2022: Artificial Intelligence and Decision Making, Course 6-4. It remains to be seen what the steady state for 6-9 enrollment will be.

BCS also has one of the largest undergraduate research opportunities programs on campus, hosting over 200 students this past academic year.

Master of Engineering

Course 6-9 students who meet admission criteria can participate in the Master of Engineering (MEng) program, which typically adds a fifth year to the student's tenure. As of fall 2023, there were 30 MEng students in the program.

Doctoral Program

BCS offers programs of study leading to a PhD in neuroscience or cognitive science. Areas of research specialization include cellular and molecular neuroscience, systems neuroscience, computation, and cognitive science.

The strength and reputation of the doctoral program allows us to be highly selective in admission. Recent years have seen a large jump in the number of applications, including a record of 935 in the past academic year. Of those applicants, 29 were admitted and 17 enrolled.

Doctoral students in BCS are supported by the department for the first two years; students who join labs in the McGovern and Picower Institutes are supported by the respective institute for their third year and those who are not receive a third year of support from the department. The extended duration of this support, which comes through a combination of Institute, School, departmental, and fellowship funds, allows students to more fully explore a range of interests and to develop a working relationship with their mentor before a final choice of thesis advisor.

Awards

Teaching is also an important element of a student's early years in the program, and each year the department recognizes a number of graduate students for their excellence in this area. This year's award recipients were:

Angus MacDonald Award for Excellence in Undergraduate Teaching:

- Minqing Jiang
- David Stoppel
- Moshe Poliak
- Nicole Coates
- Daniel Leible
- Verna Peng

Walle Nauta Award for Excellence in Graduate Teaching:

- Cheng Tang
- Amanda Fath
- Fernanda De La Torre
- Shannon Knight
- Thomas Clark

In 2023-24, the department celebrated the graduation of 17 doctoral students:

- Andrew Bahle
- Victoria Beja-Glasser
- Andres Crane
- Gabrielle Drummond
- Alexandra Ferguson
- Eghbal Hosseini asl
- Carina Kauf
- Hunter King

- Sara Kornfeld Simpson
- Gurrein Madan
- Mahdi Ramadan
- Mark Saddler
- Sugandha Sharma
- Michael Skuhersky
- John Tauber
- Katherine Tsimring
- Dae Hee Yun

Finances and Funding

Research funding to the department's faculty is robust and growing. Management of pre- and post-award research funding is divided among the DLCs in the building: of the 38 faculty with primary appointments in BCS, 13 (33%) manage their research funding through BCS Headquarters. Fourteen (36%) manage research through the McGovern Institute, and the remaining 12 (31%) have their research funding managed by The Picower Institute.

Research expenditures by BCS faculty continue to rebound from the pandemic-related dip in 2020, reaching a total of nearly $70 million. The McGovern and Picower Institutes house the largest labs and nearly all of the wet-lab research, which is costlier than dry-lab research, accounting for their larger shares of the expenditures.

Philanthropy is an important source of funds for the department. Over the past 3 fiscal years, BCS has averaged $3.04 million in annual pledges and gifts.

Financial priorities looking ahead include:

1. Building discretionary reserves in order to have adequate resources to offer competitive startup packages to new faculty and counteroffers to retain faculty who receive offers from elsewhere.

2. Generating fellowship support for graduate students in years 1 to 3. While the program is on a solid and sustainable financial footing for its current size, there is an appetite in the department for a larger graduate program. We hope to increase the total enrollment from 110 to 132 by increasing the incoming class size from 18 to 22.

3. Funding the Research Scholars Program. This program is a highly successful component of the Building 46 DEIJ program. The cost to the department currently supports four scholars per year at approximately $100,000 each. This program is a prime opportunity for philanthropic investment, with significant commitments already in place.

Research Highlights

The following are some examples of the extraordinary contributions our faculty have made in their fields in the past year:

- Even though the human visual system has sophisticated machinery for processing color, the brain has no problem recognizing objects in black-and-white images. A study led by **Pawan Sinha** offers an explanation for how the brain comes to be so adept at identifying both color and color-degraded images. Using experimental data and computational modeling, the researchers found evidence suggesting the roots of this ability may lie in development.

- Using thousands of hours of transcribed audio recordings of children and adults interacting, a research team led by **Roger Levy** created computational models to reverse engineer how adults interpret what small children are saying. Models based on only the actual sounds children produced in their speech did a relatively poor job predicting what adults thought children said. The most successful models made their predictions based on large swaths of preceding conversations that provided context for what the children were saying.

- If anesthesiologists had a rigorous means to manage dosing, they could maintain exactly the right depth of unconsciousness while reducing postoperative cognitive side effects in vulnerable groups like the elderly. But with myriad responsibilities for keeping anesthetized patients alive and stable while maintaining their profoundly unconscious state, anesthesiologists don't have the time without the technology. To solve the problem, researchers led by **Emery N. Brown** at The Picower Institute for Learning and Memory at MIT and Massachusetts General Hospital have invented a closed-loop system based on brain state monitoring that accurately controls unconsciousness by automating doses of the anesthetic drug propofol every 20 seconds.

- Many naturally occurring proteins have functions that could make them useful for research or medical applications, but they need a little extra engineering. Researchers led by BCS Professor **Ila Fiete** have developed a new computational approach that makes it easier to predict mutations, speeding up the process of optimizing proteins.

- A study by Professor **Ev Fedorenko** of people who speak many languages has found that there is something special about how the brain processes their native language. In the brains of these polyglots — people who speak five or more languages — the same language regions light up when they listen to any of the languages that they speak. In general, this network responds more strongly to languages in which the speaker is more proficient, with one notable exception: the speaker's native language. When listening to one's native language, language network activity drops off significantly. The findings suggest there is something unique about the first language one acquires, which allows the brain to process it with minimal effort.

- The discovery of a brain circuit that drives vocalization and ensures that you talk only when you breathe out, and stop talking when you breathe in was detailed in a study whose senior author was Professor **Fan Wang** of the McGovern Institute.

- Patients undergoing chemotherapy often experience cognitive effects such as memory impairment and difficulty concentrating — a condition commonly known as "chemo brain."

Researchers led by **Li-Huei Tsai** have now shown that a noninvasive treatment that stimulates gamma frequency brain waves may hold promise for treating chemo brain. In a study of mice, they found that daily exposure to light and sound with a frequency of 40 hertz protected brain cells from chemotherapy-induced damage.

- Human sensory systems are very good at recognizing objects that we see or words that we hear, even if the object is upside down or the word is spoken by a voice we've never heard. Deep neural networks can be trained to do the same thing, correctly identifying an image of a dog regardless of what color its fur is, or a word regardless of the pitch of the speaker's voice. A study led by Professor **Josh McDermott** found that these models often also respond the same way to images or words that have no resemblance to the target, offering a new way to evaluate how well these models mimic the organization of human sensory perception

- In a study of 12 to 14-year-olds whose socioeconomic status (SES) varied widely, researchers led by Professor **John Gabrieli** found that children from lower SES backgrounds showed less sensitivity to reward than those from more affluent backgrounds. Using functional magnetic resonance imaging (fMRI), the research team measured brain activity as the children played a guessing game in which they earned extra money for each correct guess. When participants from higher SES backgrounds guessed correctly, a part of the brain called the striatum, which is linked to reward, lit up much more than in children from lower SES backgrounds.

- Throughout the brain's cortex, neurons are arranged in six distinctive layers, which can be readily seen with a microscope. A team of MIT and Vanderbilt University neuroscientists has now found that these layers also show distinct patterns of electrical activity, which are consistent over many brain regions and across several animal species, including humans. Senior authors of the study included Professor **Earl Miller** of The Picower Institute and **Robert Desimone**, Director of the McGovern Institute.

Michale Fee, PhD
Glenn V. and Phyllis F. Dorflinger Professor of Neuroscience
Department Head