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HOWARD HUGHES MEDICAL INSTITUTE

RESEARCH NEWS

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HHMI Awards $10 Million for Interdisciplinary Graduate Education

Biomedical science is becoming increasingly interdisciplinary, as reliant on the physical and computational sciences as on biology. But how are the biomedical investigators of the future going to learn to work effectively across disciplinary lines?

U.S. universities will lead the way, using grants of $1 million from the Howard Hughes Medical Institute (HHMI) to initiate fundamental changes in the way Ph.D. scientists are trained. They will use the three-year grants to develop innovative graduate education programs designed to produce a cadre of scientists with the knowledge and skills to conduct research at the interface between the biomedical, physical, and computational sciences.

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HHMI is partnering with the National Institutes of Health's National Institute of Biomedical Imaging and Bioengineering (NIBIB) to ensure sustaining support as well as start-up funds for the new programs. Following a second competition to ensure that the HHMI-funded recipients achieved their original goals, the NIBIB—committed to integrating the physical and life sciences—will support the second phase of this program, which is aimed at sustaining interdisciplinary graduate education.

"The HHMI-NIBIB partnership capitalizes on the special strengths of each organization," said HHMI President Thomas R. Cech. "HHMI can provide flexible support to catalyze development of new interdisciplinary programs, and the NIBIB will sustain these and related programs once they are developed, as NIH does so well with traditional training grants."

The recipients of the HHMI awards were chosen from 132 applicants. Their proposed programs are:

Brandeis University Quantitative biology: A new curriculum to link the physical and biomedical sciences **Carnegie Mellon University**

(collaborator—University of Pittsburgh) A new comprehensive, inter-university Ph.D. program in computational biology **The Johns Hopkins University** Interdisciplinary graduate research training program in nanotechnology for biology and medicine **New Jersey Institute of Technology, Rutgers-Newark, the University of Medicine and Dentistry of New Jersey-New Jersey Medical School** (equal partners) Development of a quantitative neuroscience doctoral training program **University of California, Irvine** Mathematical, computational and systems biology **University of California, San Diego** Multi-scale analysis of biological structure and function **University of California, San Francisco** Integrated program in complex biological systems **University of Chicago** Graduate program in biophysical dynamics and self-organization **University of New Mexico** Program for interdisciplinary biomedical sciences **University of Pennsylvania** Integrated graduate training program in clinical imaging and informational sciences

After HHMI support ends, NIBIB will step in with peer-reviewed institutional training grants. "NIBIB is excited to enter into this historic alliance with HHMI to support training of the biomedical scientist of the future, one skilled in interdisciplinary research," said Roderic Pettigrew, NIBIB director. "These scientists will be better equipped to advance medical research in the 21st century, solve major challenges, and optimize the delivery of human healthcare."

"We hope that the proposal preparation at many institutions, whether funded or not, initiated conversations across disciplinary groups that might not have occurred otherwise and that will have lasting effects," said Peter J. Bruns, HHMI vice president for grants and special programs. "Our goal is to facilitate changes in doctoral education that will enable biomedical scientists to work well across disciplinary lines."

The new graduate training grants mirror HHMI's commitment to collaborative, interdisciplinary research by biologists, physical and computational scientists, and engineers at Janelia Farm, the Institute's new research campus that will open in 2006 in Loudoun County, Virginia.

2005 Interdisciplinary Graduate Training Award Recipients: Brandeis University Working together to solve problems in molecular and cell biology, life scientists and those from the physical sciences have already shown the potential for pushing the boundaries of modern biological research. Brandeis University's new Quantitative Biology (QB) program aims to train a new generation of collaborative scientists by recruiting students from biochemistry, biophysics and structural biology, chemistry, molecular and cellular biology, neuroscience and physics. QB students with life sciences backgrounds will learn to use instrumentation and modeling, while those with backgrounds in computer science and physics will learn to apply their knowledge in life-science laboratories. The simultaneous cross training of each group of students will include interdisciplinary graduate-level courses, as well as special lectures, events, and "boot camps" to foster the communication skills necessary for a team approach to science. Students will

graduate with Ph.D.s in their chosen fields and an additional specialization in quantitative biology.

Carnegie Mellon University (collaborator—University of Pittsburgh) Using the latest computer technology, scientists are rapidly advancing their understanding of the natural world. The new joint Ph.D. program in computational biology created by Carnegie Mellon University and the University of Pittsburgh promises to produce researchers well-versed in the basics of the life and computational sciences. They will be prepared to apply the theories and methods of math, engineering, and computing to the challenging questions and problems facing biology today. The new program will feature tracks in computational genomics, computational structural biology, systems modeling, bioimage informatics—an emerging discipline using image-based and robotics-based technologies—and computational neurobiology. An interdisciplinary team of researchers drawn from many departments and schools at both universities will train the graduate students. The major focus of work under the HHMI grant will be creating a new laboratory course specially designed for computational biology students and creating new curricula in bioimage informatics and computational structural biology. An additional focus will be recruitment of minority Ph.D. candidates.

The Johns Hopkins University Scientists are in the early stages of learning how to manipulate molecules and atoms to build incredibly tiny machines and revolutionary new materials. Once found only in the pages of science fiction, a new age of nanotechnology is coming to medical science. The Johns Hopkins University's new training program in nanotechnology for biology and medicine (NBMed) aims to produce researchers able to create new particles and materials to be used in the detection, treatment, prevention, and cure of human disease. The program will recruit students from biochemistry, chemistry, physics, biology, and engineering, while making a special effort to include minorities under-represented in science. NBMed students will take three new core courses and an interdisciplinary lab course, participate in a new professional development seminar series, and present their research results at an annual NBMed symposium. This diverse group of students will learn to reach across disciplines as they advance the field of medicine through the application of nanotechnology.

New Jersey Institute of Technology, Rutgers-Newark, the University of Medicine and Dentistry of New Jersey-New Jersey Medical School (equal partners) As people live longer, brain disorders are becoming increasingly common. Furthering our understanding of the human brain—both healthy and diseased—requires the use of every cutting-edge tool that modern science has to offer. To that end, New Jersey Institute of Technology is partnering with the University of Medicine and Dentistry of New Jersey-New Jersey Medical School, and with Rutgers-Newark to create a new Ph.D. program in quantitative neurosciences. Students in this program will use a new, interactive curriculum of classroom and laboratory courses to study the behavior of cells and organisms. The curriculum incorporates principles of physiology, math, engineering, and physical and computer science. The

program will recruit students with backgrounds in math, computer science, the physical sciences, or engineering who have also had some exposure to biology or biomedical science. The program is committed to seeking students from groups under-represented in the sciences. The researchers who emerge from this program will be integrative neuroscientists.

University of California, Irvine Systems biology studies organisms as integrated and interacting networks of genes, proteins and biochemical reactions. It is an inherently hybrid discipline that utilizes the tools of engineering, math, and computer science to address biological questions. Such a multi-disciplinary approach poses significant training challenges. To address those challenges, the University of California, Irvine is creating a new Ph.D. program in mathematical, computational, and systems biology (MCSB). Courses will focus on the essentials of biology, math engineering, and computer science, as well as on critical thinking and collaboration skills. MCSB students will also receive individualized mentoring. They will participate in summer workshops and journal clubs, and they will choose student research partners from academic backgrounds different from their own. The goal of MCSB is to produce scientists with sufficient depth to be leaders in their specialized areas, but also have the breadth of knowledge and skills to enable them to know when, how, and with whom to collaborate.

University of California, San Diego With the completion of the sequencing of the human genome in 2003, biomedical science entered into its post-genomic era. One of the fundamental challenges scientists face in this era is studying biological systems across diverse scales of physical complexity, from the structure of protein molecules to the function of tissues and organs in living animals. Meeting that challenge means using an array of technology, from mass spectrometry and high-tech imaging to tissue engineering and computer modeling. The University of California, San Diego has designed a new graduate training program in multi-scale analysis of biological structure and function. The program will offer students six new hands-on graduate laboratory courses focusing on applying a wide range of technology to different scales simultaneously. The program will give students the practical experience in research methods and technologies that they can then use to address some of the most pressing problems in human disease research. These students are expected to become the next generation of leaders in integrative, multi-disciplinary biomedical science.

University of California, San Francisco Everyone has heard of military boot-camps, but the University of California, San Francisco, is going to send graduate science students to boot-camp. There they will be immersed in disciplines other than their own. Students in UCSF's new Integrative Program in Complex Biological Systems (ipCBS) will also take five new courses in computer modeling and observation of molecular and cellular behavior. The program hopes to produce scientists who speak the language of math, physics, and engineering, as well as biology. The program will recruit students from a range of scientific backgrounds as well as groups underrepresented in the sciences. Students will receive degrees from existing programs in biophysics, biological and medical informatics, and

bioengineering at UCSF with an ipCBS emphasis.

University of Chicago The study of naturally recurring patterns, such as the ripples in wind-blown sand or the stripes of a zebra, has taught scientists principles of self-organization that they have applied to creating computer networks. These emerging patterns also reveal mechanisms that have inspired the design of materials whose behavior changes depending on the environment—for example, a change in pH or temperature. Such materials hold promise for medical applications. Harnessing the simplicity of nature, however, is a complex undertaking, requiring a multidisciplinary approach and application of physical and computer science to the study of biology. The University of Chicago's cross-disciplinary training program in biophysical dynamics and self-organization will prepare graduate students to tackle questions at the interface between the life and physical sciences. The program will include faculty from the university as well as Argonne National Laboratory. A new, interdisciplinary curriculum includes a year-long laboratory course to help students learn to apply the latest laboratory and computer technology to the study of biological systems.

University of New Mexico Scientists increasingly find themselves having to take a collaborative approach to studying the structure and function of complex biological systems, such as a cell, a tissue, or an entire organism. The University of New Mexico's program for interdisciplinary biomedical sciences will formalize and centralize the training of doctoral students who are already engaged in this team approach to research. The program's students will continue to work in small teams, collaborating with faculty from different departments within the University of New Mexico, the Santa Fe Institute, Los Alamos National Laboratories, and research centers in Latin America. The program will consolidate and coordinate a new curriculum that teaches students to apply the tools of math, physics, and computer science to the study of complex systems. The program aims to give graduate students the background, tools, and experience they will need to collaborate in a variety of interdisciplinary research projects throughout their careers.

University of Pennsylvania Medical imaging has come a long way since the x-ray revolutionized medical science. It could progress even further and faster if scientists who create new imaging technologies were trained in the basics of biology and medicine. The new graduate training program in clinical imaging sciences at the University of Pennsylvania promises to produce such scientists. The program will recruit students with backgrounds in physics, computer science, math, chemistry, engineering, and basic bioscience. It will teach them the foundations of biomedical science as well as imaging science and show them how these combine in the field of radiology. The program will also include a focus on professional development—for example, how to conduct patient-oriented research. In this way, the program hopes to produce scientists who have a clear understanding of the medical basis of disease and the technological know-how to develop new methods of detection, diagnosis, monitoring, and prognosis that can guide the treatment of patients.