SURF

Summer Undergraduate Research Fellowships
California Institute of Technology

2013 and 2014 Report

Caltech's **Summer Undergraduate Research Fellowships (SURF)** program provides students an opportunity to conduct research under the guidance of leading scientists and technical researchers.

The SURF program *introduces students to the process of scientific investigation as a creative intellectual activity* and provides them with a realistic view of the demands and rewards of a professional research career.

CONNECT

JOIN the Caltech Student-Faculty Programs Office LinkedIn page to tap into the networking potential of our undergraduate research community!

CHECK US OUT on Facebook to keep current on what's happening at SURF! https://www.facebook.com/caltech.sfp

SEND US your email address to receive quarterly SURF newsletters. They are fun, informative, and brief!

from the President

Dear SURF Friends:

Independent research performed by undergraduates becomes a formative event in their college experience. A great number of Caltech students enthusiastically seek such opportunities and we are only able to meet the demand through the generous efforts of our donors, alumni, faculty, professional research mentors, graduate students, and staff.

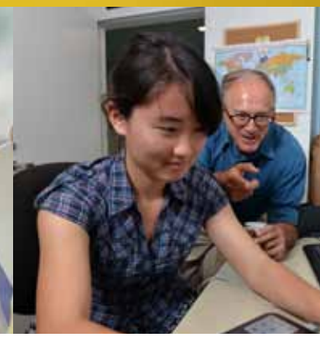
Last summer, students once again were involved in the innovative and diverse research undertaken on campus and at JPL. The projects, a few of which are featured in the report that follows, ranged from robotic technology that could one day fly on a NASA mission to corral an asteroid, to the development of tiny biosensors that potentially could eliminate manual blood sugar tests, to election polling. But they all shared the ambition, intimacy, and intensity that make Caltech SURF a program that transforms generation after generation of students.

For approximately ten weeks every summer, Caltech students delve into a self-defined area of interest, with a freedom hard to find during the academic year when class lectures, problem sets, and laboratories consume most waking hours. The focus of SURF allows students to witness firsthand the function of complex laboratories with multiple projects underway and to interact with researchers at different stages of career, from early career graduate students to veteran scientists.

This year, we are delighted to report that physicist Robert Eric Betzig is the first SURF alumnus to be awarded a Nobel Prize. Eric was awarded the 2014 Nobel Prize in Chemistry (joint with two colleagues) for their development of super-resolved fluorescence microscopy.

Your support allows the SURF program to impact generations of exceptional students, broadening and deepening their educational experience at Caltech, and preparing them to contribute to science and society in unprecedented ways. We are very grateful.

Thomas F. Rosenbaum
President, California Institute of Technology



Dedication

2013

SURF 2013 was dedicated to Mark Reinecke, Senior Director of Development at Caltech. During the *There's only one. Caltech* campaign, Mark provided extraordinary support to SURF. He served as an exceptional liaison between the program, his colleagues, and our donors. Mark cares deeply about the SURF "story" and in helping to match us with donors who share our commitment to undergraduate research. He says, "Behind every SURF gift, there are personal and often touching reasons someone decides to invest in this program." As a result of his guidance and efforts, the Institute reached its goal of increasing the SURF endowment by $10M.

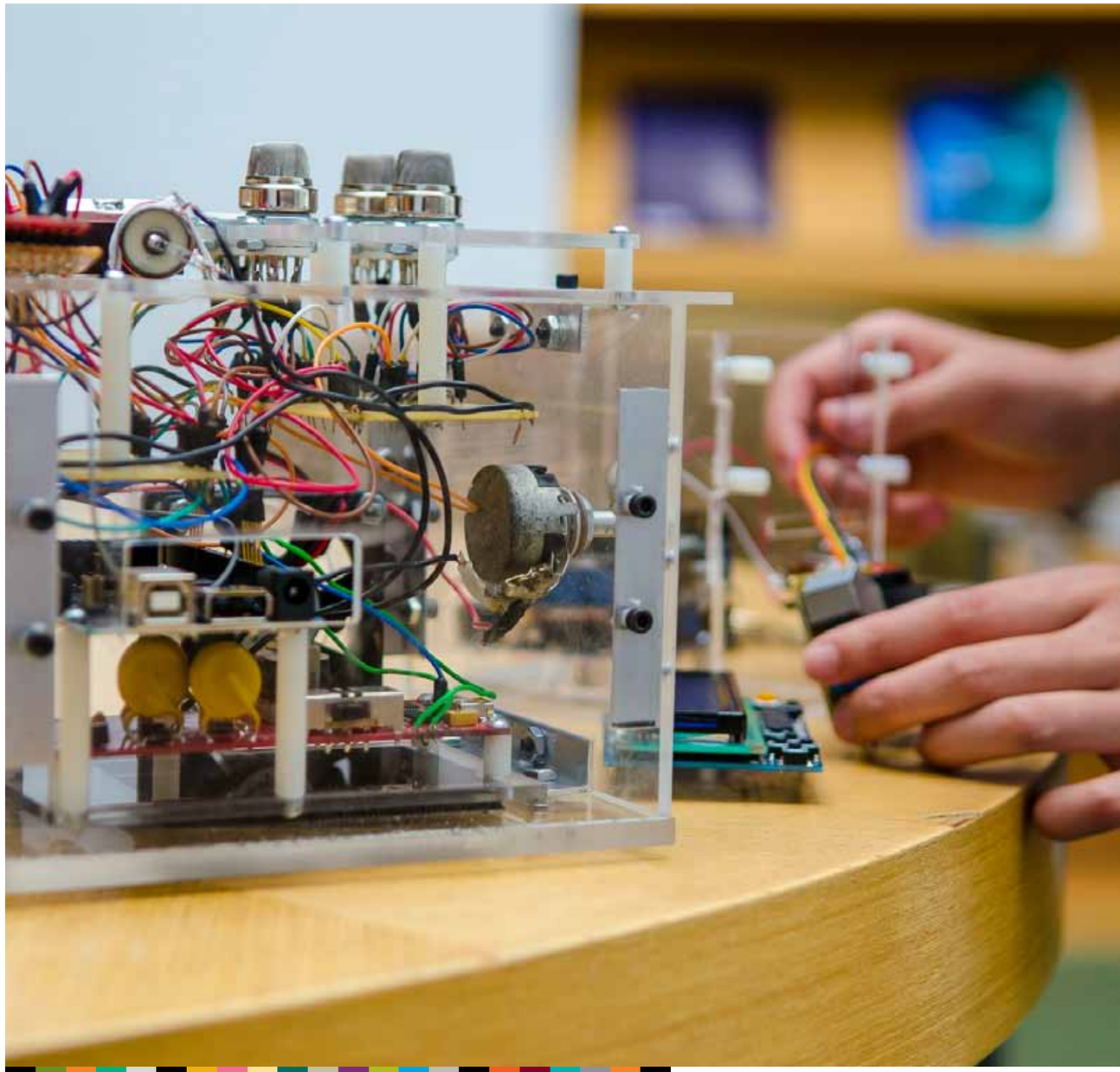
2014

Dr. and Mrs. Daniel (Ph.D. '73 CH) and Sally Harris have been friends of the SURF program since 1995. Together they have established four endowments that have provided funding for over 20 students to date. Dr. and Mrs. Harris have a profound respect for excellence in teaching and research, leading them to name their endowments in honor of four Caltech professors who share their commitment.

Selected by the SURF Administrative Committee and SURF Board, dedicatees are selected on the basis of the extraordinary support they provide to the program, our students, and the Institute.

SURF Dedicatees

1985	Dr. Ernest Swift
1986	Dr. Lee A. DuBridge
1987	Dr. Robert P. Sharp
1988	Dr. Ray D. Owen
1989	Dr. Hans W. Liepmann
1990	Dr. Fredrick H. Shair
1991	Dr. Lew Allen, Jr.
1992	Dr. John D. Roberts
1993	Dr. Robert E. Bacher
1994	Dr. Edward C. Posner
1995	Mr. Samuel P. Krown
1996	Dr. Edward B. Lewis
1997	Dr. Harold Brown
1998	Dr. Thomas E. Everhart
1999	Dr. Ward Whaling
2000	Dr. Terry Cole
2001	Dr. William M. Whitney
2002	Dr. Edward C. Stone
2003	Dr. Thomas A. Tombrello, Jr.
2004	Dr. Harry B. Gray
2005	Paul K. Richter and Evalyn E. Cook Richter Memorial Funds
2006	Lew and Edie Wasserman
2007	Ms. Carolyn A. Ash
2008	Dr. David L. Goodstein
2009	Carl and Shirley Larson
2010	Bob and Toni Perpall
2011	John and Barbara Gee
2012	Ms. Carol Casey



how to grip an asteroid

by Kimm Fesenmaier

FOR SOMEONE LIKE EDWARD FOUAD, a junior at Caltech who has always been interested in robotics and mechanical engineering, it was an ideal project: help develop robotic technology that could one day fly on a NASA mission to visit and sample an asteroid. Fouad spent 10 weeks this summer as part of the Summer Undergraduate Research Fellowships (SURF) program working in the lab of Aaron Parness, a group leader at JPL, where researchers are designing, prototyping, and refining technology for a device called a microspine gripper. Looking something like a robotic circular foot with many toes extending radially outward, such a gripper has the ability to grab onto a rocky surface and cling to it even when hanging upside down.

That makes it a good candidate to be included in the robotic capture phase of NASA's Asteroid Redirect Mission, which aims to capture an asteroid and haul it into lunar orbit where robotic and manned missions could study it more easily. One of two concepts that NASA is currently considering for that mission involves using robotic arms to grab a boulder for return from a much larger asteroid. Microspine gripper technology is being evaluated for use on these robotic arms.

Researchers at JPL have been working on this technology for almost five years. The latest version of the gripper is made entirely of metal and consists of two concentric rings of carriages—the toe-like appendages that stick out from the gripper. Each of those carriages is in turn made up of a number of "microspines" with steel hooks at their tips. When the gripper makes contact with a rocky surface, the carriages extend downward onto the rock and then pull inward toward the gripper's center. Because the carriages and microspines all move independently, the gripper is able to conform well to the rock's nooks and crannies.

For his SURF project, Fouad helped with the construction of the latest gripper prototype and worked on improving the design of the microspines for the next generation. In particular, his goal was to design a metal microspine that could conform to a rocky surface and stretch as needed toward the center of the gripper. One of the key elements in such a design is a compliant flexure, a material that can bend and flex, allowing each hook to move independently of its neighbors, to grab onto the crags of an uneven surface. In the past, elastic polymers and metal extension springs have been used for this purpose, but elastic polymers cannot stand up to the extreme temperatures of space, and the springs greatly increase the complexity of the gripper's design and complicate the manufacturing and assembly processes. A different metal option was needed.

"I started by brainstorming many different flexure designs, modeling them on the computer with CAD software, and laser cutting them out of acrylic to test their compliant properties," Fouad says. After repeating that process and improving the designs over several weeks, Fouad and Parness settled on two designs to prototype in metal and test on different rock types. In the end, one of Fouad's designs worked so well in bench-top tests that Parness's group is now incorporating it into their new gripper design.

"Edward did a great job this summer," says Parness. "The SURF program provides a great balance; it ensures an educational experience for the student but also provides a lot of value to the projects and mentors. I always try to work with the students before the summer so that the SURF projects provide some autonomy but give the students a chance to work toward something that could make a long-term contribution to the main project. Edward's project was a good example."

Fouad says he went into the SURF project with a lot of relevant experience. A statics and material mechanics course (ME 35—now ME 12) had provided him with the background he needed to understand how the microspine toes of a particular geometry would deform under different loading conditions. A mechanical design and fabrication class (ME 14) taught him important design skills. And, he says, "The experience I have gained leading the mechanical subgroup of the Caltech Robotics Team was invaluable for my work this summer. Through designing and constructing an autonomous underwater vehicle over the past year, I have acquired a great deal of design and machining techniques as well as the skills necessary to collaborate with others on a large group project."

Fouad says he loved working in Parness's lab and enjoyed having the freedom to pursue the design paths that he found most interesting and promising. And he says that he will now strongly consider pursuing a future career at JPL. "It is an incredible environment for someone looking for exciting robotics opportunities." ■

The SURF program provides a great balance; it ensures an educational experience for the student but also provides a lot of value to the projects and mentors.

sensors

to simplify diabetes management

by Jessica Stoller-Conrad

FOR MANY PATIENTS diagnosed with diabetes, treating the disease can mean a burdensome and uncomfortable lifelong routine of monitoring blood sugar levels and injecting the insulin that their bodies don't naturally produce. But, as part of their Summer Undergraduate Research Fellowships (SURF) projects at Caltech, several engineering students have contributed to the development of tiny biosensors that could one day eliminate the need for these manual blood sugar tests.

Because certain patients with diabetes are unable to make their own insulin—a hormone that helps transfer glucose, or sugar, from the blood into muscle and other tissues—they need to monitor frequently their blood glucose, manually injecting insulin when sugar levels surge after a meal. Most glucose monitors require that patients prick their fingertips to collect a drop of blood, sometimes up to 10 times a day for the rest of their lives.

In their SURF projects, the students, all from Caltech's Division of Engineering and Applied Science, looked for different ways to do these same tests but painlessly and automatically.

Senior applied physics major Mehmet Sencan has approached the problem with a tiny chip that can be implanted under the skin. The sensor, a square just 1.4 millimeters on each side, is designed to detect glucose levels from the interstitial fluid (fluid found in the spaces between cells) that is just under the skin. The glucose levels in this fluid directly relate to the blood glucose concentration.

Sencan has been involved in optimizing the electrochemical method that the chip will use to detect glucose levels. Much like a traditional finger-stick glucose meter, the chip uses glucose oxidase, an enzyme that reacts in the presence of glucose, to create an electrical current. Higher levels of glucose result in a stronger current, allowing the device to measure glucose levels based on the charge that passes through the fluid.

Once the glucose level is detected, the information is wirelessly transmitted via a radio wave frequency to a reader that uses the same frequency to power the device itself. Ultimately an external display will let the patient know if their levels are within range.

Sencan, who works in the laboratory of Axel Scherer, the Bernard Neches Professor of Electrical Engineering, Applied Physics, and Physics, and who is co-mentored by postdoctoral researcher Muhammad Mujeeb-U-Rahman, started this project three years ago during his very first SURF.

"When I started, we were just thinking about what kind of chemistry the sensor would use, and now we have a sensor that is actually designed to do that," he says. Over the summer, he implanted the sensors in rat models, and he will continue the study over the fall and spring terms using both rat and mouse models—a first step in determining if the design is a clinically viable option.

Junior electrical engineering major Sith Domrongkitchaiporn from the Scherer laboratory, also co-mentored by Mujeeb-U-Rahman, took a different approach to glucose detection, making tiny biosensors that are inconspicuously wearable on the surface of a contact lens. "It's an interesting concept because instead of having to do a procedure to place something under the skin, you can use a less invasive method, placing a sensor on the eye to get the same information," he says.

He used the method optimized by Mehmet to determine blood glucose levels from interstitial fluid and adapted the chemistry to measure glucose in the eyes' tears. This summer, he will be attempting to fabricate the lens itself and improve upon the process whereby radio waves are used to power the sensor and then transmit data from the sensor to an external computer.

SURF student and sophomore electrical engineering major Jennifer Chih-Wen Lin wanted to incorporate a different kind of glucose sensor into a contact lens. "The concept—determining glucose readings from tears—is very similar to Sith's, but the method is very different," she says.

Instead of determining the glucose level based on the amount of electrical current that passes through a sample, Lin, who works in the laboratory of Hyuck Choo, assistant professor of electrical engineering, worked on a sensor that detects glucose levels from the interaction between light and molecules.

In her SURF project, she began optimizing the characterization of glucose molecules in a sample of glucose solution using a technique called Raman spectroscopy. When molecules encounter light, they vibrate differently based on their symmetry and the types of bonds that hold their atoms together. This vibrational information provides a unique fingerprint for each type of molecule, which is represented as peaks on the Raman spectrum—and the intensity of these peaks correlates to the concentration of that molecule within the sample.

"This step is important because once I can determine the relationship between peak intensities and glucose concentrations, our sensor can just compare that known spectrum to the reading from a sample of tears to determine the amount of glucose in the sample," she says.

Lin's project is in the very beginning stages, but if it is successful, it could provide a more accurate glucose measurement, and from a smaller volume of liquid, than is possible with the finger-stick method. Perhaps more importantly for patients, it can provide that measurement painlessly.

Also in Choo's laboratory, sophomore electrical engineering major Sophia Chen's SURF project involves a new way to power devices like these tiny sensors and other medical implants, using the vibrations from a patient's vocal cords. These vibrations produce the sound of our voice, and also create vibrations in the skull.

"We're using these devices called energy harvesters that can extract energy from vibrations at specific frequencies. When the vibrations go from the vocal folds to the skull, a structure in the energy harvester vibrates at the same frequency, generating energy—energy that can be used to power batteries or charge things," Chen says.

Chen's goal is to determine the frequency of these vibrations—and if the energy that they produce is actually enough to power a tiny device. The hope is that one day these vibrations could power, or at least supplement the power of, medical devices that need to be implanted near the head and that presently run on batteries with finite lifetimes.

Chen and the other students acknowledge that health-monitoring sensors powered by the human body might be years away from entering the clinic. However, this opportunity to apply classroom knowledge to a real-life challenge—such as diabetes treatment—is an important part of their training as tomorrow's scientists and engineers. ■

voting rights in peril

A database of racial discrimination in voting laws (1957-2012)

AS A FRESHMAN, Matt Smalley already has big plans for his future. One day he hopes to start his own biotech company and intends to run for political office.

Q: In your SURF application you mention wanting to run for political office one day. What did you have in mind?

Matt: I would eventually like to run for Congress and take it from there. I am fascinated with politics, I enjoy managing and public speaking, and I also believe there are not enough scientists in government (and our current Congress has made it clear that there really need to be). I would like to change that. I do not have a specific political role model, though I have always considered myself to be very patriotic, and I believe that running for office will give me more opportunities to improve my country—the primary reason I applied for this SURF was that I saw it as an opportunity to make a real (positive) difference.

Q: Can you tell us more about your SURF project?

Matt: My mentor, Dr. Kousser, and I are compiling and preparing the largest database of modern (after 1959) voting rights violations. In 1870, the ratification of the Fifteenth Amendment to the United States Constitution guaranteed, to all citizens, that no American would be denied the right to vote on the basis of race, color, or previous condition of servitude. Nearly 100 years later, the passage of the Voting Rights Act finally made this promise real. Unlike all previous Civil Rights Legislation, the Voting Rights Act required jurisdictions with a history of racial discrimination to pre-clear any and all election law changes with the Department of Justice. This past June, the Supreme Court of the United States declared unconstitutional the formula used to determine subjected jurisdictions, citing that the data used was too old to be accurate. In this decision, the Court urged Congress to pass a new formula based on more modern data. Admittedly, racially discriminatory voting laws have dramatically decreased as a result of the Voting Rights Act.

By documenting all voting rights cases, thwarted attempts to pass discriminatory laws, and the circumstances surrounding such events, our database is able to reveal modern patterns of racial discrimination in voting laws. This database can be used to produce maps to show existence of discrimination, and potential formulas to prevent its return.

Q: What was the most interesting finding?

Matt: One of the most fascinating findings thus far is that it appears the passage of a law enabling a lawsuit on the basis of a voting rights violation has relatively little effect until it is upheld by a court. For example, the California Voting Rights Act was passed in 2001, however only one case in the database was filed between 2001 and 2007 under the CVRA. That case, Sanchez v City of Modesto, was initially decided against the minority plaintiff in 2004, but was appealed up to the State Supreme Court. The final decision made in 2007 upheld the CVRA and abolished the at-large election used by Modesto. From 2008 onward, over 100 local governments have removed their at-large elections because of the CVRA (either through lawsuits, or the threat of one). This pattern is also seen with some other laws and cases which will be addressed in the report.

I however am somewhat worried about the current strength of Sections 2 and 5 of the Voting Rights Act. The decline in reported voting rights violations seems to coincide with the Supreme Court's recent slew of increasingly restrictive decisions, and this decline is seen in the use of both Section 2 and Section 5. The patterns found in my data seem to imply that Section 2 is far less prepared to combat the dramatic increase in attempted disenfranchisement reappearing in many jurisdictions no longer subject to Section 5. ■

SURFing and the brain

Along-side nationally recognized scientists, engineers, innovators, and artists, two SURF students wowed audiences at the TEDxCaltech: The Brain event.

Three-time SURFer Tong (Joy) Lu spoke about her work in the Rangel Neuroeconomics Laboratory examining the visual cues that influence consumer choice and using mouse tracking to understand the time course of the decision making process.

Ketaki Panse, who has done three SURFs with Dr. David Anderson, Seymour Benzer Professor of Biology, spoke with her graduate student co-mentor, Hidehiko Inagaki, on emotion in the hungry fly brain.

To watch their presentations go to: tedxcaltech.caltech.edu

"As a frosh, the SURF application process seemed pretty intimidating. Because I'm an expert hyperventilator, I remember being very worried about SURF interviews with professors. When I went to meet with Dr. Anderson, I arrived 10 minutes early, paced down the hallway right by his office door, biting my nails and generally looking terrified. This continued for about 8 minutes, until I decided to knock on the door and walk in. During the interview, Dr. Anderson and I discussed mapping neuromodulation, and he stressed that someone with no prior research experience would need to work diligently and read textbooks and papers beforehand to familiarize myself with the ever beautiful *Drosophila melanogaster* a.k.a the fruit fly.

Now I realize that all of my hyperventilating and my worrying was unnecessary. The Caltech SURF program is so well-run and well-suited for undergraduates, since Caltech faculty realize that students need to get experience in their research fields as soon as possible. To get a SURF, you don't need any prior research experience—professors love to have undergrads in their labs." ■

improving the view

through tissues and organs

by Kimm Fesenmaier

THIS SUMMER, several undergraduate students at Caltech had the opportunity to help optimize a promising technique that can make tissues and organs—even entire organisms—transparent for study. As part of the Summer Undergraduate Research Fellowships (SURF) program, these students worked in the lab of Assistant Professor of Biology Viviana Gradinaru, where researchers are developing such so-called clearing techniques that make it possible to peer straight through normally opaque tissues rather than seeing them only as thinly sectioned slices that have been pieced back together.

Gradinaru's group recently published a paper in the journal *Cell* describing a new approach to tissue clearing. The method they have created builds on a technique called CLARITY that Gradinaru helped develop while she was a research associate at Stanford. CLARITY allowed researchers to, for the first time, create a transparent whole-brain specimen that could then be imaged with its structural and genetic information intact.

CLARITY was specifically developed for studying the brain. But the new approach developed in Gradinaru's lab, which the team has dubbed PARS (perfusion-assisted agent release in situ), can also clear other organs, such as the kidney, as well as tissue samples, such as tumor biopsies. It can even be applied to entire organisms.

Like CLARITY, PARS involves removing the light-scattering lipids in the tissue to make samples transparent without losing the structural integrity that lipids typically provide. First the sample is infused with acrylamide monomers that are then polymerized into a hydrogel that provides structural support. Next, this tissue–hydrogel hybrid is immersed in a detergent that removes the lipids. Then the sample can be stained, often with antibodies that specifically mark cells of interest, and then immersed in RIMS (refractive index matching solution) for imaging using various optical techniques such as confocal or lightsheet microscopy.

Over the summer, Sam Wie, a junior biology major at Caltech, spent 10 weeks in the Gradinaru lab working to find a polymer that would perform better than acrylamide, which has been used in the CLARITY hydrogel. "One of the limitations of CLARITY is that when you put the hydrogel tissue into the detergent, the higher solute concentration in the tissue causes liquid to rush into the cell. That causes the sample to swell, which could potentially damage the structure of the tissue," Wie explains. "So I tried different polymers to try to limit that swelling."

Wie was able to identify a polymer that produces, over a similar amount of time, about one-sixth of the swelling in the tissue.

"The SURF experience has been very rewarding," Wie says. "I've learned a lot of new techniques, and it's really exciting to be part of, and to try to improve, CLARITY, a method that will probably change the way that we image tissues from now on."

At another bench in Gradinaru's lab, sophomore bioengineering major Andy Kim spent the summer focusing on a different aspect of the PARS technique. While antibodies have been the most common markers used to tag cells of interest within cleared tissues, they are too large for some studies—for example, those that aim to image deeper parts of the brain, requiring them to cross the blood–brain barrier. Kim's project involved identifying smaller proteins, such as nanobodies, which target and bind to specific parts of proteins in tissues.

"While PARS is a huge improvement over CLARITY, using antibodies to stain is very expensive," Kim says. "However, some of these nanobodies can be produced easily, so if we can get them to work, it would not only help image the interior of the brain, it would also be a lot less costly."

During his SURF, Kim worked with others in the lab to identify about 30 of these smaller candidate binding proteins and tested them on PARS-cleared samples.

While Wie and Kim worked on improving the PARS technique itself, Donghun Ryu, a third SURFer in Gradinaru's lab, investigated different methods for imaging the cleared samples. Ryu is a senior electrical engineering and computer science major at the Gwangju Institute of Science and Technology (GIST) in the Republic of Korea.

Last summer Ryu completed a SURF as part of the Caltech–GIST Summer Undergraduate Research Exchange Program in the lab of Changhuei Yang, professor of electrical engineering, bioengineering, and medical engineering at Caltech. While completing that project, Ryu became interested in optogenetics, the use of light to control genes. Since optogenetics is one of Gradinaru's specialties, Yang suggested that he try a SURF in Gradinaru's lab.

This summer, Ryu was able to work with both Yang and Gradinaru, investigating a technique called Talbot microscopy to see whether it would be better for imaging thick, cleared tissues than more common techniques. Ryu was able to work on the optical system in Yang's lab while testing the samples cleared in Gradinaru's lab.

"It was a wonderful experience," Ryu says. "It was special to have the opportunity to work for two labs this summer. I remember one day when I had a meeting with both Professor Yang and Professor Gradinaru; it was really amazing to get to meet with two Caltech professors."

Gradinaru says that the SURF projects provided a learning opportunity not only for the participating students but also for her lab. "For example," she says, "Ryu strengthened the collaboration that we have with the Yang group for the BRAIN Initiative. And my lab members benefited from the chance to serve as mentors—to see what works and what can be improved when transferring scientific knowledge. These are very important skills in addition to the experimental know-how that they master." ■

Dr. Gradinaru was a SURF student in 2003 and 2004.

orchestrating the healing process in a

damaged cornea

by Kathy Svitil

IT IS SAFE TO SAY that the eye is an amazing biological system. One reason is its keratocyte cells—specialized cells that make up the bulk of the cornea. Unlike most of the other cells in our body, those in the cornea are transparent, making sight possible. Should something happen to make the cornea opaque, blindness results.

Sadly, injuries to the cornea do occur, sometimes in the simplest of ways, such as getting sand in one's eyes and scratching the cornea. The scar tissue that then grows to heal the cornea may have the unwanted side effect of being opaque. This does not happen, however, if the cornea and the tissue around it heal in a very orderly fashion. The question, then: Is it possible to encourage this orderly healing after an injury, thus preserving vision?

Professor of Chemical Engineering Julia Kornfield and graduate student Amy Fu are very much hoping that this is the case. To find out, they have assigned a few students, including Caltech senior and recent SURF fellow Jacqueline Masehi-Lano, to experiment with various growth factors that might inhibit the formation of scar tissue and promote orderly wound healing.

"We chose three growth factors to test because Amy Fu and I read several papers on growth factors that have been able to suppress some types of scar tissue," Masehi-Lano says. "In particular, we want to inhibit the formation of alpha smooth muscle actin, the type of stress fiber that creates opaque scars over corneal wounds. So far, the experiments I've done with cell cultures have worked pretty well, so it looks promising."

Eventually, the researchers hope to encapsulate the growth factors in a hydrogel that is reminiscent of the native cornea. "Our hydrogel starts out as a liquid and gels in situ on the eye," explains Masehi-Lano.

Masehi-Lano is enthusiastic about her experience with the SURF program. This past summer was her second in Kornfield's lab, and last year she was a recipient of an Amgen scholarship. "I'm really grateful that my mentor and my co-mentor have entrusted me with my own project and have allowed me to conduct my own experiments. And since it was my second summer in this lab, I was able to take up a leadership role by training a new SURF student," she says. "For me, SURF has gone beyond research. I've been able to improve my ability to present my research to the general public, which I think is extremely important." Indeed, Masehi-Lano was awarded the Caltech Doris S. Perpall SURF Speaking Competition for delivering the most outstanding oral research presentation.

Masehi-Lano plans to continue in bioengineering and is contemplating an MD/PhD program. "I've always been interested in the medical field, and though I'm committed to doing research," she explains, "I'd like to be able to do clinical trials and directly apply new medical technologies to people." ■

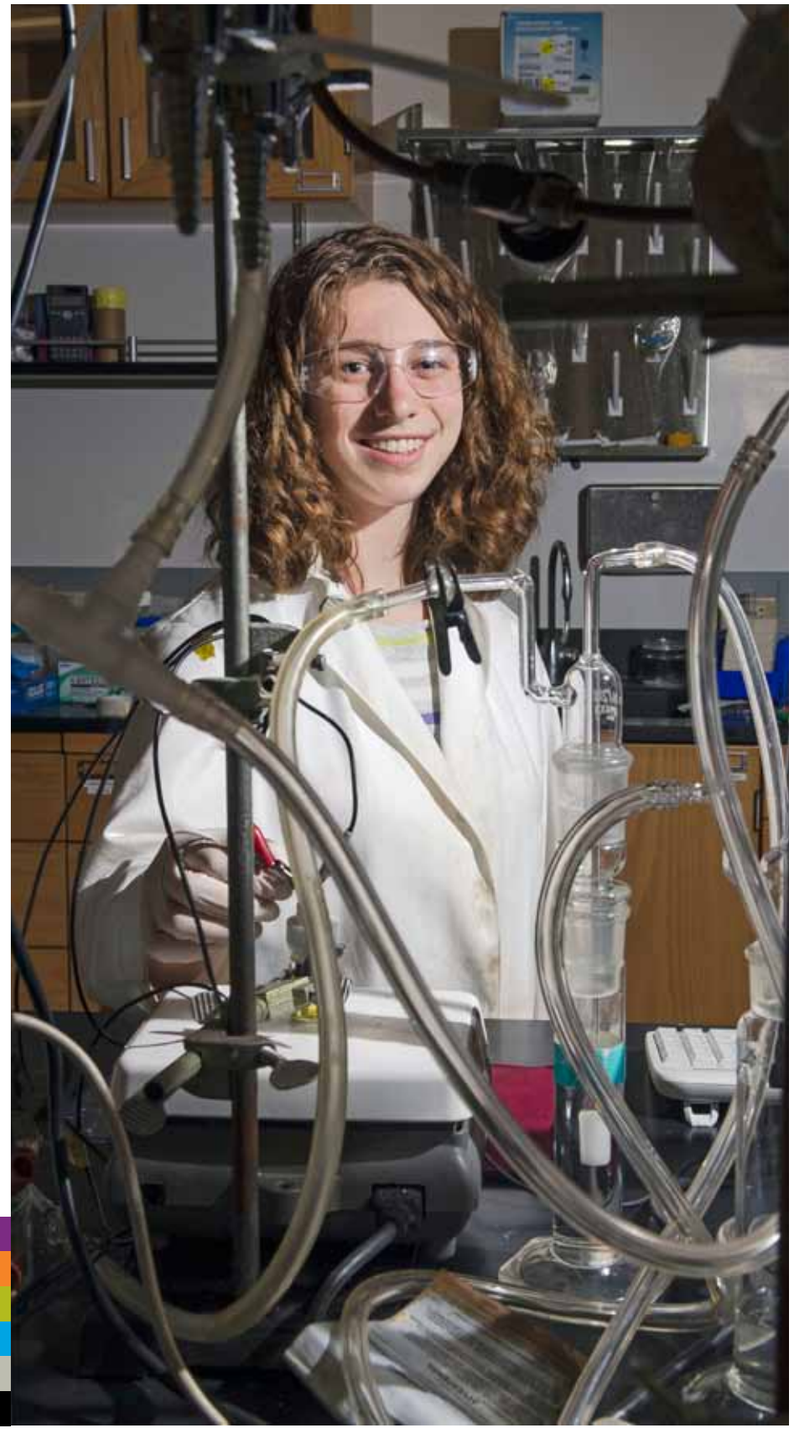
Dr. Kornfield was a SURF student in 1981.

a curious chemist searches for

cleaner catalysts

by Katie Neith

"Megan is a real ball of fire who makes molecules do what she tells them!" says Gray, the Arnold O. Beckman Professor of Chemistry and founding director of the Beckman Institute. "And she is great fun to be with—a star in our group."



CALTECH's CLASS OF 2013 is a group of passionate, curious, and creative individuals who have spent their undergraduate years advancing research and challenging both conventional thinking and one another. They have thrived in a rigorous, unique academic environment, building the kinds of skills in both leadership and partnership that will support them as they pursue their biggest and best ideas.

While college graduation is traditionally a time to celebrate scholarly achievements and to toast future pursuits, for many it is also an occasion to reflect on how they arrived at this significant milestone. Caltech senior Megan Jackson, who will receive a chemistry degree on June 14, can trace her interest in science to a chemistry teacher in high school, who encouraged Jackson to design her own research.

"My chemistry teacher gave us an independent study assignment, and I decided that I wanted to do an experiment," she recalls. "So she sent me home with a stack of books and told me to come back with an idea."

Jackson's project, which involved determining the molecular composition of the artificial sweetener Equal, got her thinking about tackling more pressing scientific questions, so she decided to attend Caltech. Although Jackson came to Caltech undecided on a major, she quickly gravitated to chemistry.

"As soon as I got in a chemistry lab, I knew that chemistry was what I wanted to do,'" she says of her first experience as a Summer Undergraduate Research Fellow (SURF) in chemistry professor Harry Gray's lab her freshman year.

That summer, she worked with a graduate student, Alec Durrell (PhD '12), on binuclear palladium catalysts for carbon-hydrogen bond functionalization. These reactions are essential in the synthesis of many pharmaceuticals, but they are quite difficult due to the inert nature of carbon-hydrogen bonds. Additionally, these reactions often require harsh chemical oxidants such as chlorine gas. Jackson and Durrell developed an electrocatalyst that reacts with chloride, essentially replacing chlorine gas with table salt and a wall socket—a much friendlier solution. Their work was published in the European Journal of Inorganic Chemistry.

After Durrell graduated, Jackson built upon the team's findings by designing and synthesizing a series of related palladium complexes, probing their electronic and spectroscopic properties.

"It was fantastic to be able to have my own project," she says, adding that she is thrilled to have been part of Gray's Solar Army. "Harry has been the best research advisor, and the entire group has been really supportive."

In addition to participating in the SURF and Amgen Scholars programs at Caltech, Jackson's research earned her the Renuka D. Sharma Award, the Arie J. Haagen-Smit Memorial Award, and the George W. and Bernice E. Green Memorial Prize, as well as graduate fellowships sponsored by the National Science Foundation and the Department of Defense. She has also had several opportunities to present her work at conferences, including this year's American Chemical Society conference in New Orleans. Jackson's travel to the meeting was funded through Caltech's George W. Housner Student Discovery Fund.

"Megan is a real ball of fire who makes molecules do what she tells them!" says Gray, the Arnold O. Beckman Professor of Chemistry and founding director of the Beckman Institute. "And she is great fun to be with—a star in our group."

When she wasn't in the lab at Caltech, Jackson could be found playing for the women's volleyball team as a libero and participating in Blacker House activities.

"A lot of my best stories come from living in Blacker and doing Ditch Day and the other fun traditions," she says.

For this year's Ditch Day, Jackson and a friend built a Harry Potter–themed stack that began with a "potions" puzzle. Divided into two teams—Gryffindor and Ravenclaw—students trying to solve the stack mixed colorful solutions for wildly different results. While the Gryffindor potions turned vibrant colors, the Ravenclaw potions turned murky white or simply failed to react.

"That's when the Ravenclaws found out they weren't really wizards, but scientists trying to learn about magic—the storylines evolved from there," she says.

Next up for the curious chemist is graduate school—Jackson will be attending MIT in the fall and plans to focus on energy-related chemistry. Her long-term goal is to have her own lab at a research university. ■

cutting wait times for voters

using simulation and optimization

by Jessica Stoller-Conrad

NO ONE EVER LIKES LONG LINES. Waiting in line may be inconvenient at the coffee shop or the bank, but it's a serious matter at voting centers, where a long wait time can discourage voters—and can be seen as an impediment to democracy.

However, with millions of Americans showing up at the polls, can long lines really be avoided on Election Day? By developing a tool to help better prepare polling places, Caltech sophomore Sean McKenna is using his Summer Undergraduate Research Fellowships (SURF) project as an opportunity to address that problem.

Over the summer, McKenna, an applied and computational mathematics major who works with Professor of Political Science Michael Alvarez, has been building a mathematics-informed tool that will predict busy times in precincts on Election Day and allocate voting machines in response to those predictions. This information could help election administrators minimize wait times for millions of voters.

"My project is based on a report from the Presidential Commission on Election Administration, which asserted that no American should ever have to wait more than 30 minutes to vote," McKenna says. "And so we're trying to see if we can help reach that goal by allocating voting machines in a new way." McKenna's work is part of the Caltech/MIT Voting Technology Project (VTP), which has been working on voting technology and election administration since the 2000 election. At a June workshop for the collaborative VTP project, which aims to improve the voting process through research, McKenna met with academics and election administrators who suggested how he might apply his background in mathematics to create a tool for voting administrators to use on the VTP's website.

The tool he is developing uses a branch of applied mathematics called queueing theory to quantify the formation of lines on Election Day. "Queueing theory assumes that arrivals to a system like a polling place have a random, memoryless pattern. Under this assumption, the fact that one person just showed up to the precinct doesn't tell us whether the next person will show up two seconds from now or two minutes from now," he says. "Furthermore, queueing theory predicts line lengths and wait times as long-term averages, which scientists might call a steady-state approximation."

Although queueing theory provided a good jumping off point, there were a few real-world problems that an analytical model on its own couldn't address, McKenna says. For example, voter arrival behavior is not completely random on Election Day; early morning and late afternoon spikes in arrivals are the norm. In addition, polls are usually only open for 12 or 13 hours, which is not considered to be enough time for steady-state queueing approximations to be applicable.

"These challenges led us to review the literature and determine that running a simulation with actual data from administrators, as opposed to attempting to adjust strictly analytical models, was the best way to represent what actually happens in an election," McKenna explained.

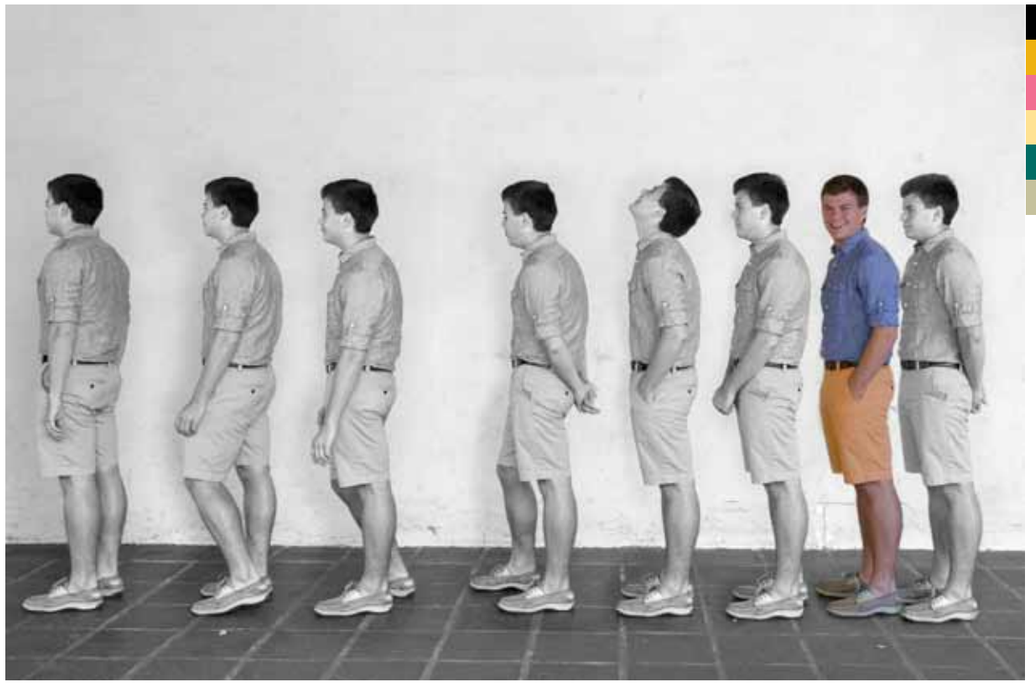
The goal of the research is to create a simulation of an entire jurisdiction, such as a county with multiple polling places. The simulation would estimate wait times on Election Day based on information election administrators enter about their jurisdiction into the web-based tool. Administrators would then receive a customized output prior to Election Day, suggesting how to allocate voting machines across the jurisdiction and detailing the anticipated crowds—information that could both predict the severity of long lines and prompt new strategies for allocating voting machines to preempt long waits.

Several other Caltech undergraduates in Alvarez's group also have been working on alternative ways to improve the voting process. Senior physics major Jacob Shenker has been developing a system for more secure and user-friendly postal voting, and recent graduates Eugene Vinitsky (BS '14, physics) and Jonathan Schor (BS '14, biology and chemistry) produced a prototype of a mobile phone app that could help voters determine if there is a long line at their polling place.

While these projects were completed separately, McKenna says there may be room for collaboration in the future. "One thing that we're hoping my tool will be able to do is to predict for administrators what times are going to be busiest, and we could also export this information to the app for voters," he says. "For example, the app could alert someone that their polling place is very likely to have long lines in the morning so they should try to go in the afternoon.

"The technologies that McKenna and his student colleagues are developing could change the way that millions of Americans participate in democracy in the future—which would be an impressive accomplishment for a young student who has yet to experience the physical aspect of lining up to vote.

"So that's one kind of sticky situation about my working on this project: I've never actually been in to vote in person. I've only been able to vote once, and since I'm from Minnesota, it had to be absentee by mail," he says. ■



ALUMNI SPOTLIGHT

Eric Betzig ’83

wins 2014 Nobel Prize in Chemistry

by Kathy Svitil

“SURF provided me an important counter weight to the very theoretical education I was getting the other nine months of the year, and was instrumental in my decision to do applied experimental science.”

Dr. Eric Betzig, SURF ’80
2014 Nobel Prize in Chemistry

ERIC BETZIG (BS ’83), a group leader at the Howard Hughes Medical Institute’s Janelia Farm Research Campus in Ashburn, Virginia, has been awarded the 2014 Nobel Prize in Chemistry along with Stefan W. Hell of the Max Planck Institute for Biophysical Chemistry and William E. Moerner of Stanford University. The three were honored “for the development of super-resolved fluorescence microscopy,” a method that allows for the creation of “super-images” with a resolution on the order of nanometers, or billionths of a meter. In essence, the work turns microscopy into “nanoscopy.”

The technique developed by the trio overcomes the so-called Abbe diffraction limit, which describes a physical restriction on the sizes of the structures that can be resolved using optical microscopy, showing that, essentially, nothing smaller than one-half the wavelength of light, or about 0.2 microns, can be discerned by these scopes. The result of the Abbe limit is that only the larger structures within cells—organelles like mitochondria, for example—can be resolved and studied with regular microscopes but not individual proteins or even viruses. The restriction is akin to being able to observe the buildings that make up a city but not the city’s inhabitants and their activities.

Betzig, building on earlier work by Hell and Moerner, found that it was possible to work around the Abbe limit to create very-high-resolution images of a sample, such as a developing embryo, by using fluorescent proteins that glow when illuminated with a weak pulse of light. Each time the sample is illuminated, a different, sparsely distributed subpopulation of fluorescent proteins will light up and, because the glowing molecules are spaced farther apart than the Abbe diffraction limit, a standard microscope would be able to capture them. Still, each of the images produced in this way has relatively low resolution—that is, they are blurry. Betzig, however realized that by superimposing many such images, he would be able to obtain a sharp super-image, in which nanoscale structures are clearly visible. The new technique was first described in a 2006 paper published in the journal Science.

After Caltech, Betzig, a physics major from Ruddock House, earned an MS (1985) and a PhD (1988) from Cornell University. He worked at AT&T Bell Laboratories until 1994, when he stepped away from academia and science to work for his father’s machine tool company. Betzig returned to research in 2002 and joined Janelia in 2005.

To date, 33 Caltech alumni and faculty have won a total of 34 Nobel Prizes. Last year, alumnus Martin Karplus (PhD ‘54) also received the Chemistry Prize.

highlights of Summer

We, as the Caltech SFP House Ambassadors, aspire to make the summer meaningful and enjoyable for all students at Caltech. We will do it in the following ways:

1. **Promote and uphold the Honor Code.**
2. **Encourage communication among all students.**
3. **Ensure that no one slips through the safety net.**
4. **Be conscientious and aware of our surroundings.**
5. **Foster long-lasting friendships.**

This year the Student-Faculty Programs (SFP) office initiated the SFP House Ambassador Program. Our vision for the House Ambassador Program was to create a vibrant, scholarly, welcoming, and inclusive community of summer undergraduate researchers living in Caltech’s houses. Acting as liaisons between the SFP office and the student community, the House Ambassadors (HA) would strive to recognize and embrace all realms of difference, identify emerging issues that affect the undergraduate research community, serve as a peer advisor for Caltech and visiting students, develop strategies for building a welcoming and inclusive student community, and implement program efforts that promote and foster a cohesive student community within the houses.

Twenty-four students representing all houses were selected as House Ambassadors. These eager students spent the spring planning on how best to achieve their charge. As summer began, the HAs thought of creative ways to welcome the visiting students into their houses. Some posted welcome notes on room doors, while others handed out small gift cups filled with treats as welcome favors. Throughout the summer, they not only hosted small social events within their houses but were also responsible for hosting one inter-house event. Overall, all events were successful in bringing students together in a social and relaxed setting!

Upon reflecting on the first year of the program, it is clear the House Ambassadors were successful in achieving our vision of creating a welcoming and inclusive environment for both the visiting and Caltech students. Generating creative ideas to organically bring students together combined with hard work, focus, and teamwork, the HAs successfully built and fostered a student community while sharing the unique culture of each house at Caltech. Additionally, they had the opportunity to further develop their own leadership skills as a result of their role as a House Ambassador. Moving forward, we hope to build on what we learned this summer and continue the SFP House Ambassador program for years to come!

Bravo, and thank you, to our amazing House Ambassadors!

Avery: Alina Hwang, Jacqueline Masehi-Lano, Ben Wang; **Blacker:** Talia Minear, Catherine Pavlov; **Dabney:** Alex Ball, Kayane Dingilian; **Fleming:** Mary Boyajian, Courtney Chen, Rushikesh Joshi, Grace Lee, Lilly Luo, Pedro Ojeda; **Lloyd:** Sophia Chen, Stephanie Moon; **Page:** Roshan Agrawal, Kalyn Chang, Wen Min Chen, Xiaomi Du; **Ricketts:** Aritra Biswas, Laura Watson; **Ruddock:** Anne Davis, Sirus Han, Bianca Lepe

Wednesday Seminar Series

The Wednesday Seminar Series is designed to introduce students to the breadth of research happening at Caltech.

2013

Tracy Dennison
Professor of Social Science History
Forget Everything You Know About History

John Doyle
Jean-Lou Chameau Professor of Control and Dynamical Systems, Electrical Engineering, and Bioengineering
Brains, Bugs, Nets, Dance, Art, Music, Literature, Fashion, and Zombies

Andrei Faraon, SURF '02, '03
Assistant Professor of Applied Physics and Materials Science
Controlling Light on a Tip at the Single Photon Level

James Heath
Elizabeth W. Gilloon Professor of Chemistry
Synthetic Molecules Designed to Emulate Monoclonal Antibodies

David Hsieh
Assistant Professor of Physics
Topical Insulators

Eric Larour
Research Scientist, JPL
Toward Modeling the Contribution of Polar Ice Sheets to Sea-Level Rise

Shu-ou Shan
Professor of Chemistry
Decision Making and Quality Control in the Early Moments of a Protein's Life

Andrew Thompson
Assistant Professor of Environmental Science and Engineering
Oceanography Down South

Leeat Yariv
Professor of Economics
What Parents Want: Evidence From Child Adoption

2014

Jamie Bock
Professor of Physics
Detecting Vibrations From the Big Bang

Colin Camerer
Robert Kirby Professor of Behavioral Economics
Irrational Exuberance and Neural Warning Signals During Endogenous Experimental Market Bubbles

Frederick Eberhardt
Professor of Philosophy
Causation vs. Correlation in Human and Machine Learning

Bethany Ehlmann
Assistant Professor of Planetary Science; JPL Research Scientist
Aqueous Environments During Mars' First Billion Years: A Video From Rovers and Orbiters

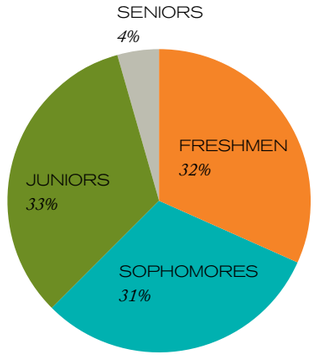
Richard Ellis
Steele Family Professor of Astronomy
Let There Be Light: Finding the Earliest Galaxies

Dennis Kochmann
Assistant Professor of Aerospace
Everyone Starts Small: Where Materials Learn to Behave

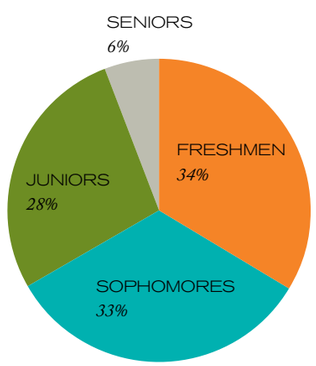
Markus Meister
Lawrence A. Hanson, Jr., Professor of Biology
Neural Computations in the Retina: From Photons to Behavior

Sarah Reisman
Professor of Chemistry
Why I Love Natural Products

2013 SURFers



2014 SURFers



Each year, one pre-freshman participated in SURF representing less than 1% of each SURF class.

The William Whitney Workshops on Professional Development

The Whitney Workshop series is designed to help students make short-term decisions in the context of long-term academic, professional, and life goals.

2013

Decisions, Decisions!
Daniel Brooks, *Graduate Student in Applied Physics*
Crystal Dilworth, *Graduate Student in Chemistry and Chemical Engineering*
Heather Duckworth, *Graduate Student in Aeronautics*
Christopher Kucharczyk, *Graduate Student in Materials Science*

Letters of Recommendation and Essays: An In-Depth Look
Candace Rypisi, *Director, Student-Faculty Programs Office*

Unraveling the Mysteries Behind the GRE
Kevin Sun, *Kaplan Test Prep*

Mastering the Graduate School Visit
Dr. Felicia Hunt, *Associate Dean of Graduate Studies*

A Day in the Life of…
Dr. John Dabiri (MS '03, PhD '05), *Professor of Aeronautics and Bioengineering (SURF '00)*
Paul Graven (BS '85), *CEO of Cateni*
Dr. Melany Hunt, *Dotty and Dick Hayman Professor of Mechanical Engineering; Vice Provost*
Kevin Noertker (BS '09), *Mechanical Engineer at Northrop Grumman (SURF '06, '08)*
Dr. Guruswami Ravichandran, *John E. Goode, Jr., Professor of Aerospace and Professor of Mechanical Engineering; Director, Graduate Aerospace Laboratories*

Networking for the Introvert
James Berk, *Career Counselor/Pre-Health Advisor, Career Development Center*

Establishing Your Professional Presence
James Berk, *Career Counselor/Pre-Health Advisor, Career Development Center*

How an Idea Becomes a Business
Dr. Calum Chisholm, *Visiting Associate in Applied Physics and Materials Science*
Cole Hershkowitz, *Founder and CEO of Chai Energy*
Dr. Stephen Mayo, *Bren Professor of Biology and Chemistry; William K. Bowes Jr. Leadership Chair, Division of Biology and Biological Engineering*
Dr. Aditya Rajagopal (BS '08, MS '10, PhD '14), *Postdoctoral Scholar in Physics (SURF '05, '06, '07)*

What to Do With a Science Degree?
Dr. Chantal D'Apuzzo, *Associate General Counsel, Caltech*
Dr. Mary Beth Campbell, *Licensing Associate, Office of Technology Transfer at Caltech*
Dr. Jenn Hodas (PhD '09), *Assistant Director, Office of Technology Transfer at Caltech*
Dr. Donna Wrublewski, *Chemistry Librarian and Information Specialist at Caltech*

2014

Decisions, Decisions!
Daniel Brooks, *Graduate Student in Applied Physics*
Christopher Kucharczyk, *Graduate Student in Materials Science*
Stephanie Mitchell, *Graduate Student in Aeronautics*
Christine Morrison, *Graduate Student in Chemistry and Chemical Engineering*

What Do Faculty Look for in a Grad School Applicant?
Dr. Kaushik Bhattacharya, *Howell N. Tyson, Sr., Professor of Mechanics and Professor of Materials Science; Executive Officer for Mechanical and Civil Engineering*
Dr. George Rossman, *Eleanor and John R. McMillan Professor of Mineralogy*
Dr. Alan Weinstein, *Professor of Physics*

How to Manage Yourself, Your Mentor, and Your Peers in Lab
James Berk, *Career Counselor/Pre-Health Advisor, Career Development Center*

Letters of Recommendation
Candace Rypisi, *Director, Student-Faculty Programs Office*

Networking for the Introvert
James Berk, *Career Counselor/Pre-Health Advisor, Career Development Center*

A Day in the Life of…
Dr. Morgan Cable (PhD '10), *Research Scientist at JPL (USRP '04)*
Paul Graven (BS '85), *CEO of Cateni*
Kevin Noertker (BS '09), *Mechanical Engineer at Northrop Grumman (SURF '06, '08)*
Dr. Angelike Stathopoulos, *Professor of Biology*

Translating Your Undergraduate Research Experience to Help You Identify Future Internships
James Berk, *Career Counselor/Pre-Health Advisor, Career Development Center*

SURF Academic-Year Program

Explore JPL Seminar Series
The Explore JPL Seminar Series is designed to introduce Caltech undergraduate students to the variety of research opportunities that exist at JPL.

2013

Paul Backes
Group Supervisor, Mobility and Robotics Systems, JPL

Nick Benardini *(SURF '02)*
Planetary Protection Lead for InSight and M2020, JPL

Morgan Cable *(USRP '04)*
Imaging Spectroscopy Technologist, JPL

Victoria Chernow
PhD Candidate in Materials Science, Caltech

Serina Diniega *(SURF '02)*
Systems Engineer, JPL

Jennifer Hasenoehrl *(Space Grant '12)*
Research Scientist, JPL

John Leichty *(SURF '07)*
Robotics Platforms Engineer, JPL

Glenn Orton
Senior Research Scientist, JPL

Aaron Parness
Robotics Group Leader, JPL

Erika Podest
Research Scientist, Water and Carbon Cycles Group, JPL

Jason Rhodes
Research Scientist, JPL

Anita Sengupta
Cold Atom Laboratory Project Manager, JPL

Sue Smrekar
Deputy Principal Investigator for InSight, JPL

Melissa Soriano
Senior Engineer, JPL

Ashley Stroupe
Staff Engineer, JPL

David Thompson
Machine Learning and Instrument Autonomy Group, JPL

Brian Trease
Mechanical Engineer, JPL

Neal Turner
Group Supervisor, JPL

Lauren White
Systems Engineer II, Earth, Astronomy & Physics Mission Formulation, JPL

SURFers

	2013				2014			
Division	*Total # of Students*	*CIT Students*	*Non-CIT Students*	*Mentors*	*Total # of Students*	*CIT Students*	*Non-CIT Students*	*Mentors*
Biology and Biological Engineering	52	40	12	23	42	33	9	20
Chemistry and Chemical Engineering	65	47	18	24	60	54	6	22
Engineering and Applied Science	93	63	30	34	95	69	26	34
Geological and Planetary Sciences	26	21	5	16	18	16	2	12
Humanities and Social Sciences	19	13	6	8	14	10	4	8
Physics, Mathematics, and Astronomy	90	57	33	50	95	66	29	51
Jet Propulsion Laboratory	59	27	32	44	63	37	26	38
Off Campus	29	24	5	28	33	26	7	32
International	21	21	0	17	11	11	0	8
Total	454*	313	141	244	431*	322	109	225

**this includes LIGO and exchange SURF students*

Strengthening Effective Communication Skills

Throughout the year, SURF students are encouraged and provided opportunities to develop effective communication skills. This process begins with the research proposal which is submitted as part of the application and continues long after students give their final talk at Seminar Day. Here are just some of the ways in which students' oral and written communication skills are supported.

The Doris S. Perpall Speaking Competition was endowed by Robert C. Perpall (BS '52, MS '56) in memory of his late wife, Doris Perpall. The prize encourages students to prepare excellent SURF presentations. The competition is a three-round event. The best SURF Seminar Day presenters, as evaluated by the session chair and a judge from the discipline, advance to a semifinal round held in November. Six to eight finalists advance to a final round held in January. The 2014 Perpall finals will be held in January 2015.

2012 Winners
Alexander Mouschovias (First Place)
Reuben Britto (Second Place)
Andrea Ritch and Max Wang (tied for Third Place)

2013 Winners
Jacqueline Masehi-Lano (First Place)
Keegan Ryan (Second Place)
Connor Rosen (Third Place)

	2013	*2014*
Women	42%	40%
Minorities	9%	9%
Average GPA*	3.53	3.51

** Caltech students only, excluding freshmen*

The Gee Family Poster Competition was created by Barbara and John (BS '53) Gee to encourage and support excellence in scientific communication. Students delivering a research poster are encouraged to learn how to present highly technical information to a general, yet educated, audience. Posters are judged on content, visual organization, and verbal presentation.

2012 Winners
Doreen Chan (First Place)
Sebastián Rojas (Second Place)

2013 Winners
Michael Dieterle (First Place)
Ellen Price (Second Place)

CURJ—*The Caltech Undergraduate Research Journal (CURJ)* is an award-winning undergraduate research journal, dedicated to highlighting the accomplishments of the numerous undergraduates conducting research during the SURF program and throughout the academic year. CURJ is edited, designed, and published entirely by students. CURJ has repeatedly won the National Pacemaker Award, administered by the Associated Collegiate Press and widely considered to be the Pulitzer Prize of student journalism. Entries are judged on content, quality of writing and editing, art and graphics, layout and design, and theme.

Winter 2014, Vol. 15 No. 1
Editors-in-Chief: Edward Fouad and Conway Xu
Student authors: Lisa Eshun-Wilson, Davide Gerosa, Adam Ryason, Herbert Franz Mehnert Stadeler

Spring 2013, Vol. 14 No. 1
Editors-in-Chief: Marvin Gee and Conway Xu
Student authors: David Miller, Mahati Mokkarala, Bertrand Ottino-Loffler, Sangavi Pari, Caroline Yu

Winter 2013, Vol. 13 No. 1
Editors-in-Chief: Marvin Gee and Conway Xu
Student authors: Phillip Daniel, Claire Drolen, Jingyuan Li, Elizabeth Ryan, Nikita Sinha, Conway Xu

To view the 2013 and 2014 issues, please visit http://curj.caltech.edu/

Funding SURF

Each SURF Fellow received an award of $6,000 for the ten-week summer period, a total budget of $2.3 million per year. Funding comes from a variety of sources including: gifts from individuals, foundations, and corporations; endowment revenue; and mentor contributions. SURF depends on the generosity of its many friends for annual gifts and SURF endowments. This support ensures that Caltech students will continue to have the opportunity to engage in the research enterprise. Thank you to the donors who supported SURF 2013 and 2014!

Annual Gifts

We deeply appreciate the gifts from our SURF friends who have made contributions in all amounts to support our students. Each gift is important! We especially thank our SURF alumni and their parents. Their gifts are a testament to the impact the program has had and to the value they place on the SURF experience.

Endowments

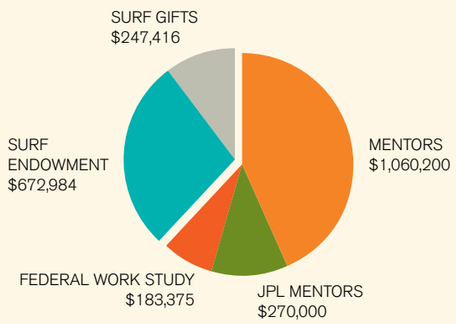
Individuals or groups may establish an endowment for $125,000 to support one student annually in perpetuity and may be named as the donor designates. There are several ways to establish endowments—they may be paid in full at creation; given in installments over a period of time, or specified in a donor's estate plan. Endowment donors receive special benefits. Each year a student will be selected to bear the endowment name, and the donor will receive a letter introducing the student and describing the project. If they choose, donors may have the opportunity to meet the students supported by their gifts, and they often receive letters of appreciation from "their" students. Donors are invited to attend a Student-Donor Dinner and SURF Seminar Day.

We are delighted to announce the establishment of several new endowments:

Class of '52 60th Reunion SURF Endowment
Richard H. Cox SURF Endowment
David L. Glackin Memorial SURF Endowment
Ronan Armaan Mack SURF Endowment
James G. and Elaine Peterson SURF Endowment
Mark Reinecke SURF Endowment
Sampson Carlson SURF Endowment

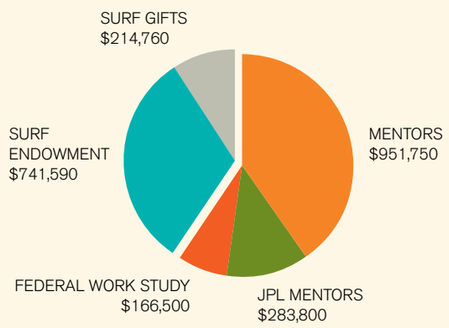
2013 SURF Award Funding

$2,433,975



2014 SURF Award Funding

$2,358,400



Honor Roll of SURF Donors

ANNUAL GIFTS

$6000 or more

Dr. Jane C. Chen*
Mr. and Mrs. Kevin Crook*
Mr. David M. Cutrer, SURF '89, '91
Mr. and Mrs. Paul G. and Heather Haaga
Ms. Nadia Haq (SURF '01) and Mr. Ryan Mack
Dr. and Mrs. Daniel C. Harris*
Mrs. Douglas B. Nickerson
Mr. and Mrs. David P. Rossum*
Mr. and Mrs. Tandy Trower
Mr. Samuel Vodopia and Ms. Carol Hasson*

$2500–$5999

Mr. Matthias Blume
Mrs. Hannah Bradley
Mr. Richard E. Burke
Ms. Maria Chan
Mr. Manit M. Limlamai, Space Grant '03
Mr. Glenn E. Reynolds
Mr. and Mrs. Richard M. Rosenberg*
Dr. Gary W. Stupian*

$1000–$2499

Mr. James C. Beck*
Mr. Christopher (SURF '92, '93) and Dr. Jasmine (SURF '93, '94) Bryant
Mr. Joseph O. Bunting
Dr. Jean-Lou A. Chameau and Dr. Carol S. Carmichael
Mr. Daniel Chou, SURF '97*
Ms. Susan Dahle-Fuller
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Mr. and Mrs. Hideo Ikawa
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Mr. and Mrs. James M. Kendall, Jr.*
Dr. Robert M. Kieckhefer*
Ms. Janice Lau Wee, SURF '92, '93, '94
Mr. Young Lee
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Dr. Susan Murakami and Mr. Leroy J. Fisher*
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Mr. and Mrs. Don M. Pinkerton*
Mr. and Mrs. Mark W. Randolph, SURF '90*
Dr. Robert K. Roney*
Dr. and Mrs. Evangelos Simoudis*
Mr. and Mrs. Richard J. Soghoian*
Drs. Tab (SURF '87) and Keri Stephens
Mr. Kaytaro G. Sugahara
Mr. Matthew A. Terrel
Mr. Thomas A. Tisch
Mr. and Mrs. Leslie A. Waite

$500–$999

Ms. Kathy N. Anemogiannis
Mr. Hoang M. Banh, SURF '04*
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Dr. K. W. Chow
Dr. Ming-chung Chu, SURF '82
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Mr. Shaun P. Lee, SURF '02, '03
Mr. and Mrs. Timothy Lin*
Dr. Aron J. Meltzner, SURF '97, '98, '99*
Mr. and Mrs. Sunil Mirpuri
Mr. and Mrs. M.T. Santhamma Nair
Mr. and Mrs. Tracy V. Petersen*
Dr. and Mrs. Charles C. Reel, SURF '83, '84*
Mr. and Mrs. Benjamin M. Rosen
Mr. David D. Rowlands and Ms. Peggy Ann Kwik*
Mr. Stephen J. Salser, SURF '86
Mr. and Mrs. Richard A. Schulman*
Mr. Stanley H. Shepherd
Mr. and Mrs. Andrew Sutherland*
Mr. Ki-Ching Wong, SURF '89
Dr. and Mrs. James M. Wu
Ms. Susan J. Wyble*

$250–$499

Mr. and Mrs. Stuart Adler*
Dr. Crystal Anderson
Mrs. Ellen F. Barrett
Mr. and Mrs. John N. Barrett*
Dr. and Mrs. Donald L. Blumenthal*
Mr. Joseph R. Boeke*
Ms. Jane F. Bondi
Mr. and Mrs. Evan G. Colgan, SURF '81
Dr. and Mrs. James A. Cutts
Mr. James H. and Mrs. Laura (SURF '94) Dooley*
Dr. Fred H. Eisen
Dr. Iljie J. Fitzgerald, SURF '98, '99, '00*
Dr. David C. Gakenheimer*
Mr. and Mrs. Robert A. Grogan
Mr. Everett W. Howe, SURF '85
Mr. and Mrs. Andrei Iancu
Mr. and Mrs. Santosh Krishnan, SURF '83, '84, '85*
Dr. David M. Krum, SURF '93
Dr. Wai P. Kwan, SURF '95*
Dr. Wayne W. Lam
Dr. Mark W. Land*
Mr. Arthur Lee
Mr. Benjamin G. Lee, SURF '99, '00, '01*
Mr. and Mrs. James L. Lester
Dr. Jennifer Low, SURF '89
Dr. T. S. Michael*
Ms. Linda Y. Papermaster
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