COLUMBIA | RESEARCH
Office of the Executive Vice President for Research

Columbia University Bolsters Interdisciplinary Research Collaborations with Distinctive Funding Competition

RISE competition identifies six teams to receive funding for innovative research collaboration

NEW YORK, March 3, 2016—The Columbia University Office of the Executive Vice President for Research announced today the names of six teams receiving funding through **Research Initiatives in Science and Engineering** (RISE), one of the largest internal research grant competitions within the University. The annual award provides funds for up to six interdisciplinary faculty teams from the basic sciences, engineering, and medicine to pursue nascent and extremely imaginative research projects. Each team's award is worth $80,000 per year for up to two years.

The RISE competition was created in 2004 to provide Columbia faculty and research scientists with the initial funding necessary to explore paradigm-shifting and high-risk ideas. Amidst federal budget cuts for the basic sciences, researchers are increasingly challenged to provide more conclusive initial proofs of concept to demonstrate viability, even though they lack funding to complete such preliminary work. In this competition, Columbia follows the National Institutes of Health definition of high-risk research as having "an inherent high degree of uncertainty, and the capability to produce a major impact on important problems."

"This year's competition was exceptionally rigorous and inspiring," says **G. Michael Purdy**, Executive Vice President for Research, and Professor of Earth and Environmental Sciences. "RISE is an important University program for supporting interdisciplinary scholarship, and Columbia faculty met our open challenge of conceptualizing innovative collaborations with potentially substantial impact on multiple fields. The proposed collaborations in the applicant pool spanned a total of nine individual schools and 30 departments, thus revealing an interdependent and concerted research community. Through this distinct program, we are investing in the next generation of innovative research and in the productive careers of our world-class faculty, and we observe a positive return on our investment: We have already distributed $8.82 million in RISE funding, and, after the initial funding period has ended, these same projects have received in excess of $36 million in follow-on grants from external sponsors."

The 2016 competition accepted 38 Round 1 applications, thereafter inviting 11 Round 2 full proposals. Applications were evaluated through two rounds of review, with at least six reviewers assigned to each second-round application. 78 reviewers—tenured or tenure-track faculty within the University—participated in selecting this year's awarded teams.

"Research at Columbia receives Nobel Prizes; it wins prestigious center grants; it earns international praise for its impact; it ultimately obtains over $700 million in external funding every year," says **Victoria Hamilton**, Executive Director of Research Initiatives, and administrator of RISE. "These accomplishments are borne of a culture of tenacious entrepreneurialism and novelty on the parts of our faculty, research scientists, postdoctoral scholars, and graduate and undergraduate students. RISE targets interdisciplinary teams who chart unknown territories. We are proud of these newly awarded teams and the 55 who came before them."

2016 RISE AWARDEES

Designing a New Generation of Low-Power Neuromorphic Memory for Pervasive Sensing Devices Having Online Learning Ability
Mingoo Seok, Assistant Professor, Department of Electrical Engineering, The Fu Foundation School of Engineering and Applied Science
Stefano Fusi, Associate Professor, Department of Neuroscience, College of Physicians and Surgeons

Over the last four decades, pervasive sensing devices have played a crucial role in society. They have been workhorses for industrial control and infrastructure monitoring, and they are now finding applications in areas such as mobile health, unmanned vehicles, smart cities, and the Internet of Things. Designing the new generation of these devices will be extremely challenging, as they will be demanded to perform more complex and cognitive tasks with less energy budget. The approach to this challenge is to design and realize electronic devices that implement artificial neural networks using digital neuromorphic hardware. The advantage of neuromorphic hardware is energy efficiency, as it takes inspiration from the biological brain, which is far more efficient than traditional computers. One of the fundamental limitations of existing neuromorphic hardware is related to memory capacity, which can be catastrophically low when the network is required to learn online from its experience by changing its synaptic weights. This is particularly problematic when these synaptic weights have limited precision. In this project, Seok and Fusi propose to devise scalable synaptic memory models by taking inspiration from the biological synapses. The new synaptic models may be individually more complex than a conventional model, but provide significantly better scalability for storing a large number of memories in large-scale neuromorphic hardware. If successful, this proposed research can cause a ground-breaking paradigm shift by enabling synaptic memory to be compact, low power, and powerful enough to allow neural pervasive sensing devices to learn autonomously.

Listening to the Physics of Earthquakes, With Applications to Geothermal Energy Production
Ben Holtzman, Lamont Associate Research Professor, Division of Seismology, Geology, and Tectonophysics, Lamont-Doherty Earth Observatory
Douglas Repetto, Assistant Professor of Professional Practice in Visual Arts, School of the Arts
Felix Waldhauser, Lamont Research Professor, Division of Seismology, Geology, and Tectonophysics, Lamont-Doherty Earth Observatory
John Paisley, Assistant Professor, Department of Electrical Engineering, The Fu Foundation School of Engineering and Applied Science
Dan Ellis, Professor, Department of Electrical Engineering, The Fu Foundation School of Engineering and Applied Science

This project is an effort to understand how rocks fracture, by developing an entirely new approach based on how humans perceive sound. In previous work, this interdisciplinary team found that people can identify remarkable subtleties in seismic data —waves radiated by earthquakes—that is converted to sound. People identify these differences using the innate capacity to interpret physical process through sound, without knowing anything about the causes of those differences. The next step is perform experiments in which researchers squeeze and break rocks while recording the microscopic earthquakes occurring inside them. This team can identify the process causing the fracture and emitting the sound, thus being able to ask, "What aspect of the sound is being associated with a certain process?" The team will mimic this learning process with computers, using methods for pattern recognition in complex datasets. In the process, the team will be developing algorithms for the automatic remote detection of different fracture processes in the Earth. These algorithms have a very practical and potentially important application that will be pursued in this project: enhanced geothermal energy extraction involves injecting cold water into hot rock deep in the Earth's upper crust (about 5 km) to "mine" its heat— to bring that thermal energy back to the surface where it can drive turbines and generate electricity. Geothermal energy is free of CO_2 and other greenhouse gases, and is relatively inexhaustible. When cold water is injected into the crust, the water pressure and sudden temperature change can create fracture networks. The efficiency of the process depends on how well the geometry of the fracture networks and the flow of the water through them can be controlled. Identifying and understanding the fracture processes in the hot rock and controlling their transitions is where the detection algorithms will come in. Reservoir engineers will be able to make real time decisions based on the identification of fracture processes, hopefully greatly improving the efficiency of geothermal power generation.

A New Approach to Studying Natural Selection in Humans

Molly Przeworski, Professor, Department of Biological Sciences, Faculty of Arts and Sciences
Joe Pickrell, Adjunct Assistant Professor, Department of Biological Sciences, Faculty of Arts and Sciences

While there is overwhelming evidence of natural selection over long timescales and compelling examples of it operating in lab settings, in only a handful of cases has natural selection been directly observed. In humans, notably, our understanding of selection pressures acting on the genome is based on indirect statistical inferences from patterns of genetic variation and experiments in fairly distantly related species or cell lines. Przeworski and Pickrell propose a new approach: to identify variants that affect viability in extant humans by leveraging genotype data from the huge biomedical data sets now available. The idea is to mine these data sets in order to identify variants that change frequency over birth cohorts more than expected by chance, i.e., that currently affect development and aging. This approach avoids making a decision *a priori* about what traits matter to viability, and focus not on an endpoint (such as lifespan) but on any shift in allele frequencies with age. In addition, the researchers propose to look at how polygenic scores for quantitative traits vary with age, using sets of variants previously associated with one of >40 traits in genome-wide association studies. The team further plans to integrate phenotypic information with population genetic signals of past selection (i.e., over the past roughly 200,000 years) in order to elucidate the evolutionary history of alleles that affect human quantitative variation in these >40 traits or that impact survival. This research will lead to the identification of new loci with current effects on development and aging, as well as provide the first comprehensive look at natural selection in extant humans and its relationship to longer-term selective pressures.

Laboratory Study of Glacier-Bedrock Dynamics Using Centrifuge-Enhanced Gravity

Christine McCarthy, Lamont Assistant Research Professor, Division of Seismology, Geology, and Tectonophysics, Lamont-Doherty Earth Observatory
Colin Stark, Lamont Associate Research Professor, Division of Marine Geology and Geophysics, Lamont-Doherty Earth Observatory
Liming Li, Manager of the Centrifuge Laboratory, Department of Civil Engineering and Engineering Mechanics, The Fu Foundation School of Engineering and Applied Science

Understanding ice flow, in particular its slip over rock, is critical to a wide range of scientific problems with big societal impact—from predicting sea-level rise to assessing the health of mountain glaciers. Unfortunately, processes taking place at the glacier-bedrock interface, including erosion of the bedrock and the role of evolving bed roughness on friction, remain poorly constrained by observation, and many long-held theories have yet to be confirmed by experiment. To remedy this omission, this interdisciplinary team will design and build a novel centrifuge-based experimental apparatus to explore glacier-bedrock processes at natural spatial scales. The goal is to use enhanced gravity to study: (1) interaction between subglacial debris and bedrock, including rock abrasion and melt channel formation, and (2) interaction between basal melting and cavity formation in the lee of basal bumps. The results will contribute to the improved understanding of complex glacier dynamics and provide better parameters for future projections of glacier flow and mass balance.

Nanophotonics Platform for Enabling Memory Trace Visualization* In Vivo *Over a Lifetime

Michal Lipson, Professor, Department of Electrical Engineering, The Fu Foundation School of Engineering and Applied Science
Christine Denny, Assistant Professor of Clinical Neurobiology, Department of Psychiatry, College of Physicians and Surgeons

The notion that memories are stored in the brain has been around since Plato, but many attempts to localize a memory trace or an engram have proved insufficient until recently. Here, Lipson and Denny define a memory trace as a population of neurons activated during learning, and whose reactivation by the original stimuli results in memory retrieval or behavioral expression. Recent techniques have allowed scientists to identify, optogenetically activate and inhibit, and alter the content of a previously learned memory. In order to visualize and manipulate memory traces, it is critical to break the tradeoff between the time at which data are acquired and the size of the imaged brain area. Currently, data can either be acquired: 1) for an entire brain but at a single time point using *ex vivo* postmortem techniques, such as immunolabeling-enabled three-dimensional imaging of solvent-cleared organs (iDISCO), or 2) only on a small brain region, but at numerous time points using high resolution microscopy of Ca2+ transients in awake behaving mice. Here, the team proposes to resolve this discrepancy and image whole-brain memory traces in awake behaving mice across the lifespan by developing nanowaveguides. Lipson and Denny will create a minimally invasive probe with an embedded array of microfabricated nanowaveguides, similar to nano-fibers, transparent to visible light, and with micron-size diameter. With these nanowaveguides, the team aims to optogenetically target individual neurons and to acquire large areas of activity in awake-behaving mice. Key questions could be asked, such as: How are memories stored across brain circuits? Do similar memories reactivate similar neural ensembles? How do memories change over a lifetime? How do diseases affect memory?

Imaging a Single-Molecule Circuit

Latha Venkataraman, Associate Professor, Department of Applied Physics and Applied Mathematics, The Fu Foundation School of Engineering and Applied Science
Colin Nuckolls, Higgins Professor, Department of Chemistry, Faculty of Arts and Sciences

Advances in creating new functional materials for applications in electronics, sensing, and photovoltaics rely on understanding the relation between material structure and device function. With the tremendous advances in the integrated circuits industry in the past decades, device dimensionality has shrunk into the nanometer scale. Creating innovative devices using novel materials thus requires understanding device structure at these dimensions. Here, Venkataraman and Nuckolls will develop techniques to image the structure of a single-molecule device with atomic precision using a transmission electron microscope. The ability to image these devices will not only allow researchers to “see” what has never been observed before, but, more importantly, will capture the atomic scale structure of the complex nanoscale interfaces between organic molecules and metal electrodes.

PROGRAMMATIC IMPACT

“A distinguishing factor of Columbia’s research community is its interconnectedness—faculty are very enthusiastic about new collaborations—especially across the traditional boundaries of department, school, or campus,” says **Barclay Morrison**, Associate Professor of Biomedical Engineering and 2015 RISE awardee. “RISE enhances this connectivity by incentivizing creativity, and we see that some of the most exciting basic research happens at the interface between disciplines. I’m a biomedical engineer, and, together with **Steven Kernie**, a pediatric intensivist, our RISE project explores new ways of treating cerebral edema, when a brain swells following injury. We anticipate that a range of government sponsors will be interested in the outcomes of our interdisciplinary project, which was made possible by this unique competition.”

RISE not only awards critical seed funding for risky and interdisciplinary collaborations; once the funding has ceased, it tracks how the seed funding contributes to the researchers' abilities to obtain subsequent sponsorship from government agencies and private foundations.

"Using a brand new experimental method, our project will provide fundamental understanding of the physical processes controlling glacier flow rate, which is critical to a wide range of scientific problems with big societal impact—from predicting sea level rise to assessing the health of mountain glaciers," says **Christine McCarthy**, Lamont Assistant Research Professor and 2016 RISE awardee. "We have assembled an interdisciplinary team that combines the bedrock and ice specialists at the Lamont-Doherty Earth Observatory with the engineering powerhouse of the Robert A. W. Carleton Strength of Materials Laboratory to embark on this entirely novel method of testing glacier-bedrock interaction using centrifuge-enhanced gravity. Since these experiments have never been conducted, there are numerous technical challenges as well as inherent skepticism to surmount before traditional funding can be obtained. This seed funding from RISE allows us to build a prototype apparatus, and obtain the preliminary data needed to procure NSF funding and ultimately solve outstanding puzzles in glaciology."

Since 2004, RISE has awarded $8.82 million to 61 projects. These 61 teams later secured more than $36 million from governments and private foundations: an over 400% return on Columbia's investment. These projects have additionally garnered more than 110 peer-reviewed publications and educated more than 100 postdoctoral, graduate, undergraduate, and high school students. A complete list of **RISE-funded researchers** is available online.

Nominations for the 2017 competition will run from September to mid-October 2016, with five to six awarded teams announced by spring 2017.

For interview requests and additional information, contact Marley Bauce (**marley.bauce@columbia.edu**; 212-854-7836). To partially or fully fund a new RISE project, and learn more about supporting Columbia University's **Science Initiative**, contact Sylvia Humphrey (**sylvia.humphrey@columbia.edu**; 212-851-4377).

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