MILLER INSTITUTE NEWSLETTER

Spring 2009

Miller Fellow Focus: Jonathon Shlens

Deciphering the Neural Code

We envision our brain as an amazing computer, yet we often take for granted the world in which it operates. Our brain never sees the light of day, never smells the odor of a flower, nor even feels the touch of a person's hand. Rather, our brain receives patterns of electrical activity emanating from our body's senses and interprets these signals as the environment in which we live and interact. Even though we operate and think in a world of sights, sounds, and smells, our brains operate in a world of electrical pulses, blips, and patterns.

Loosely speaking the senses communicate to the brain in a unique language– not unlike a version of Morse code. These

electrical pulses, or *action potentials*, were discovered about one century ago, yet only in the last few decades have scientists begun to seriously examine what this neural codebook is. From this perspective our brain is an amazing *inferential engine*, receiving an unending stream of patterned electrical activity and interpreting these patterns as an ongoing commentary about the sensory world.

For his graduate degree, Jonathon Shlens helped devise new experimental and statistical techniques for understanding the neural code from the eye to the brain. All visual signals traverse along the optic nerve. The optic nerve, in turn, is composed of approximately one million tiny fibers emanating from individual cells in the retina. These cells in the retina termed *retinal ganglion cells* provide a one-way communication channel for all visual signals to the brain (*see* Figure 1 *on* Page 2). Jonathon's work has pursued new methods for recording the simultaneous electrical activity of large populations of these cells and deciphering what these signals mean about the visual world.

Consider for a moment two simple facts: (1) the cable from the eye to the brain consists of approximately one million

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Announcement: Call for Nominations

Miller Fellow nominations are due on
Thursday, September 10, 2009

Miller Professor applications are due on
Thursday, September 17, 2009

Visiting Miller Professor Departmental nominations are due on
Monday, September 21, 2009

Please see the enclosed insert for details on making nominations for the Miller Fellowship program. For complete information on all our programs, visit: http://millerinstitute.berkeley.edu

INSIDE THIS EDITION

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channels; (2) visual processing is performed by several billion cortical neurons. The billions of cortical neurons dedicated to visual processing are responsible for perceiving every shade of color, computing the velocity of objects, detecting individual photons at night, and recognizing every face from the past. Despite the vast resources the brain dedicates to solving these problems, all of these computations are ultimately constrained by the fidelity of visual information available to the brain, i.e. the signal traveling down the optic nerve. Given that all visual information is squeezed into one million channels, one is left to wonder how evolution managed to compress all visual information through the tremendous bottleneck that is the optic nerve.

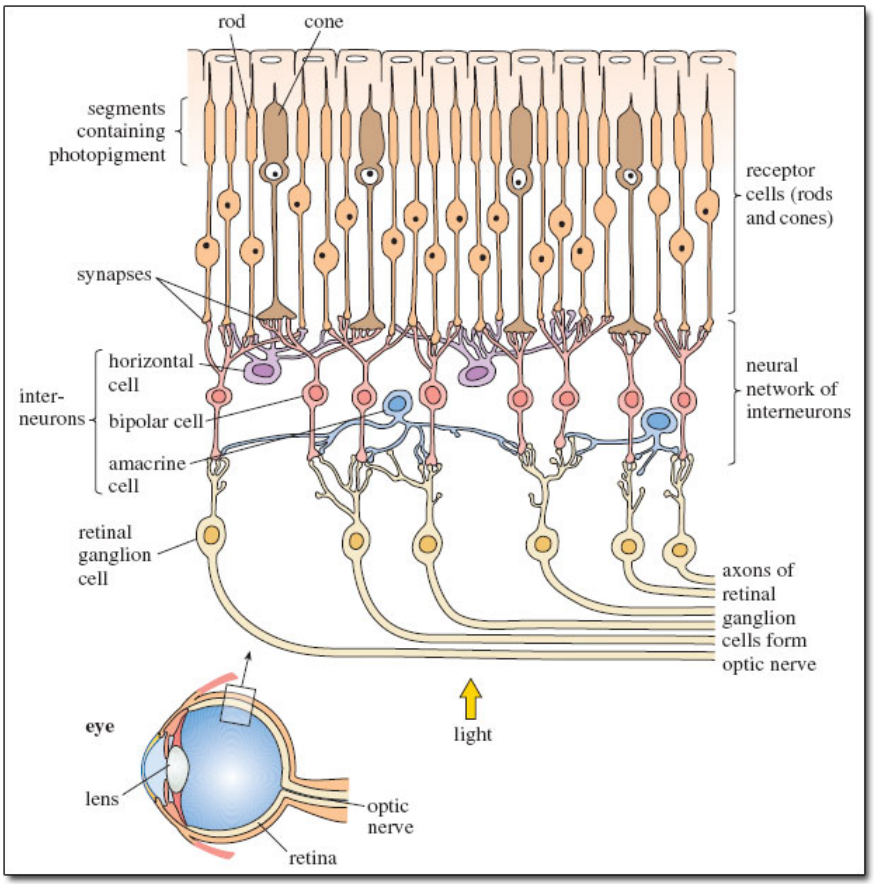

Figure 1. Diagram of retinal anatomy. Photons of light are converted to an electrical signal in the photoreceptors. The electrical signal from photoreceptor propagates through retinal circuitry before arriving at retinal ganglion cells. The fibers emanating from retinal ganglion cells form the optic nerve, which sends all visual information to the brain. Jonathon's work is focused on understanding the electrical signal transmitted by the optic nerve, or equivalently, the electrical activity of retinal ganglion cells.

Credit: http://openlearn.open.ac.uk/file.php/3820/formats/print.htm.

How the optic nerve compresses and transmits this voluminous amount of information is largely unknown. Recent theories have suggested that the visual signal from the eye to the brain might be encoded in an efficient manner due to evolutionary constraints. This so-called *efficient coding* hypothesis predicts that the signal sent from the eye to the brain is highly processed to minimize redundancy and to extract crucial features of the visual scene. One direction for examining this question is to ask whether the eye might be exploiting an idea from electrical engineering, namely *multiplexing*.

The idea is quite simple: are unique visual signals distributed over multiple distinct visual channels? Or, in biological language, do many retinal ganglion cells send their signal from the eye to the brain in a concerted manner? Neural circuits internal to the retina are known to spread the electrical signal across multiple retinal ganglion cells.

The question that Jonathon and his collaborators wish to ask is whether these neural circuits in the retina instruct populations of retinal ganglion cells to send unique visual signals in their joint activity. He and his team have been among the first to observe that individual retinal ganglion cells do not act independent of one another. Instead, they find that populations of these neurons fire action potentials in a concerted manner (*see* Figure 2 *on* Page 7).

Beyond the signal from the eye to the brain, this observation of concerted activity in retinal ganglion cells belies a deeper question prevalent through neuroscience: *how is a network more than the sum of its parts*? Many neural computations cannot be attributed to individual neurons, but are solely the property of a

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MILLER RESEARCH FELLOWSHIPS FOR 2010-2013 **May 2009**
Nomination *Receipt* Deadline: 10 September 2009 4 p.m.

The Miller Institute for Basic Research in Science invites you to assist the faculty scientists at the University of California at Berkeley by nominating candidates for Miller Research Fellowships in the basic sciences. The Miller Institute seeks to discover and encourage individuals of outstanding talent, and to provide them with the opportunity to pursue their research on the Berkeley campus. Fellows are selected on the basis of their academic achievement and the promise of their scientific research. Each Miller Fellow is hosted by an academic department on the Berkeley campus and performs his or her research in the facilities provided by the host UC Berkeley academic department. The Fellowships are intended for brilliant young women and men of great promise who have recently been awarded, or who are about to be awarded, the doctoral degree. A nominee cannot hold a paid or unpaid position on the Berkeley campus at the time of nomination or throughout the competition and award cycle.

The deadline for *receipt* of nominations is 4:00 p.m. September 10, 2009. Early nominations are encouraged to allow the candidate more time to prepare their application materials and request references by deadline. An online version of the Nomination Form is available on our website. Submit nominations by email, fax, or mail to the address above and to the attention of the *Selection Committee*. ***Incomplete nominations cannot be processed and will be returned to the Nominator for required information resulting in nomination processing delays.***

Nominations can also be a letter that must include **all** of the following information to be processed:

1) Nominee's full and legal name
2) Nominee's complete and current **active** E-mail address, current mailing address and telephone & fax numbers
3) Nominee's Ph.D. Institution and (expected) Date of Ph.D. (month & year required)
4) Recommendation and judgment of nominee's promise by the nominator.
5) Nominator's current **active** E-mail address, title, and professional mailing address (include zip code/campus mail code)

This letter of nomination can be of any length, but must include all of the information requested above in order to ensure that nominees receive notification of the nomination and advice of subsequent procedures for completion of the fellowship application process. In addition to the above items, the Executive Committee also finds it helpful in the nomination letter to have the candidate compared with others at a similar stage in their development. Eligible nominees will be invited by the Institute to apply for the fellowship. Direct applications and self-nominations are not accepted. ***Please note that persons already in positions on the Berkeley campus are not eligible for nomination or receipt of an award. Also, nominees who are non-US citizens are contingent upon eligibility for obtaining J-1 Scholar visa status for the duration of the Miller Fellowship.*** *The Miller Institute does not support H1B visa status*. The Institute will provide an annual stipend of $60,000 and a research fund of $12,000 per annum. There is provision for travel to Berkeley for Miller Fellows and their immediate families and a maximum allowance of $3,000 for removal of personal belongings. The Miller Institute also provides benefits including medical, dental, vision and life insurance. Fellowships are awarded for three years, generally beginning August 1, 2010 and ending July 31, 2013. Approximately eight to ten Fellowships are awarded each year. Candidates will be notified of the results of the competition starting in mid-December, and a general announcement of the awards will be made in the spring.

We are grateful for your thoughtful participation in this process and hope that you regard the time you may devote to this effort justified by the contribution you will be making to the careers of distinguished young scientists.

Sincerely,

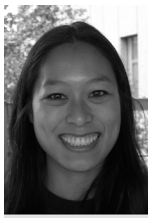
Mimi A. R. Koehl

Professor of Integrative Biology and Executive Director,
Miller Institute for Basic Research in Science

Miller Research Fellowship Awards 2009-2012

The Miller Institute is pleased to announce the 2009-2012 Miller Research Fellows. Each year, the Miller Institute seeks to discover individuals of outstanding talent and to bring to Berkeley young scholars of great promise. Candidates are nominated for these awards and are selected on the basis of their academic achievement and the potential of their scientific research. The Fellows will be working with Berkeley faculty hosts for a three-year term beginning in the 2009 academic year. A full list of all past and present Miller Fellows is available on our website at http://millerinstitute.berkeley.edu/all.php?nav=46.

Candace Chan
Ph.D. - Stanford University
Berkeley Department: Chemistry
Faculty Host: Peidong Yang



Dr. Chan is interested in synthesizing and understanding nanoscale heterointerfaces, nanostructured materials, and nanocomposites for use in energy storage and energy harvesting applications.

Gregory Crutsinger
Ph.D. - University of Tennessee, Knoxville
Berkeley Department: Integrative Biology
Faculty Host: Paul Fine

Dr. Crutsinger is interested in the links between genetic diversity within species, species diversity within communities, and the functioning of terrestrial ecosystems. In particular, he focuses on functional trait variation within dominant plants and the effects on above- and belowground community members, as well as ecosystem processes such as primary production, nutrient cycling, and invasion resistance.

Alexander Engström
Ph.D. - KTH, The Royal Institute of Technology, Sweden
Berkeley Department: Mathematics
Faculty Host: Bernd Sturmfels

Dr. Engström's research in mathematics is on algebraic methods in statistics and topological combinatorics. As a Miller Fellow, he will also work on a topic close to these, tropical geometry.

Genevieve Graves
Ph.D. - UC Santa Cruz
Berkeley Department: Astronomy
Faculty Host: Chung-Pei Ma

Over the last 13 billion years of cosmic time, galaxies have assembled from smaller components, drawn together by their mutual gravitational attraction. This assembly process (which is dominated by invisible dark matter) can be modeled with computer simulations, but the physics of star formation (which produces the visible galaxies) is too complicated to model. Dr. Graves attempts to bridge the gap by comparing observations from the most extensive spectroscopic survey of galaxies ever undertaken with the results of the largest cosmological computer simulations ever produced. The goal is to achieve a cradle-to-grave understanding of galaxy formation and evolution.

Heather Knutson
Ph.D. - Harvard University
Berkeley Department: Astronomy
Faculty Host: Geoffrey Marcy

Dr. Knutson is interested in characterizing the atmospheres of planets orbiting nearby stars, including their temperatures, compositions, and weather patterns. The planets Dr. Knutson studies are too far and too faint to resolve directly, therefore she uses observations of eclipsing systems, where the planet periodically passes in front of and then behind its parent star, to infer their properties. Many of these unique worlds have characteristics that differ substantially from those of the solar system planets, including such oddities as hot, Jupiter-like planets orbiting at a fraction of the earth-sun distance. Observations of these systems allow us to study the potential diversity of planetary atmospheres and provide an important testing ground for our models of these atmospheres.

Chang Liu
Ph.D. - The Scripps Research Institute
Berkeley Department: Bioengineering
Faculty Host: Adam Arkin

Much of nature's complexity emerges from evolution in the context of interacting organisms. Dr. Liu is interested in modeling and enforcing various forms of interaction among bacteria in order to understand the dynamics of the resulting ecologies. He will also conduct directed evolution experiments within the constraints of these interdependences with the aim of finding new dynamical properties.

Scott Morrison
Ph.D. - UC Berkeley
Berkeley Department: Mathematics
Faculty Host: Vaughan Jones

Dr. Morrison is interested in the interplay between low dimensional toplogy (knots, surfaces and 3-manifolds) and algebra. He works on algebraic classification problems (e.g. fusion categories) using topological and combinatorial techniques. Conversely, he uses rather algebraic constructions (Khovanov homology and blob homology) to develop new invariants of 3- and 4-dimensional manifolds.

Tae Joo Park
Ph.D. - University of Texas, Austin
Berkeley Department: MCB
Faculty Host: Richard Harland

Dr. Park's research will focus on cartilage and bone development. Abnormal development of cartilage and bone is among the most common congenital birth defects. However, the precise mechanisms of bone development are not well understood. Most of our bones develop using a well-conserved mechanism known as endochondral bone formation. Considering the high conservation of cellular mechanisms for bone formation, the diversity of shapes seen in cartilages and bones is very intriguing. Dr Park is specifically interested in bone shaping. To address the mechanism for shaping our bone and cartilage, he will combine computational prediction and live confocal imaging techniques. Also, conditional mutations will be introduced into mice to study cartilage and bone formation.

Nicholas Piro
Ph.D. - MIT
Berkeley Department: Chemistry
Faculty Host: Christopher Chang

The availability of inexpensive, renewable fuels will be vital to the future of a healthy planet and population. Important to new technologies will be chemical catalysts that can form and break bonds for the synthesis and utilization of these fuels. Dr. Piro's work will focus on the synthesis and study of molecular catalysts that carry out reactions of small molecules, such as H2, O2 and CO2, that are relevant to these processes. A key feature of this work will be the use of inexpensive, earth-abundant metals (including iron, cobalt, and nickel) to carry out these challenging transformations.

Daniel Rabosky
Ph.D. - Cornell University
Berkeley Department: Integrative Biology
Faculty Host: John Huelsenbeck

One of the most striking features of the natural world is the disparity in diversity among groups of organisms: some groups contain an impressive array of different species and morphologies, yet many other groups are just as noteworthy for what they lack in diversity. Dr. Rabosky studies evolutionary radiations across a variety of organisms, timescales, and geographic settings in order to make sense of this variation. His research combines empirical analyses of diversification in Australian lizards and other taxa (including marine phytoplankton and birds) with the development of new mathematical and computational techniques for modeling evolutionary data.

Birth Announcements

Congratulations to **Younjoon Jung** (Miller Fellow 2002 - 2005) on the birth of their daughter Hye-Ihn (meaning Grace) Jung, born May 30, 2007.

Congratulations to Vitaliy and **Sasha Turchyn** (Miller Fellow 2005 - 2008) on the birth of their daughter Alesya Turchyn, born December 24, 2008.

Congratulations to Elizabeth and **Ed Feng** (Miller Fellow 2005 - 2008) on the birth of their son, Eli Minli Feng, born January 6, 2009.

Awards & Honors

March 23, 2009: **Matt Francis** (Miller Fellow 1999 - 2001) has been awarded a 2009 Distinguished Teaching Award from the UCB Committee on Teaching.

March 11, 2009: **Andrew Streitweiser** (Miller Professor 1964 - 1965, 1979 - 1980) and **Rich Saykally** (Miller Professor 1985 - 1986, 1997 - 1998, Fall 2006) were both included in the Berkeleyan's Laurels section for their outstanding achievements in chemistry. Streitweiser has been awarded the American Chemistry Society's Roger Adams Award in Organic Chemistry while Rich Saykally has been awarded the Peter Debye Award in Physical Chemistry.

March 9, 2009: **Ray Jayawardhana** (Miller Fellow 2000 - 2002) has been awarded a Steacie Fellowship from the Natural Sciences and Engineering Council of Canada (NSERC).

February 23, 2009: **Paul Richards** (Miller Professor 1970 - 1971, 1987 - 1988, Fall 2001) was awarded the Dan David Prize for his contributions to the field of astrophysics. He shares this award with Andrew Lange and Paolo De Bernardis.

February 20, 2009: **Munira Khalil** (Miller Fellow 2003 - 2006) has been awarded a 2008 David and Lucille Packard Fellowship.

February 19, 2009: The Miller Institute is proud to announce the following recipients of the 2009 Sloan Research Fellowship:
--**Subhadeep Gupta** (Miller Fellow 2003 - 2006)
--**Benjamin McCall** (Miller Fellow 2001 - 2004)
--**Rory Waterman** (Miller Fellow 2004 - 2007)

February 2, 2009: **Alexander Levitzki** (Visiting Miller Professor Spring 2008) was awarded the Paul Ehrlich Magic-Bullet Lifetime Achievement Award for his outstanding scientific contributions in the field of oncology.

January 28, 2009: **Heino Falcke** (Visiting Miller Professor Fall 2006) was awarded an Advanced Investigator Grant from the European Research Council for his work on black holes and cosmic rays.

January 22, 2009: **Paul Alivisatos** (Miller Professor 2001 - 2002) has been appointed Interim Director of the Department of Energy's Lawrence Berkeley National Laboratory.

January 19, 2009: **Rich Saykally** (Miller Professor 1985 - 1986, 1997 - 1998, Fall 2006) has been awarded the Peter Debye Award In Physical Chemistry for his contributions to the field of high-resolution spectroscopy.

January 15, 2009: **Mimi Koehl** (Miller Executive Director 2008-2009, Miller Professor 2000 - 2001) has been awarded the John Martin Award from the American Society of Limnology and Oceanography for research that created a paradigm shift in an area of aquatic sciences and the Muybridge Award, which is the highest honor given by the International Society of Biomechanics.

December 5, 2008: **Neil Shubin** (Miller Fellow 1987 - 1989) won the Phi Beta Kappa Book Award in Science for his book Your Inner Fish: A Journey into the 3.5-Billion-Year History of the Human Body.

Miller Fellow Focus (continued)

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network of neurons. For instance, when a moving object traverses the field of view, no individual retinal ganglion cell communicates the object motion. Instead, populations of retinal ganglion cells communicate the object's motion. How is this global property available to a network when no individual cell contains this information? What information about the sensory world exists in the concerted activity of neurons that can not be extracted from individual neurons? It is these larger questions that drive Jonathon's own work forward and makes him believe that "cracking" the neural code provides a unique avenue for approaching these issues. Addressing larger questions in relatively simple systems such as the retina not only offers an opportunity for understanding a vital sensory modality but also might serve larger lessons for insights into the cortex.

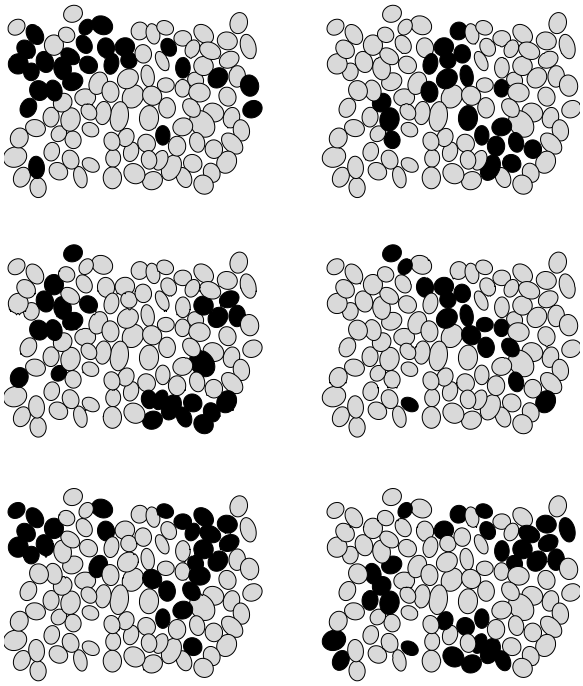
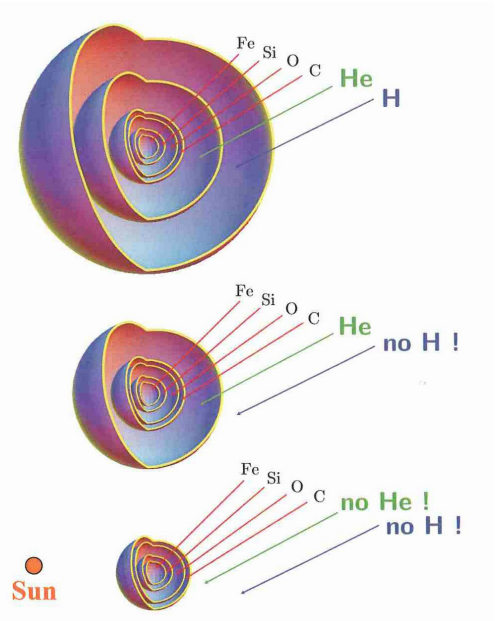


Figure 2. Concerted activity in the retina. Each frame is a measurement of the simultaneous electrical activity of populations of retinal ganglion cells. Each retinal ganglion cell, represented by an oval, sends a fiber to the brain, and thus represents a single one-way channel for communicating visual information to the brain. Individual cells are colored if they fire an actual potential, or electrical pulse, down the optic nerve. Each frame corresponds to moments in time in which spatially organized groups of cells fired action potential nearly simultaneously (within 10 ms) in response to a visual stimulus. Jonathon and his collaborators have been investigating how this patterned activity represents a distinct channel for visual information to the brain.

Credit: Jonathon Shlens

Winter 2009 Newsletter Correction



In the printed edition of our Winter 2009 issue, we accidentally left out the sun graphic, which should have been part of Figure 1 on page 2 of the Miller Fellow Focus. The Miller Institute regrets this error. The corrected version appears above and in the PDF version of the newsletter available at: http://millerinstitute.berkeley.edu/docs/Winter2009.pdf.

Obituaries

John Stallings (Miller Professor 1972 - 1973) passed away on November 24, 2008 after a battle with prostate cancer. He was 73.

John Roy Whinnery (Miller Professor 1973 - 1974), a former Dean of Engineering at UC Berkeley distinguished for his work in electromagnetism and communication electronics, passed away February 1. He was 92.

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Spring 2009
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Spring Dinner 2009 Snapshots

Miller Fellows Maryam Modjaz and Phil Hopkins

Miller Fellows Raman Sanyal, Reimundo Heluani, and Chris Douglas

This year's annual Spring Dinner was held on Monday, March 2. The guest speaker was UC Berkeley Professor Claire Kremen from the Department of Environmental Science, Policy, and Management.

The Miller Institute is "dedicated to the encouragement of creative thought and the conduct of research and investigation in the field of pure science and investigation in the field of applied science in so far as such research and investigation are deemed by the Advisory Board to offer a promising approach to fundamental problems."