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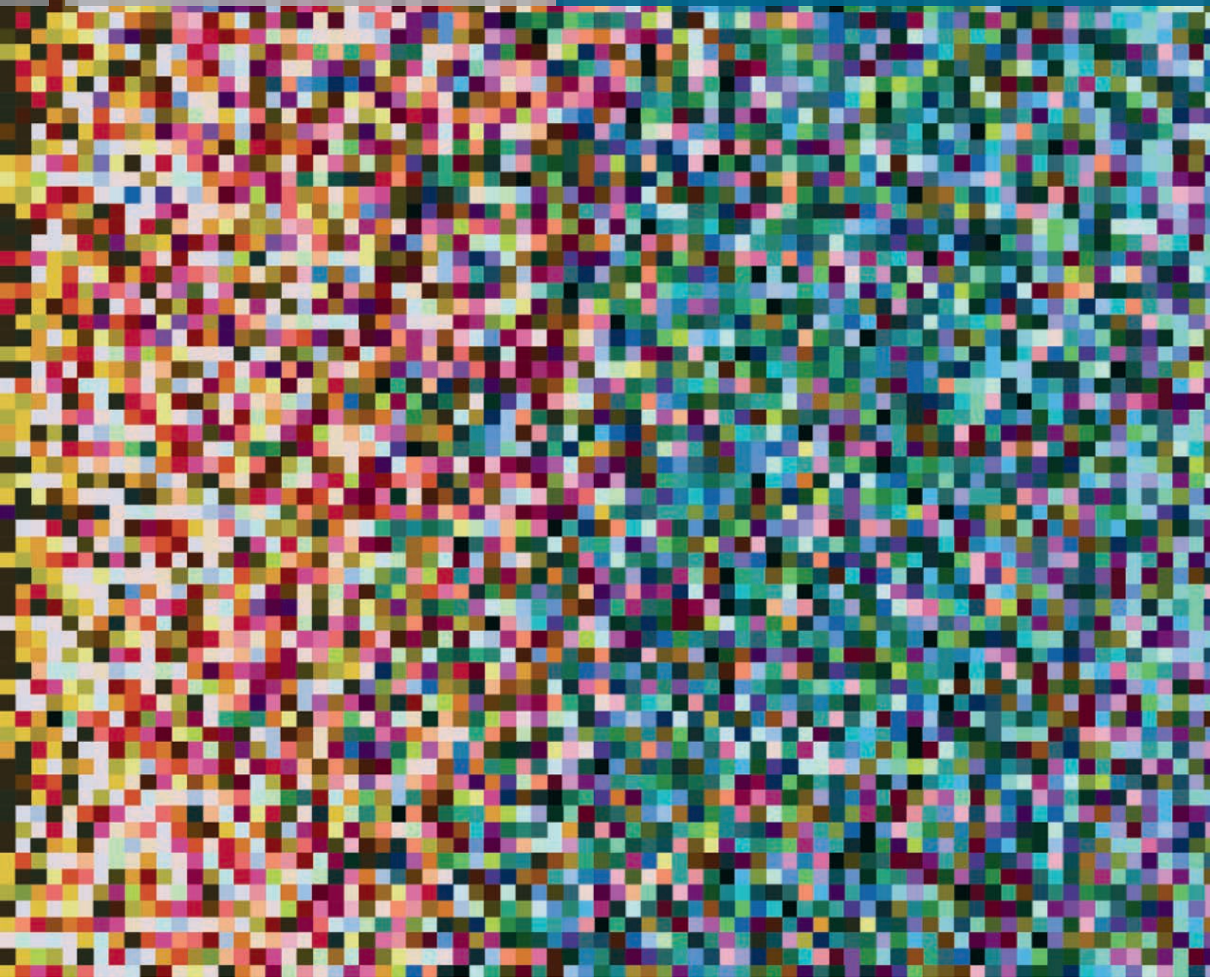

brain+cognitive sciences

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A Message from the Department Head
Jim DiCarlo

When Hans-Lukas Teuber founded the Department of Psychology at MIT in 1960, his vision—to understand questions of the mind, we must study the brain—was a vision for the future. Under the wise stewardship of successive departmental leaders, that idea has advanced into our core research mission, to reverse engineer the mechanisms of the mind. And the driving force behind that mission is our vibrant BCS community of faculty, staff, and students.

Our mission is built upon a foundation of basic science, which means the knowledge we seek will have world-changing impact in many unexpected ways. With this in mind, we are also motivated by how we will almost certainly affect human lives as we approach our goal. These include amelioration of disorders of the mind, next-generation artificial intelligence to empower us, and transformative ways of educating our children and ourselves. In this issue, we highlight two centers within the BCS Community that are working at the ground level to further the progress on two of these areas.

The Center for Brains, Minds and Machines (CBMM) has been a key driver to bring the engineering and computation part of our reverse-engineering mission in contact with the science part of our mission. Funded by the NSF, it has yielded important insights in how brain and cognitive science can further our efforts to solve intelligence since it was founded five years ago. CBMM will continue to play a key role in advancing MIT's commitment to invest in artificial and human intelligence research, along with our new industry partner IBM.

The Simons Center for the Social Brain (SCSB) is one of several key initiatives that brings together efforts both within and beyond the BCS Community to support research and provide education around disorders of the mind. Others include the new Yang Center for Autism Research led by the McGovern Institute for Brain Research (MIBR) and the Aging Brain Initiative led by the Picower Institute for Learning and Memory (PILM). SCSB has led the way, has had a remarkable impact on the BCS Community mission over the past five years, and was recently renewed for its second phase. You can read more about both SCSB and CBMM in this newsletter.

We are also thrilled to welcome Mike Halassa on board as a new assistant professor in BCS. A former BCS postdoctoral researcher, he returns to us from New York University, where he spent the last three years as a faculty member studying the mechanisms of cognitive functions like attention, executive function, and working memory. As a practicing psychiatrist, he brings a unique clinical perspective to his research, and will be a fabulous bridge between multiple areas of BCS community research and education.

The BCS community is not only building the future through its research today, it is also building the future by training the next generation of science and industry leaders. There are so many remarkable stories among our students and postdocs — far too many to tell in one newsletter. In this issue, we introduce you to junior Madison Darmofal, a UROP student working with BCS Professor and MIBR Investigator Guoping Feng and members of his laboratory. Looking more broadly, the interest of MIT undergraduates such as Madison in doing research in BCS community laboratories continues to grow and inspire, and such on-the-ground efforts and dedication of students, postdocs and staff is the key driver of our success. I am deeply honored and humbled to help lead this amazing community.

James J. DiCarlo MD, PhD
Peter de Florez Professor of Neuroscience
Head, Department of Brain and Cognitive Sciences

On the Cover

MIT researchers have found that languages tend to divide the "warm" part of the color spectrum into more color words than the "cooler" regions, which makes communication of warmer colors more consistent. From left to right, this chart shows the order of most to least efficiently communicated colors in 110 non-industrialized languages, plus English, Bolivian-Spanish and Tsimane'. Image generated by Richard Futrell, Gibson Lab.

Center for Brains, Minds and Machines Leads Progress in Human and Artificial Intelligence

By Sara Cody

When it comes to brain teasers, understanding how the human mind produces intelligent behavior is one of the most puzzling. Especially when it comes to programming machines with human-level intelligence. Figuring out how humans see, hear, move, reason, communicate and learn is complicated. But as a society, we have a lot to gain by succeeding.

"I think the problem of intelligence is the greatest problem in science because it means understanding ourselves and understanding the tool we use to understand all other problems," said Prof. Tomaso Poggio, Director of the Center for Brains, Minds and Machines (CBMM) and Investigator in MIBR and CSAIL. "It means that if we can make progress in intelligence then we can make ourselves a bit smarter. It means that we can build machines that help us think better so we can solve all other problems more easily. Though we've made progress, we are still very far from solving intelligence."

Members of the CBMM management team include Mandana Sassanfar, Joshua Tenenbaum, Kenneth Blum (Harvard), Kathleen Sullivan, Tomaso Poggio, Matt Wilson, Boris Katz, Gabriel Kreiman, Ellen Hildreth and Nancy Kanwisher.

Photo Credit: Kris Brewer

BCS has embraced computation as a core impact area of research; in order to develop a deeper understanding of the brain, it is vital to develop a comprehensive understanding of the human mind by building links across multiple levels of analysis, from molecules to synapses to neurons to circuits to algorithms to human behavior and cognition. Moreover, neuroscience has an important role to play to move the engineering of intelligent machines forward. Taking inspiration from neuroscience has yielded major breakthroughs in artificial intelligence in the past 20 years, such as deep learning and reinforcement learning, biological phenomena that have been replicated in machines like AlphaGo Zero and Mobileye systems for autonomous driving. Since it was founded in 2013, CBMM has been central to this approach.

"The goal of CBMM is to foster collaboration between engineers, neuroscientists, computer scientists and cognitive scientists to make progress in understanding intelligence by understanding how the brain makes the mind, how the brain works and how to build intelligent machines," said Poggio. "We believe the science of intelligence will enable better engineering of intelligence. It is a good bet that in order to reach the next breakthrough in artificial intelligence, we have to look at our own brain."

In 2016, IBM Research announced a multiyear collaboration with BCS to advance the scientific field of machine vision, a core aspect of artificial intelligence. IBM was particularly attracted to collaborate with BCS and MIT because of the CBMM hub. This new industrial collaboration has brought together leading brain, cognitive, and computer scientists to conduct research in the field of unsupervised machine understanding of audio-visual streams of data, using insights from next-generation models of the brain to inform advances in machine vision. In 2017, MIT announced the institute-wide MIT-IBM Watson AI Lab, bringing together a multidisciplinary team from across IBM and MIT to work together advancing AI hardware, software and algorithms. BCS will continue to play a key role in this new initiative while continuing to make progress through efforts like CBMM.

"Looking forward at the next five years, we will be focusing on developing a novel architecture of intelligence beyond deep learning networks, and explore a number of very basic questions," said Poggio. "There are very interesting mathematical questions in deep networks spanning approximation theory, optimization, and learning theory. We are already getting quite some interesting results. Since the science of intelligence is, like biology, not just one problem, but many problems requiring separate research breakthroughs, it will take time to solve it. And it will not be solved by individual labs, but by collaboration among many labs. CBMM aims to be a nucleus and driver of that."

To learn more about CBMM, visit **cbmm.mit.edu**

Simons Center for the Social Brain Enters Second Phase

By Eleana Ricci and Alexandra Sokhina

The mission of the Simons Center for the Social Brain (SCSB) at MIT, now in its sixth year, is to understand the neural mechanisms underlying social cognition and behavior, and to translate this knowledge into better diagnosis and treatment of autism spectrum disorders (ASD). SCSB was founded in January 2012 with support from the Simons Foundation Autism Research Initiative, and completed its first five-year phase of funding in December 2016. In January 2017, it was renewed for a second phase.

"We believe that the most novel research ideas and approaches come from collaborations, rather than within-lab research funded by usual mechanisms", says Prof. Mriganka Sur, SCSB Director. "SCSB offers a unique window into the success of this approach and how it can help move the field forward."

SCSB studies the underlying mechanisms of ASD in both humans and relevant model organisms and systems, as neural correlates of social cognition and behavior exist in diverse species. Its approaches take advantage of MIT's strengths in genetics and genomics, molecular and cell biology, analyses of neural circuits and systems, cognitive science, computation and engineering.

To strengthen its community, SCSB runs a colloquium series which brings major autism researchers to MIT, and has become the preeminent forum in the Boston area for research on autism and neurodevelopmental disorders.

In addition, SCSB hosts a lunch talks series featuring postdoctoral fellows and faculty PIs presenting their latest, ongoing research.

"SCSB provided the community and resources that shaped my research directions, helped me find collaborators, and gave me the support and freedom to try some of the outside-the box experiments that wouldn't have been successful otherwise," says Ian Slaymaker, a former Simons Postdoctoral Fellow. "Additionally, the diverse speakers hosted by SCSB broadened my exposure to varied research."

In its first phase, SCSB funded seed grants that required two co-PIs, postdoctoral fellows who were required to have two mentors across different labs, equipment for multiple researchers, and targeted projects that involved three-four researchers bridging multiple levels of analysis—such as gene discovery, animal models, brain imaging, cognitive science, computation. In its second phase, SCSB will focus on targeted projects and postdoctoral fellowships.

"Our challenge is to continue to build the strength of our vision, and show that our collaborative research model is transformative for the field," says Sur. "I strongly believe it is!"

For more information on SCSB research, events, targeted projects, and postdoctoral fellowships, visit ***scsb.mit.edu***

SCSB by the Numbers: The First Five Years

SCSB serves as a bridge connecting

11

Boston-area institutions. At MIT alone, it supports

18

departments, laboratories and centers.

SCSB has provided

$15,435,558

in funding to researchers, supporting seed grants, postdoctoral fellowships, targeted projects and equipment. Subsequently, initial support from SCSB has enabled

$43,160,851

in grants from external sources, like the NIH and private foundations, to pursue research projects further.

SCSB has supported

74

investigators and

31

postdoctoral fellows.

In the first five years alone,

208

publications have resulted from SCSB support.

Events Celebrate Research and Donor Impact on BCS Community

By Amanda O'Neill

During the spring 2017 semester, BCS hosted its biennial symposium, A Day with MIT's Brains on Brains, which showcases the various research initiatives that the members of the BCS community are working towards.

MIT President L. Rafael Reif welcomed attendees to the event, followed by Department Head Jim DiCarlo, who provided an overview about why we study the brain.

"Connecting the physical mechanisms of the brain to the mental states of what we call the mind is what our department is all about" said DiCarlo.

After hearing from Li-Huei Tsai, Director of The Picower Institute for Learning and Memory and Robert Desimone, the Director of McGovern Institute for Brain Research, guests enjoyed talks on brain disorders, reverse-engineering the mind, and a new non-invasive way to potentially treat Alzheimer's disease.

During lunch time, attendees sat at faculty-hosted tables around themes such as cognition, autism, intelligence, and memory. Guests enjoyed the opportunity to ask questions and discuss the issues and ideas from the morning talks. This year featured a new series of lightning talks from graduate students and postdocs. These were short, five-minute presentations moderated by a member of the faculty around four themes: Intelligence and Cognitive Computing; Tools and Technologies; Science of Education; and Disorders of the Mind.

The day concluded with remarks by Jim '58 Simons, who spoke spoke about his personal philanthropic journey and the decision he and his wife Marilyn made to support discovery-based science.

Postdoctoral associate Caroline Robertson and graduate students Dheeraj Roy'17, Tobias Kaiser, and Amanda Vernon discuss their research during the "Disorders of the Mind" lightning talk.

Photo Credit: Bryce Vickmark Photography

Donors Jim and Muguette Alder met the Brain Fellow they support, Anthony Martorell (center) at the *Champions of the Brain Fellows* event.

BCS held its fourth annual Champions of the Brain Fellows event on October 18, 2017. The event celebrates BCS graduate students and those champions who make it possible for students to explore their scientific dreams and to drive the department's exciting research.

DiCarlo provided opening remarks for the dinner, detailing the importance of fellowship support to attracting the top students and faculty. He discussed how students connect labs across the department and foster collaboration.

"The students are driving our quest in understanding how the brain gives rise to the mind, and they are the reason that we are leaders in the field," said DiCarlo.

The night continued with dinner and talks by three current graduate students and fellows. Heather Kosakowski, a first-year student in the Kanwisher and Saxe labs, spoke about how she uses fMRI in infants to study cortical specialization for speech perception and vision. The second speaker, Karen Cruz, a third-year student in Professor Mriganka Sur's lab, spoke about her project studying economic approaches in the rodent brain in an effort to understand why decision-making changes in social settings. The final student speaker of the night was Anthony Martorell, a third-year student in Professor Li-Huei Tsai's lab, who discussed his work investigating the therapeutic effects of non-invasive gamma auditory stimuli on Alzheimer's disease.

The evening concluded with remarks from Barrie R. Zesiger HM, MIT Corporation Life Member and the founding Champion of the Brain Fellows. Zesiger discussed the impact of supporting neuroscience research through the next generation of scientists. She also encouraged continued involvement and support from the audience.

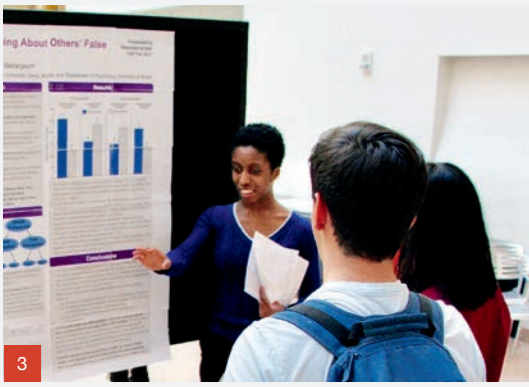
The annual Champions of the Brain Fellows honors those donors who commit $70,000 or more through an endowed, expendable, or corporate gift to support graduate students at the forefront of cutting-edge research in BCS.

To learn more about supporting BCS, visit **bcs.mit.edu/give-bcs**

Community Highlights

1. The MIT Academic Expo is an annual event held during orientation week. Faculty and academic advisors were on hand to discuss what it's like to be a BCS undergrad, from coursework to research opportunities, with prospective majors. Graduate student Alex Kell, who works in the McDermott laboratory, demonstrated a sheep brain dissection for curious visitors.

2. BCS welcomed new graduate students at the annual fall harbor cruise: (left to right) Jarrod Hicks, Mahdi Ramadan, Nhat Minh Le, John Tauber, Mark Saddler, Leo Kozachkov, Junyi Chu, Jon Gauthier, Martin Schrimpf, Mitch Murdock, Michael Happ, Maxwell Nye, Paloma Sanchez, Heather Lynne Kosakowski, Guerrein Madan, Victoria Beja-Glasser, Halie Olson, Jenna Aronson, and Peng Qian. Missing from photo: Jungsoo Kim, Francisco Garcia, Alexandra Ferguson and Anna Ivanova



3. Nwamaka Ashley Amobi'19 presented her cognitive development project for Prof. Laura Schulz's course 9.85 poster session in November.

Noteworthy News

BCS would like to congratulate Institute Emeritus Prof. **Emilio Bizzi** and Emeritus Prof. **Gerald Schneider** on their retirements!

Congratulations to **Kay Tye** for her recent promotion to Associate Professor with Tenure at MIT!

Prof. **Tomaso Poggio** received the PAMI Azriel Rosenfeld Lifetime Achievement Award at the 2017 International Conference on Computer Vision.

Three members of BCS Faculty were honored with awards from the NIH Common Fund's High-Risk, High-Reward program: Prof. **Kay Tye** and Prof. **Feng Zhang** received Pioneer Awards, and Prof. **Ed Boyden** received the Transformative Research Award.

Zhang also received the 2017 Albany Medical Center Prize in Medicine and Biomedical Research, the 2017 $500,000 Lemelson-MIT Prize, the largest cash prize for invention in the United States in recognition for his work with CRISPR and was named a laureate of the 2017 Blavatnik National Awards for Young Scientists.

Prof. **Mark Harnett** received a $200,000 grant from the Dana Foundation. The grant, a part of the David Mahoney Neuroimaging Program, will launch his project "Imaging Synaptic Computations in Human Neural Circuitry."

Prof. **Mehrdad Jazayeri** was named a 2017 McKnight Scholar Award recipient.

Max Kleiman-Weiner, graduate student in the Tenenbaum lab, received two recent best paper awards: the William James Award from the Society for Philosophy and Psychology (SPP) and the Best Paper Award from the Third Multidisciplinary Conference on Reinforcement Learning and Decision Making (RLDM).

Prof. **Michale Fee** was the inaugural recipient of MIT's Fundamental Science Investigator Award.

Prof. **Molly Potter** received the Society of Experimental Psychologists Norman Anderson Lifetime Achievement Award.

Profs. **Edward Boyden**, **Earl Miller** and **Molly Potter** were elected to the American Academy of Arts and Sciences (AAAS).

Prof. **Mriganka Sur** received the Cortical Discoverer Prize from the Cajal Club, the oldest neuroscience society in the US.

Prof. **John Gabrieli** was the recipient of the Alice H. Garside Lifetime Achievement Award, Massachusetts Branch of the International Dyslexia Association.

To view the full list of noteworthy news, view the newsletter online at **bcs.mit.edu**

Department Welcomes New Assistant Professor

Michael Halassa studies the mechanisms of cognitive function

By Sara Cody

For Michael Halassa, who will join the BCS faculty as an assistant professor in January 2018, returning to MIT is a homecoming. And he is ready to hit the ground running.

Assistant Professor Michael Halassa

Photo Credit: Vilcek Foundation

"As a graduate student at the University of Pennsylvania, I studied molecular and cellular neuroscience, where the focus was not so much on behavior but on figuring out how the cells themselves worked. From there, I joined BCS in Matt Wilson's lab as a postdoctoral fellow to study systems neuroscience," says Halassa. "I saw it as the intermediate level of organization between cellular and cognitive neuroscience, so I wanted to tackle that area by studying neural circuits in a behavioral context."

In addition to a strong background in molecular, cellular and systems neuroscience, Halassa brings another unique asset to the table: he is a practicing psychiatrist.

"I grew up in Jordan, and after high school I decided to follow in my parents' footsteps and attend medical school, but I quickly realized that pursuing a purely clinical career was not the right path for me because I wanted to understand how things worked rather than apply existing models of how they worked," says Halassa. "But in medical school, I developed an interest in the brain, which led me to study neuroscience in graduate school and ultimately to my interest in behavior."

As a postdoctoral fellow in BCS, Halassa also underwent psychiatry residency at Massachusetts General Hospital. According to Halassa, working with patients suffering from schizophrenia and other brain disorders provides him with a unique perspective that helps inform his research approach.

"In a disease like schizophrenia, we can attribute the symptoms, like an inability to distinguish bizarre thoughts from sound ones, to a loss of cognitive control," says Halassa. "It's humbling to see what I study in the lab out in the real world and witness how it affects real people. This drives me to continue to study the underlying brain mechanisms of cognitive control so we might develop ways to treat these disorders."

After completing his postdoctoral fellowship at MIT, Halassa established his research laboratory at New York University, where he focused on developing cognitive models in the mouse to enable studying the mechanisms of processes like attention, executive function and working memory.

"I saw there was a big opportunity to capitalize on the technological breakthroughs in molecular neuroscience and apply the tools to study the mechanisms of cognitive function," says Halassa. "In my lab we were able to develop a few complex cognitive behaviors for mice, which allowed us to observe how cognitive neural activity changed with a respect to behavior and to manipulate aspects of neural circuits to understand the actual causal structure in the brain that supports a set of basic cognitive operations".

Halassa became particularly interested in the thalamus, an area of the brain traditionally thought to play a role in the passive relay of information, received either from sensory information or the cortex itself, to other cortical regions of the brain.

"We've found the thalamus plays much more interesting roles in cognition than previously thought because it allows the cortex to maintain and switch persistent activity associated with thoughts and integrating decisions over time, which defines our mental life," says Halassa. "To sum it up, my lab focuses on the thalamus to understand how it interacts with the cortex and how that interaction gives rise to basic cognitive operations".

At MIT, Halassa will continue to follow this research path while taking it in exciting new directions. In the short term, he plans on building his research team, which already features a robust group of research scientists, technicians and postdoctoral fellows who have joined him from NYU. In the long term, he will expand the area of neural modeling in his group which will enable his team to develop descriptions of thalamo-cortical functions in terms of neural "hardware" and "software".

"I'm really excited to join the faculty and to be here. It's a huge opportunity for me to share my experience and to learn from the other amazing faculty at BCS," says Halassa. "The fact that I will contribute to the department that had such a formative impact on my career is a huge privilege."

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Undergraduate Researcher Tackles Disorder with Cutting-Edge Tool

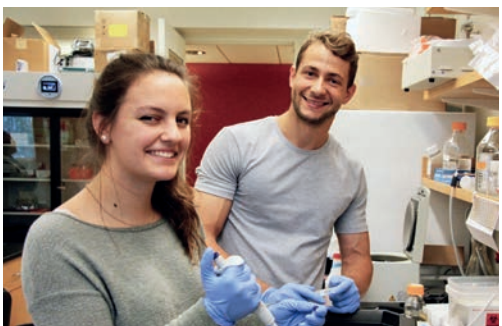
Madison Darmofal'19 Uses CRISPR-Cas9 to Study William's Syndrome

By Sara Cody

CRISPR-Cas9, a genome-editing technology, is one of hottest new research techniques in science. For Madison Darmofal'19, it's a tool she gets to work with every day as an undergraduate researcher.

"Working so closely with CRISPR, sometimes you have to take a step back to remember that you are not only working with a research tool, you are working with something that has this incredible potential to really make a difference with some of our toughest problems," says Darmofal. "But access to new and exciting technology is exactly why I chose to come to MIT, particularly when it comes to the abundance of undergraduate research opportunities, where you get to work with these new techniques."

Darmofal, a biological engineering major, works in BCS Professor Guoping Feng's lab, which she was connected to through MIT's Undergraduate Research Opportunities Program (UROP). Feng, an investigator in MIBR, focuses his research on the development and function of synapses, and their disruption in brain disorders. UROP encourages multidisciplinary research at MIT and allows undergraduate students like Darmofal to earn laboratory experience in a variety of fields, an important asset for anyone majoring in science or engineering.



Madison Darmofal and her advisor, Tobias Kaiser

In addition to assisting with big laboratory projects, Feng's lab also encourages undergraduate researchers to pursue their own ideas and projects under the guidance of graduate students or postdoctoral fellows. Working in tandem with her advisor, Tobias Kaiser, a graduate student in the Feng lab, Darmofal develops therapeutic approaches for William's syndrome, a genetic disorder. According to the National Organization for Rare Disorders, William's syndrome affects 1 out of every 10,000-20,000 births in the US, and causes physical defects, learning disabilities, and abnormal social tendencies.

For Darmofal, the practical experience she gets in the lab is an important component of her education, and the skills she learns on the bench translate well to her other courses, whether it's engineering problem sets, coding, or biology. Ultimately, her goal is to go to graduate school and her experience working in Feng's lab has further solidified her commitment.

"Working in a lab has completely changed my perception about academic research because it's so inspiring to see people care so much about what they're researching and how it will make an impact on the world," says Darmofal. "For me, making a contribution to a project that could help people is very meaningful because even just like a small step forward in the process feels huge because it's my own."

To learn more about undergraduate research opportunities at MIT, visit **uaap.mit.edu/research-exploration/urop**