

## **Department of Biology**

The Department of Biology finished the 2008–2009 academic year with notable accomplishments in its progressive and innovative research, in its recognition of faculty in the form of prestigious awards and successful competitive grant applications, and in its interdepartmental initiatives. Biology has 54 primary faculty members, located in Building 68 (24), the Koch Institute for Integrative Cancer Research (12), the Whitehead Institute (14), the Broad Institute (2), and the Picower Institute for Learning and Memory (2). Joint faculty appointments provide important connections to other departments, including Brain and Cognitive Sciences (BCS) (5), Chemistry (3), Physics (1), Biological Engineering (2), and Civil and Environmental Engineering (1). Two of these joint appointees (Catherine Drennan and Alexander van Oudenaarden) have relocated their research labs to Building 68. Including active emeritus faculty, the department has four Nobel laureates, 24 members of the National Academy of Sciences, and 12 Howard Hughes Medical Institute investigators.

The prominence of the Department of Biology is based not only on its research activities—the department is known as one of the great international centers of fundamental research and scholarship in molecular life sciences—but also from its recognition as a national resource because of its long and distinguished record of training undergraduate and graduate students, as well as postdoctoral fellows, to become future leaders in biological and biomedical sciences.

This is an extraordinary time for the development and advancement of life sciences. Technological improvements have provided a platform for increased, in-depth study of biology and related disciplines. Unfortunately, because of the recent decline in endowment income and subsequent decrease in operating budgets, we must also be vigilant in terms of cost containment. The difficulty arises when the necessary support for initiatives meets with decreased funding, creating a “perfect storm.” Fortunately, we have been successful, so far, in applications for competitive grants for our researchers and in building successful partnerships with the biotech industry, thereby creating alternative funding opportunities for graduate students.

### **Research Highlights**

The Department of Biology, widely recognized as one of the best nationally and internationally, is renowned for its cutting-edge research and its subsequent impact on medical science and the biotech industry. A sampling of significant research accomplishments this past year follows.

Angelika Amon and her lab gained new insights into how cells divide, a process important to cancer research. Her lab has shown that mammalian cells with extra chromosomes share some common traits that could be exploited to develop cancer treatments. Having too many chromosomes, a condition known as aneuploidy, wreaks havoc on an organism and usually results in birth defects or death. However, it seems to confer an advantage on tumor cells, which are nearly always aneuploid.

Laurie Boyer has examined the role of chromatin, the structure that forms when DNA is wound around a core of proteins called histones, on gene expression in embryonic stem cells. The Boyer lab has discovered that a histone variant, H2AZ, plays a critical role in differentiation of stem cells to become different types of adult cells. These findings could also shed light on the possible role of DNA packaging in cancer development.

Christopher Burge and his lab have explored the degree to which human genes express multiple messenger RNAs through a process known as alternative splicing, and they have shown that in humans alternative splicing is far more prevalent and varies more between tissues than was previously believed. They also found that different people's brains often differ in their expression of alternative spliced mRNA isoforms.

Frank Gertler's lab—in collaboration with scientists at MIT, the Albert Einstein College of Medicine, and Weill Cornell Medical School—has developed a test based on an earlier finding that the co-mingling of three cell types can predict whether localized breast cancer will metastasize. The test could enable physicians to identify which breast cancer patients should receive aggressive therapy, thereby sparing those with a low risk for metastatic disease from undergoing unnecessary and potentially dangerous treatment.

Robert Horvitz and his group have demonstrated that multiple signaling pathways can control even the simplest worm behaviors. The results might have implications for the treatment of brain disorders.

Rudolph Jaenisch's lab has developed a novel method to remove potential cancer-causing genes during the reprogramming of skin cells from Parkinson's disease patients into an embryonic-stem-cell-like state. His lab was then able to use the resulting induced pluripotent stem cells to derive dopamine-producing neurons—the cell type that degenerates in patients with Parkinson's disease.

Susan Lindquist's lab is also researching Parkinson's disease and has demonstrated one of the first links between genetic and environmental causes of the disease. They found that a single gene, known as *PARK9*, protects cells from manganese toxicity and rescues neurons from overexpression of the protein alpha-synuclein. Misfolded alpha-synuclein is the hallmark of the devastatingly debilitating neurological disorder.

Amy Keating's lab has shown that new computer models can design specific protein interactions. The interactions between proteins underlie nearly everything that happens inside a cell (from reading DNA to communicating with the outside world). Many of those proteins have similar structures, yet they collocate and interact only with their specific partner.

Michael Laub and his team have discovered how bacteria ensure that they respond correctly to hundreds of incoming signals from their environment. The researchers also successfully rewired the cellular communications pathways that control those responses, raising the possibility of engineering bacteria that can serve as biosensors to detect chemical pollutants.

Dianne Newman's group has found that ancient bacteria offer a new line of attack against cystic fibrosis. The pigments responsible for the blue-green stain of the mucus that clogs the lungs of cystic fibrosis (CF) patients are primarily signaling molecules that allow large clusters of the opportunistic infection agent *Pseudomonas aeruginosa* to organize into structured communities. This insight concerning the leading cause of death of people with CF suggests that the phenazine-processing machinery could become a potential target for drugs to treat *P. aeruginosa* infections in CF patients.

David Sabatini and his group have found that blocking a specific protein complex prevents the formation of tumors in mice that are genetically predisposed to develop prostate cancer. Interestingly, inhibiting this protein complex in non-cancer cells appears to have no effect, suggesting that the protein complex may represent a promising target for drug development.

Leona Samson's research team found that "too much of a good thing" — a naturally occurring DNA repair system that normally protects cells from damage — can cause retinal degeneration and blindness when overstimulated. The team found that relatively low-level exposure to an environmental toxic agent provoked very active DNA repair that led to surprisingly high rates of retinal degeneration in mice, much higher than in mice lacking the same DNA repair pathway. The work raises the possibility of developing treatments for retinal degeneration by blocking a particular DNA repair pathway.

Phillip Sharp's lab, in collaboration with that of Richard Young, is reversing conventional DNA wisdom. The copying of DNA's master instructions into messenger RNA molecules by RNA polymerase, a process known as transcription, has always been thought to be a unidirectional process whereby the RNA polymerase starts and moves in one direction. However, in work that represents a fundamental shift in scientists' understanding of the phenomenon, new evidence points to two RNA polymerases frequently starting from the same site and moving in different directions.

Michael Yaffe's research demonstrates that a new approach could aid in tailoring chemotherapy treatments. After spending years developing a computational model to help illuminate cell signaling pathways, a team of MIT researchers decided to see what would happen if they "broke" the model. The results revealed new ways in which cells process chemical information and could indicate how to maximize the effectiveness of disease treatments such as chemotherapy.

## **Personnel**

In September 2008, Wendy Gilbert joined the department. Gilbert is a molecular biologist interested in how switches in the mode of regulation of translational initiation can give rise to adaptive global changes in gene expression. She completed her postdoctoral studies with Jennifer Doudna at the University of California, Berkeley, studying the mechanisms and regulation of eukaryotic translation. Her PhD, with Christine Guthrie at the University of California, San Francisco, studied mRNA processing and export from the nucleus in yeast.

Matthew Vander Heiden recently accepted our offer to join the department and the Koch Institute for Integrative Cancer Research beginning in September 2009. He earned his MD and PhD degrees at the University of Chicago. His postdoctoral work was done with Lewis Cantley at Harvard Medical School. Matthew has spent considerable time exploring the connections between the cellular biochemistry of central metabolism and the physiology of disease.

Effective July 1, 2009, Michael Yaffe was promoted to full professor and Thomas Schwartz was promoted to associate professor without tenure.

### **Departmental and Administrative Initiatives**

The Department of Biology has been highly successful in the development of interdepartmental graduate education programs. Specifically, we now have established programs in Computational and Systems Biology (CSBi) under the leadership of Douglas Lauffenburger and Chris Burge as codirectors, the Graduate Program in Microbiology under the direction of Alan Grossman, the Molecular Cellular Neuroscience (MCN) program led by Troy Littleton, and the Chemistry-Biology Interface Training Program run by Barbara Imperiali and Robert Sauer.

The Graduate Program in Microbiology includes more than 50 faculty from multiple departments and divisions who study or use microbes in their research. This program integrates educational resources, crosses departmental lines, builds bridges among faculty with shared interests, and fosters collegiality when training students in the study of microbial systems. Eight students entered this program in fall 2008 and the Class of 2009 will have six students.

Beginning in fall 2009, the MCN program will allow entering Biology and Brain and Cognitive Science (BCS) students to work in any designated MCN lab, regardless of whether the faculty have secondary appointments in Biology or BCS. Incoming students will follow the curriculum and policies of the department from which they entered, regardless of their lab choice, and will be supported by their entering department for their first three years. Further, students will not have to preselect this track but rather have it as an option as they move through the curriculum. We are currently organizing top teaching faculty from both Biology and BCS to form a two-semester core curriculum for graduate students in the MCN program. The MCN program recently received a great boost from a seed grant from the Fidelity Non Profit Management Foundation.

Biology has made a significant capital investment in updating equipment and adding the capability for high-throughput sequencing with the creation of the BioMicro Center. The center's scientific director will provide input to the MIT community on experimental design for genomics-based experimentation, and advice on the interpretation of data, using the appropriate computational and statistical methods. The center was made possible through equipment grants from CSBi, the Koch Institute, and Department of Biology funds. Biology, the Koch Institute, the Department of Biological Engineering, and the Center for Environmental Health Sciences jointly support the center.

As noted previously, several of our principal investigators—including Tania Baker, Cathy Drennan, Amy Keating, Bob Sauer, Thomas Schwartz, and Mike Yaffe—have made significant advances in upgrading the department’s resources for structural biology. By the end of 2009, we will have completed the acquisition of X-ray diffraction and nanoscale crystallization equipment to implement a state-of-the-art structural biology facility.

Outreach and recruitment of underrepresented minorities play an important role in the department. As a result, we have marshaled our efforts to increase the representation of minorities in our program and are aggressively recruiting these candidates. We have made considerable progress in our graduate program, and we will continue to pursue faculty and students who will further enhance the diversity of our department.

### **Faculty Honors and Awards 2008–2009**

Tyler Jacks and Monty Krieger were elected to the National Academy of Sciences this past year, in recognition of their original and significant research. The National Academy of Sciences is a prestigious, private organization dedicated to the advancement of science and its applications for improving the benefit of humanity.

Stephen Bell received the 2009 National Academy of Sciences Award for Microbiology.

Leonard Guarente was honored by the New York University School of Medicine Biotechnology Study Center as a “biomedical research pioneer” for the discovery of sirtuins alongside two other pioneers in biomedical research.

Richard Hynes was the recipient of the 2008 Pasarow Medical Research Award in recognition of his contributions to cardiovascular disease research.

Gobind Khorana (professor emeritus) was honored with the naming of Khorana Park at the University of British Columbia in Vancouver, Canada, and establishment of a new award—the Khorana Prize—by the Royal Society of Chemistry, London, for outstanding achievements in research at the chemistry and life science interface.

Dianne Newman and David Sabatini were designated as HHMI Investigators.

Aviv Regev and Alexander van Oudenaarden, a recent joint appointee with the Department of Physics, were two of the 16 scientists nationally to receive a prestigious NIH Pioneer Award. This award recognizes “pioneering—and possibly transforming—approaches to major challenges in biomedical and behavioral research.

David Page was elected to the Institute of Medicine.

JoAnne Stubbe was honored with the Nakanishi Prize, presented to recognize and stimulate significant work that extends chemical and spectroscopic methods to the study of important biological phenomena.



Graham Walker was named as an American Association for the Advancement of Science fellow. This honor recognizes him for his efforts to advance science or its applications.

Several of our junior faculty were similarly recognized for their scientific accomplishments and promise.

Laurie Boyer was awarded a three-year Massachusetts Life Sciences Center grant.

Paul Chang was named a 2008 Rita Allen Foundation Scholar.

Iain Cheeseman received the Massachusetts Life Sciences Center grant and was also named a Searle Scholar.

Dennis Kim was awarded a four-year Ellison Medical Foundation Award.

Michael Laub, Peter Reddien, and Aviv Regev were named HHMI Early Career Scientists. Regev was one of the 16 scientists nationally to receive an NIH Pioneer Award.

Jeroen Saeij was one of four MIT researchers to receive the new American Heart Association grants. He was also awarded a Massachusetts Life Sciences Center grant and a Knights Templar Foundation grant.

Thomas Schwartz—along with Tania Baker, Cathy Drennan, Amy Keating, Bob Sauer, and Mike Yaffe—was awarded a NIH shared instrument grant. This award was issued under the American Recovery and Reinvestment Act (ARRA) of 2009; it was the first ARRA grant awarded to MIT.

### **Undergraduate Education**

There were 327 undergraduates registered as biology majors during the 2008–2009 academic year. Of these students, 29 left biology for another major and 124 students declared biology as a major during the academic year, including 75 freshmen who declared biology as their major in spring 2009.

The bachelor of science degree was conferred to 73 students from September 2008 through June 2009. Of them, 54 were in Course 7 and 19 were in Course 7-A.

We are pleased to note that a number of biology majors received awards in 2008–2009.

Veena Venkatachalam (2009) from Berkeley Heights, NJ, won an Alpha Chi Sigma award for distinguished scholastic achievement, originality, and breadth of interest in chemistry.

Sarah J. Smith (2009) from Whitesboro, NY, won a Chemistry Research Award for outstanding contributions in the area of research.

Elise G. Liu (2009) from Auburn, AL, was presented with a Merck Index Award for outstanding scholarship in chemistry.

Carmel Mercado (2009) from Coral Springs, FL, won an Award for Excellence in Foreign Languages and Literatures. This award is given to undergraduates who achieve proficiency in a foreign language, cultural understanding, and enthusiasm for foreign language learning.

Adlai Grayson (2010) from Opa Locka, FL, not only received the William L. Stewart Jr. Award for outstanding contributions to extracurricular activities and events, she was also presented with the John S. W. Kellett Award for exceptional commitment to creating a more welcoming environment at MIT, including but not limited to improving the experience of lesbian, bisexual, gay, transgendered, and questioning individuals.

Kathleen Xie (2009) from North Billerica, MA, was given an Association of MIT Alumnae (AMITA) Award, presented to an outstanding senior woman who has demonstrated the highest level of academic excellence through her coursework and related professional activities at MIT.

Grace Lee (2010) from Potomac, MD, won the Priscilla King Gray Award for Public Service, for exceptional commitment to public service at MIT and its surrounding communities.

Susan Shepherd (2011) from Fresno, CA, won a second-place Prize for Writing Science Fiction and honorable mention in the Boit Manuscript Prize in Fiction.

Alexandra Corella (2010) from La Quinta, CA, received a third-place Robert A. Boit Writing Prize in Poetry.

Yuri Hanada (2010) from Farmingdale, NY, received a second-place S. Klein Prize for Science Writing.

Matthew Meisner (2011) from Madison, WI, won a first-place DeWitt Wallace Prize for Science Writing for the Public.

Clara Yuan (2009) from Campbell, CA, won a first-place Writing and Humanistic Studies Prize for Engineering Writing.

Sally Peach (2009) from Bessemer City, NC, won the Joseph D. Everingham Award, which recognizes a single creative outstanding performance or notable creative accomplishment in theater arts by a graduating senior.

Hanna Kuznetsov (2009) from Lexington, MA, won the Edward S. Darna Award, presented to a graduating student who has demonstrated excellence in theater arts and made a substantial contribution to the health of theater life on the MIT campus.

Carmel Mercado (2009) from Coral Springs, FL, was given the Peter and Sharon Fiekowsky award for excellence in teaching at Experimental Study Group.

Hanna Kuznetsov (2009) from Lexington, MA, was given a Senior Legacy Award.

Ryan A. Flynn (2010) from Mount Laurel, NJ; Yuri Hanada (2010) from Farmingdale, NY; and Minh-Phuong Huynh-Le (2010) from Silver Spring, MD, were all initiated into the Order of Omega National Honor Society.

Kathleen Li (2010) from Plano, TX, won a Public Service Center grant for summer 2008 and was selected for a Paul and Priscilla Gray Value-Added Internship for spring 2009.

Swetha Kambhampati (2010) from Irvine, CA, won a Public Service Center grant for the fall 2008 term.

Yi Wang (2009) from Woodinville, WA, won a Public Service Center grant for Independent Activities Period 2009.

Shammi Quddus (2010) from Chittagong, Bangladesh, won a Public Service Center grant for spring 2009.

Helen D' Couto (2012) from Austin, TX, was given a Public Service Fellowship for summer 2009.

Grace Lee (2010) from Potomac, MD; Anila Sinha (2010) from Nashua, NH; and Yi Wang (2009) from Woodinville, WA, received Public Service Center AmeriCorps Student Leaders in Service Education Awards.

Biology majors from the Class of 2009 Em Ho from Carlisle, MA; Tristan Kooistra from Campobello, SC; Sunny Lou from Wayland, MA; Carmel Mercado from Coral Springs, FL; Thomas Mildorf from Alexandria, VA; Veena Venkatachalam from Berkeley Heights, NJ; Yi Wang from Woodinville, WA; Kathleen Xie from North Billerica, MA; and Erica Young from Sharon, MA, were chosen for Phi Beta Kappa.

In addition, the department presented the following awards and prizes.

Tristan Kooistra (2009) from Campobello, SC, received the Whitehead Prize for outstanding promise for a career in biological research through academic scholarship as well as contributions to research and the MIT community.

Ryan Flynn (2010) from Mount Laurel, NJ, received the Merck Prize for outstanding research and academic performance in biophysical or bioinformatics sciences.

Grace Lee (2009) from Potomac, MD, received the Gene Brown Prize for outstanding academic scholarship and demonstrated excellence as a teaching assistant.

Amudha Panneerselvam (2010) from Cranston, RI, received the Susan Hockfield Prize in Life Sciences for a third-year MIT undergraduate student in any area of the life sciences who has demonstrated both exceptional performance and promise for graduate study and research.



Samantha Burke (2009) of Tewksbury, MA, received the Ned Holt Prize for demonstrated excellence in scholarship as well as service to the MIT community.

Jocelyn Chin (2009) of Los Altos, CA, received the Salvador E. Luria Prize for excellent scholarship and research of publication quality.

Adelaid Fuller (2009) from Weybridge, VT; Jaclyn Ho (2009) from Chappaqua, NY; Sunny Lou (2009) from Wayland, MA; Nimisha Schneider (2009) from Brookline, MA; and Shuo Han (2009) from Diamond Bar, CA, received the John L. Asinari Award for outstanding research in the field of life sciences.

Eleven students were invited by their research faculty mentors to speak at the Undergraduate Research Symposium held in January. These students included Guo-Liang Chew (2010) from Singapore; Christine Chin (2009) from Fayetteville, NY; Ryan Flynn (2010) from Mount Laurel, NJ; Tristan Kooistra (2009) from Campobello, SC; Cassie Liu (2010) from Tomball, TX; Amudha Panneerselvam (2010) from Cranston, RI; Lauren Rodda (2011) from Vienna, VA; Dima Ter-Ovanesyan (2010) from Newton, MA; Clara Yuan (2009) from Campbell, CA; Erica Young (2009) from Sharon, MA; and MaryAnn Zhang (2009) from Collegeville, PA.

### **Graduate Education**

From July 1, 2008, to June 30, 2009, the department awarded a total of 41 PhD degrees and two SM degrees in biology. Seven PhD degrees were awarded in the Joint Program in Biological Oceanography with the Woods Hole Oceanographic Institute (WHOI). There were 204 graduate students registered in the Biology Department in 2008–2009 with another 29 in the Joint WHOI Program. The incoming class for fall 2009 will consist of 42 students in the biology doctoral program, with an additional four students in the Joint Program in Biological Oceanography with WHOI.

**Chris A. Kaiser**

**Department Head**

**Professor of Biology**

*More information about the Biology Department can be found at <http://mit.edu/biology/www/>.*