

# SURF



CALIFORNIA INSTITUTE OF TECHNOLOGY

SUMMER UNDERGRADUATE RESEARCH FELLOWSHIPS

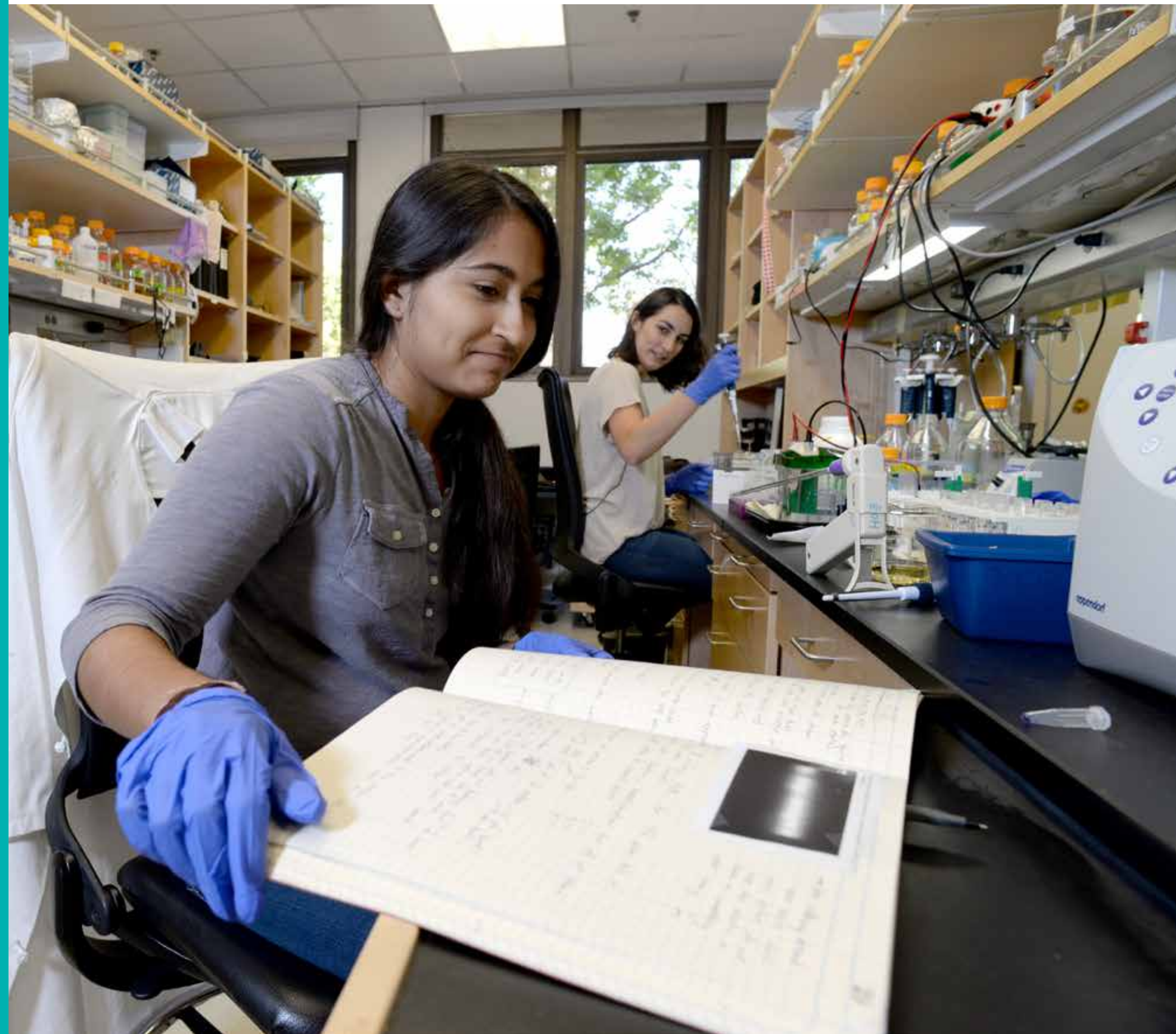
2015 AND 2016 REPORT

## CONNECT

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

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**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. Students who engage in independent research perform better academically, are more engaged in their college experience, and are more likely to attend graduate school as compared to their peers. 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.

The reach of SURF across campus is extraordinary. Seventy-eight percent of the 2016 graduating class participated in the SURF program, becoming immersed in the innovative and diverse research undertaken on campus and at JPL. In the past two years, for example, students have been investigating the role of microRNA in HIV; the chemistry behind epileptic suppressing pharmaceuticals; the application of autonomous micro-robots in human blood; and the adaptive charging systems for electric vehicles. No matter the discipline, Caltech students, along with participants from across the world, share the ambition, intimacy, and intensity that make SURF a career-defining experience.

The SURF program embeds undergraduate students in research groups that have multiple endeavors underway, calling upon them to define their own projects, cultivate areas of interest, and present their results to a general audience. They interact with researchers at various stages of career, from graduate students to veteran scientists, developing an appreciation for what may lay ahead as well as mentors to help guide them along their chosen path.

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 immensely grateful for your partnership.

Thomas F. Rosenbaum  
President, California Institute of Technology  
Sonja and William Davidow Presidential Chair and Professor of Physics

### **Dedication**

#### **2015**



Since 1992, Dr. Richard M. Murray (BS '85), Thomas E. and Doris Everhart Professor of Control and Dynamical Systems and Bioengineering, has mentored 158 SURF and MURF students. He is known for being a hands-on mentor, as well as a strong advocate for undergraduate research.

#### **2016**



The 2016 SURF dedicatee was Dr. Charles Elachi (MS '69; PhD '71). As Director of the Jet Propulsion Laboratory, Dr. Elachi has been a tremendous advocate for undergraduate research. Under his leadership, SURF (and other undergraduate programs) at JPL has grown and the number of Caltech students doing research at JPL continues to increase each year. Additionally, Dr. Elachi and his wife, Valerie, created a SURF endowment in 2006 that supports one student each year.

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

#### **SURF Dedictees**

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
2013	Mr. Mark Reinecke
2014	Daniel and Sally Harris
2015	Dr. Richard M. Murray
2016	Dr. Charles Elachi

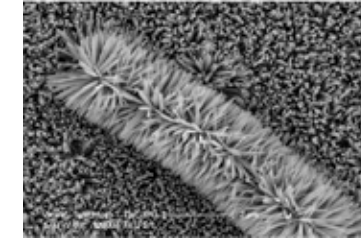


## ADVENTURES IN SUMMER RESEARCH

**T**HE SURF PROGRAM, which began in 1979, has served more than 8,000 students. SURF provides students an opportunity to conduct hands-on research under the guidance of leading scientists and technical researchers.

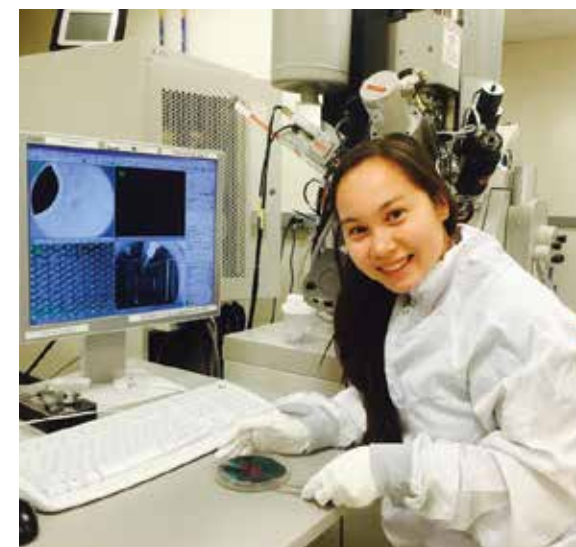
### MEDICAL ENGINEERING RESEARCH TO AID DIABETES PATIENTS

CURRENT TECHNOLOGY requires individuals with diabetes to undergo painful, inconvenient, and discontinuous measurement processes several times a day. Summer Undergraduate Research Fellowships (SURF) student Kelly Woo has been working with Hyuck Choo, an assistant professor of electrical and medical engineering, to create more convenient and accurate ways of measuring glucose levels by utilizing surface-enhanced Raman spectroscopy (SERS) techniques. SERS utilizes molecular vibrations to extract the properties of the sample and is highly sensitized through the application of metallic nanostructures. To accomplish commercially viable SERS technologies for glucose detection, an optimal substrate must be designed with higher electromagnetic enhancement so glucose can be detected in low concentrations from fluids in the body, not necessarily blood. To create these substrates, Woo hydrothermally grew zinc nanowires on silicon wafers and then deposited gold nanoparticles. She has successfully manipulated the synthesis process to produce controlled zinc nanowire growth on the silicon substrate by varying parameters of growth. ■



### CANCER DETECTION USING AFFORDABLE IMPLANTABLE TECHNOLOGY

EARLY DETECTION of cancer can improve a patient's survival chances by up to 85%. Implantable cancer biosensors, which last up to several years in the body and provide continuous detection of cancer biomarkers, have the potential to provide a low-cost and accurate alternative to existing methods of cancer detection. Accurate detection of cancer biomarkers necessitates sensitivity of detection instruments in the nanomolar range. The sensitivity of currently available micro-scale implantable sensors can be improved by using electrical engineering principles of CMOS technology to enhance electrode design. Summer Undergraduate Research Fellowships (SURF) student Anna Winnicki has been working with Professor Axel Scherer to design and develop implantable electrochemical sensors of nitric oxide, a well-known cancer signaling molecule that dictates both tumor growth and inhibition. Over the summer, she designed electrodes with optimum sensitivity and fabricated the micro-scale electrodes at Caltech's Kavli Nanoscience Institute. ■



EAS Communications Office  
<http://eas.caltech.edu/ingenious>

## TEACHING COMPUTERS TO PLAY GAMES

Jagriti Agrawal's SURF research aimed to discover whether or not a method called imitation learning could be applied to "teach" a computer how to play a 1984 Atari game called Montezuma's Revenge.

"Computers are really good at playing games in which you perform an action and get an immediate reward, such as chess," Agrawal says. "In Montezuma's Revenge, you have to take actions that will reward you in the long run, such as taking detours to pick up a key that you will later use to open a door. Computers that have tried to play this game have used a technique called random exploration, which looks at rewards and takes the best action at each step and is exponential in time. We hope that through imitation learning—learning through human demonstration—the computer can mimic human play and achieve a better play-through more efficiently."

Imitation learning hinges on a person recording their completion of a complicated task, such as playing a game or guiding a robotic arm to move like a real human arm and giving the so-called "training data" to a computer. The computer should then "learn" which actions are optimal in different scenarios.

"Humans learn first by imitation of others and then by self-guided exploration," says Yisong Yue, assistant professor of computing and mathematical sciences and Agrawal's SURF mentor. "In artificial intelligence, the latter has been the predominant approach. But our thought is that in the case of more complicated games, the computer can first learn from the experts—us."

During Agrawal's play-through of the game, she created a series of paired images and commands. "Given any image of a point in the game representing the current game state, I recorded the corresponding best action to take—move left, right, up, down, and so on. So if the computer sees an image of a ladder, it will look at what I did when I encountered this ladder, and it will perform the action that I did."

Their findings are still preliminary. "Given the current amount of data collected, we find that our convolutional neural network tends to over-fit and not generalize well to new game scenarios," Agrawal says.



"For example, the network tends to output the 'do nothing' action a disproportionate fraction of the time. Further investigation and data processing will need to be done to address this issue."

Agrawal plans to continue to work on the project throughout the school year. "The next step will be to collect a more diverse set of gameplay from a wider range of human demonstrators," Yue says. "Over the summer, Jagriti developed a pipeline to collect and process human demonstration data, and she will be deploying this at scale during the school year—we may even hold a pizza party so Caltech undergrads can play video games for science!"

Agrawal was a 2016 Rose Hills Foundation SURF Fellow. The Rose Hills Foundation SURF supports 15 Southern California students each summer. ■

—Lori Dajose

## DOMESTIC VIOLENCE IN 19th CENTURY ENGLISH LITERATURE

Grace Lee, a senior double majoring in applied mathematics and English, studied the shifting attitudes toward spousal abuse in 19th-century Britain for her SURF project.

The mid-1800s in England, during the Industrial Revolution, was a period of rapid cultural development, particularly in the area of women's rights. "As a modern woman and feminist, I was interested in learning more about women's rights of the period and, to an extent, what kind of legal changes took place to progress toward the rights women enjoy today," Lee says.

During this period, it was taboo to publicly discuss domestic violence, so authors and illustrators had to communicate their views on the topic symbolically through their publications. By studying works of fiction and satirical newspapers from the 19th century, Lee aimed to understand attitudes toward domestic violence in England.

"Fiction couldn't be published if its focus was solely domestic violence, that would be too controversial," she says. "Violence was often portrayed in a foil character to the main character, such as the character of Isabella in *Wuthering Heights* or Nancy in

*Oliver Twist*. The gender of the authors is interesting to consider as well. While they both portray domestic violence as wrong, Charles Dickens portrays Nancy as a kind of martyr, he glorifies her subservience and sacrifice. Emily Brontë, on the other hand, shows Isabella as having accidentally entered into an oppressive marriage but still finding her own voice and power."

Violent, sardonic comics in satirical magazines played a role in illustrating the problem of domestic violence to the public. The idea evolved that domestic violence was contradictory to the English ideal of a gentlemanly person.

"To understand the feminist movement of the time, I had to understand its counterpart—what Victorian people thought to be masculine," Lee says. "The public's perception of masculinity underwent a change in the mid-1800s. This made it possible for women's rights under the law to change and expand as well."

The experience of doing research into English literature and history was new and challenging to Lee.

"This SURF was a great opportunity and a lot more challenging than doing a paper for a class because I had so much freedom to explore supplementary materials," she says. "I think the background that I gained in doing independent research will really help in writing my senior thesis."

Lee was the 2016 J. Kent Clark SURF Fellow. This particular endowment was established to support research in the humanities and is named after the late J. Kent Clark, Caltech professor of literature. ■

—Lori Dajose





78% OF CALTECH'S 2016 GRADUATES HAVE SURFEd

**S**URF 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.

## TRICKING AN ENZYME INTO MAKING BETTER INSULIN

MARY BOYAJIAN, a junior majoring in chemical engineering at Caltech, spent her summer as a student in the Summer Undergraduate Research Fellowships (SURF) program trying to trick an enzyme. The enzyme, tRNA synthetase, has a very specific chemical target, and Boyajian wanted the enzyme to ease up a bit on its requirements so that it might also find acceptable a slightly altered version of the target. The work might sound esoteric, but it was Boyajian's piece of a project with an end goal that could benefit millions: devising a faster-acting insulin-replacement therapy for the treatment of diabetes.

A normally functioning pancreas keeps blood sugar within a narrow range by releasing large bursts of the hormone insulin after meals. Insulin helps cells absorb excess glucose and prevents the liver from producing additional sugar. In the case of diabetics, however, either the cells become resistant to the effects of insulin or the body simply cannot produce enough of the hormone, so additional insulin is needed.

In the 1920s, insulin isolated from animals became the first insulin-replacement therapy for diabetics. Forty years later, scientists figured out how to make human insulin in the lab. However, that synthetic insulin behaves a bit differently in the body. For example, it tends to clump up and therefore takes a long time for the body to absorb.

To improve the speed or ease of absorption, chemists have designed replacement therapies that are analogs of human insulin, made by substituting some of insulin's building blocks, or amino acids, with other naturally occurring amino acids. However, there is room for improvement. For example, scientists would like to make therapies that kick in faster, last longer, and offer a longer shelf life.

In all current insulin-replacement therapies, certain naturally occurring amino acids are swapped for other naturally occurring amino acids. But in the lab of David Tirrell, the Ross McCollum-William H. Corcoran Professor and professor of chemistry and chemical engineering at Caltech, chemists are working



with what are known as noncanonical amino acids. These variants are designed and made in the lab to have slightly altered chemical structures. If expressed in a protein, these synthetic amino acids can introduce entirely new functions or capabilities. Tirrell's group has the idea to swap out a naturally occurring amino acid from insulin with a noncanonical amino acid to create a replacement therapy that would outperform those on the market today.

Boyajian's role this summer was to introduce specific mutations in the enzyme tRNA synthetase. Each of the 20 amino acids that are expressed naturally in proteins has its own tRNA synthetase that hunts within cells for its specific amino acid target, so that the amino acid can be incorporated in the right sequence to make proteins. Even a small difference in an amino acid's structure will deter its tRNA synthetase.

"When I started this project, I had no idea that changing one amino acid could change so much about a protein, but it can," says Boyajian. "My job is to mutate the tRNA synthetase so that it won't see a modified amino acid—one of our noncanonical amino acids—and say, 'That's the wrong one. Take it out.'"

To get an idea of how she might mutate the enzyme, Boyajian studied the known structures of similar tRNA synthetases and how they interact with their target molecules.

Once she had an idea for a mutation, she introduced the changes into the gene that codes for the tRNA synthetase. Then she used a standard technique in molecular biology called polymerase chain reaction (PCR) to make many copies of it. Next she grew cells with the mutated enzymes on media lacking the naturally occurring amino acid—think of it as a type of food for cells. Once the cells ate up any small traces of the amino acid in the media, she fed them one of the noncanonical amino acids. If a mutated enzyme worked, it was able to “eat” the new amino acids; if not, the cells eventually died.

At the end of the summer, one of Boyajian’s mutated tRNA synthetases showed promising results in terms of incorporating one of the noncanonical amino acids, and she is now working to scale-up the size of cultures to determine whether the new enzyme can be used to produce proteins for future experiments. In the long term, if the enzyme is found to efficiently incorporate a specific noncanonical amino acid, the Tirrell lab would use the enzyme to produce novel insulins that could be assessed as potential biopharmaceuticals to improve the quality of life for patients.

Boyajian, who also plays basketball and serves as one of the captains of the water polo team, says she learned a lot from her SURF experience. “My grad student mentors, Seth Lieblich and Kat Fang, were great, and everybody in the lab was very welcoming,” she says. “It’s really nice to see everything you learned in the classroom being applied.” ■

— *Kimm Fesenmaier*



## ENTANGLEMENT

FOR SENIOR PATRICK RALL, a native of Munich, Germany, the summer offers one of the year’s few chances to visit home. But for the last two summers, Rall, a Caltech physics major, has been spending his summers on campus, drawn by another opportunity—the chance to conduct cutting-edge research while being mentored by John Preskill, the Richard P. Feynman Professor of Theoretical Physics, as part of the Institute’s Summer Undergraduate Research Fellowships (SURF) program. Last year, Rall worked in the laser lab of Assistant Professor of Physics David Hsieh on a condensed matter physics experiment. This summer, he switched his attention to quantum information science, a new field that seeks to exploit quantum mechanical effects to create next-generation computers that will be faster and more secure than those currently available.

A key idea in quantum mechanics is superposition of states. Subatomic particles like electrons can be described as having multiple positions, or more than one speed or energy level. This is illustrated by the thought experiment developed in 1935 by Austrian physicist Edwin Schrödinger. In it, a cat is placed into an imaginary box containing a bottle of poison, radioactive material, and a radiation detector. If a radioactive particle decays and radiation is detected inside the box, the poison is released and the cat is killed. But according to quantum mechanics, the cat could be simultaneously alive and dead. Yet if one were to open the lid of the box, the cat would become alive or dead. By opening the box, we have destroyed the quantum nature of the state; that is to say, the observation itself affects the outcome, and yet that outcome is randomly determined.

“Where this gets really interesting is when more than one cat gets involved,” Rall says. “Then we can have states where looking at one cat determines the outcome of looking at the other, even if they are on different continents or even different planets. For example, I cannot know if I will see a live or a dead cat upon opening either box, but I can know that the cats are either both alive or both dead.”

This “spooky action at a distance”—as Einstein phrased it—is called entanglement, and an entangled



state, physicists say, can store information. “When looking at systems with many cats, the amount of entanglement information is much larger than what I can obtain by looking at the cats individually,” Rall says. “To harness the sheer quantity of information stored in these so-called many-body systems, we must better understand the structure of these spooky correlations. This is what I worked on this summer.”

Quantum many-body systems are difficult to simulate on a computer, but by looking at small-enough systems and using mathematical tools, researchers can study complex entangled quantum states. Physicists have been studying many-body entanglement for a long time because of its importance in understanding certain semiconductors.

“This summer, I had the privilege to work under Professor Preskill, and that was an incredible experience,” Rall says. A central interest of Preskill’s lab is to design schemes for quantum computation. Modern computers use classical bits—ones and zeroes—to store data. A quantum computer would use quantum bits—or qubits—and use their superposition and entanglement to perform computation. Quantum computers, while still in the experimental stage (with heavy investment from companies like IBM, Microsoft, and Google), have been touted for their potential to generate unbreakable codes and to efficiently simulate many complex systems, with implications for computational chemistry and biology.

“The most interesting thing about the quantum computer is that we have no idea what it could be capable of,” says Rall. “We know some quantum algorithms that are faster than the best-known classical algorithms. But what are the limits? Nobody knows.” ■

— *Rod Pyle*

## CANCER TREATMENT IN A PAINLESS PATCH

CHEMOTHERAPY IS A LIFE-SAVING MEDICAL INTERVENTION for millions of cancer patients, but the treatment is often not a pleasant experience. To kill off cancer cells, chemotherapy drugs must directly enter the patient’s bloodstream and so they are administered intravenously. But are large, often painful needles the only reliable way to deliver the drugs?

Caltech senior Teo Wilkening, a mechanical engineering major in the Division of Engineering and Applied Science, spent this past summer testing the preliminary design of an alternative—and possibly much less painful—method: drug delivery through a patch.

Caltech’s Mory Gharib, the Hans W. Liepmann Professor of Aeronautics and Bioinspired Engineering, first came up with the idea for the patch several years ago. Gharib’s interest in painless drug delivery patches was renewed after a discussion with M. Houman Fekrazad, a cancer specialist at the City of Hope in Duarte, California. When Wilkening joined the Gharib lab in June as part of the Summer Undergraduate Research Fellowships (SURF) program, Gharib encouraged him to come up with a way to design and test the feasibility of such a patch.

“When we started thinking about designing a chemotherapy patch, we split the project into two main parts,” Wilkening says. One part is to create a compartment that holds the fluid or medicine; the second is the design of a needle-like device to physically deliver the medicine into the patient’s bloodstream. “Over the summer, I started working on the needles,” he says. Any chemotherapy delivery device must provide a way for the drug to get through the skin and into the blood. To avoid the pain caused by the large needle

traditionally used for such an intravenous injection, Gharib envisioned a patch containing hundreds of micrometer-scale needles, too small in diameter to be sensed by the nerves in the skin. Wilkening wanted to test how efficiently the tiny needles could actually deliver a drug.

Skin is made of three layers—the epidermal, dermal, and subdermal layers. For a drug to enter the bloodstream, it must be delivered into the bottom, or subdermal, layer. From there, Wilkening explains, “it can be distributed throughout the body, instead of pooling up and killing the cells around the injection site. We wanted to develop a way for the micrometer-scale needles to routinely deliver medicine to this bottom layer.”

Wilkening hoped to exploit the fact that each of the three skin layers has a different resistance level. The outer skin layer, the epidermis, is the stiffest of the three; the middle layer, the dermis, is of intermediate stiffness; and the subdermal layer is the easiest to penetrate.

To test how this resistance would affect the flow of a fluid—like a solution carrying a cancer-killing drug—Wilkening created a large-scale model of the microneedles using a pair of microliter glass pipettes. In the model, liquid flows from a common reservoir and into both pipettes at the same rate. To simulate the resistance to flow that would be present in needles in a patch, Wilkening added viscous materials, such as gelatin, to the end of both of the pipettes and then inserted them into separate gels representing the different layers of skin. By varying the stiffness of the gels, he was able to determine the likely behavior of the flow coming from the patch under the condition that one needle penetrates deep enough to the subdermal layer and the other does not. “The liquid flow penetrated through one needle or the other depending on the difference in the stiffness of the skin-like gels, generally through the less stiff one,” he says.

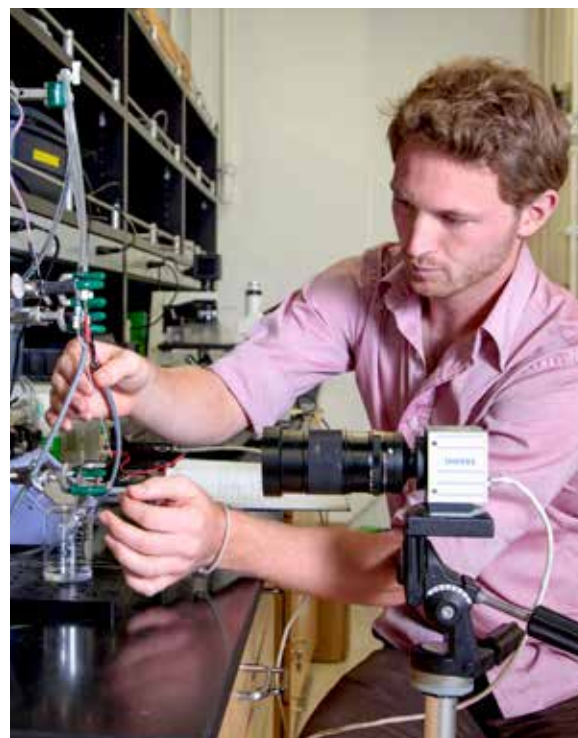
Although he spent the majority of his summer perfecting the setup of this experiment and only a little over a week in the actual testing phase, Wilkening’s preliminary results suggest that the concept behind the patch is sound. That is, once the fluid meets resistance in one needle, it will follow the path of less resistance and will flow into the other needle. That

means that in a patch composed of many hundreds of needles, a drug should be deliverable directly into the subdermal layer and able to reach the patient’s bloodstream precisely because it does not as easily flow into the two layers above the subdermis.

While his SURF project is now technically over, Wilkening—who is also a teaching assistant in the mechanical engineering shop and the captain of the Caltech soccer team—says he will be continuing his work with Gharib during the school year.

“I hope to see this project through a little bit more,” he says. “In my two previous SURF projects I worked on existing systems. This year was very different because nobody has done this before. It is kind of cool having a chance to own my own project and to use my own inspiration and ideas to really build it up from the bottom.” ■

—Jessica Stoller-Conrad



## FOCUS ON MENTORING

FROM THE BEGINNING SURF has placed an emphasis on the importance of mentoring in the undergraduate research experience. Faculty mentors and postdoctoral and graduate student co-mentors provide invaluable guidance, support, and access to students as they conduct research and make decisions about their academic and professional futures. For the past decade the SURF program has been working to provide better support, training, and recognition of these mentors.

Our most recent effort rolled out on May 26, 2016, when over 80 SURF mentors attended Caltech’s first conference on the mentoring of undergraduate researchers. Attendees were treated to a keynote opening session given by Dr. Michael Alvarez, Professor of Political Science and two-time recipient of the Caltech Graduate Student Council Mentoring Award. Dr. Alvarez spoke to the important role that mentors play in the academic, professional, and personal development of our undergraduate students and urged mentors to get to know and care for their students on a personal level. He reflected on his own experience as a SURF mentor and shared how many of his SURF summers have produced long-lasting, productive research relationships.

Throughout the day participants were able to attend talks during three different concurrent sessions. Talks focused on topics such as:

### **Identity and Unconscious Bias in Mentoring**

### **Figuring Out What Your Mentee Knows, How They Know It, and How to Help**

### **Teaching Writing and Communication to Novice Scientists and Engineers**

### **What Makes for a Great Undergraduate Research Project?**

### **Negotiating Conflict**

### **How to Mentor the WHOLE Student: Helping Students Navigate Personal Concerns**

### **Next-Level Leadership: Giving and Receiving Constructive Feedback**

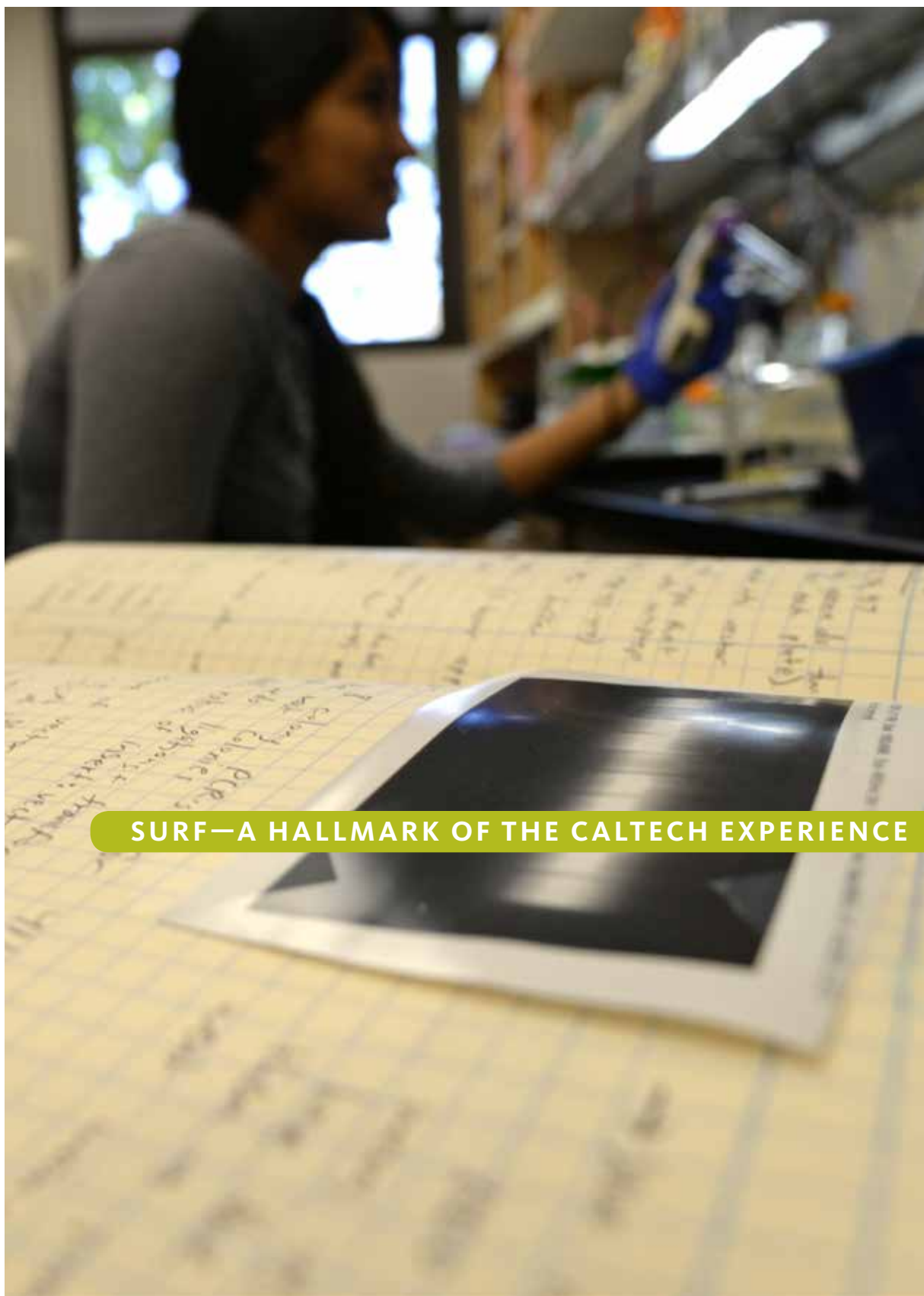


And finally, the day ended with a faculty panel sharing their own thoughts and experiences as undergraduate research mentors. Panelists included Lynne Hillenbrand, Professor of Astronomy; Beverley McKeon, Professor of Aeronautics; Mikhail Shapiro, Assistant Professor of Chemical Engineering; and Paul Sternberg, Thomas Hunt Morgan Professor of Biology.

Attendees received a copy of *How to Mentor Undergraduate Researchers* (2010, Temple et al.), a publication originally edited by SURF’s first director, Carolyn Ash.

Feedback on the conference was positive. Ninety percent of attendees felt like it was time well spent and 100% would suggest future conferences to a colleague. The next conference is scheduled for May 2017. ■





**SURF—A HALLMARK OF THE CALTECH EXPERIENCE**

**E**ACH YEAR, funding from the Caltech Associates SURF Endowment provides support for six SURF students. Three of those students—Anand Poozhikunnel, Sheila Murthy, and Gillian Kopp—shared a bit about their 2016 research.

## EXPERIENCING THE CHEMISTRY LAB

### Anand Poozhikunnel ('17)

**HOMETOWN** Wheaton, Illinois

**MAJOR** Chemistry

#### Why did you choose Caltech?

I came to Caltech because of its location in California, the SURF program, and the availability of research opportunities, and because it offered all the areas of study that interested me. Also, the financial aid package was quite generous and made it a fiscally responsible choice. I first heard about Caltech through my cousin who lived in California, and also because of the men's basketball team breaking the NCAA's longest losing streak ever.

#### What do you enjoy most about being a student at Caltech?

I love the people here and the small-school atmosphere. Everybody is really kind; they look out for each other and help one another succeed. It is easy to get to know everyone, from students to staff. Norma, Avery House's dining chef, always has some Hawaiian bread ready for me, and Sherman, one of the janitors, has a story or two to tell or just some words of encouragement. And my mentors, such as Dr. Scott Virgil (manager of the Center for Catalysis & Chemical Synthesis), who dedicates so much time to helping undergraduates as well as his other students, inspire me to become the best scientist I can be. The straightforward path to access research opportunities as I experienced with Peter Dervan (Caltech's Bren Professor of Chemistry) and my first SURF made it easy to get my feet wet in lab and begin pursuing chemistry.

I also love being able to pursue a variety of activities, from sports to dance shows to community service, all of which are easy to access through the many clubs and organizations on campus. The environment is so supportive, and it is a joy to be around. Being at Caltech has opened so many doors for me, and I expect it to do so in the future. Looking all around academia, especially in chemistry, it is not hard to see Caltech's imprint on most people.

#### Who will you be working with for your SURF this summer, and what is your project focused on?

I will be working with Eric Appel, assistant professor of materials science and engineering at Stanford University, this summer. The project will focus on creating a hyperbranched polymer material that can stabilize proteins and exploring the properties of these materials. The project is part of a broader goal of making single-injection vaccines a reality and improving immunization rates.

#### What are you most excited about as you begin your SURF?

I am excited to be living in the Bay Area, and also to be participating in some very applied science in a brand new laboratory.

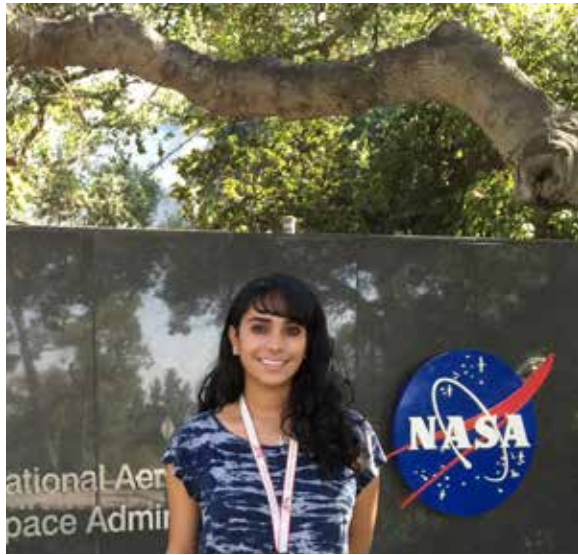
#### If you could have a superpower, what would you choose and why?

I would choose super speed, because I would love to get anywhere I needed to quickly. Commuting for longer than 10 minutes sounds painful. Also, being fast is probably the most transferrable skill across any sport.

#### Closing sentiments?

Thank you to the Caltech Associates for your generous support of the SURF program and my project! ■





## YES, IT'S ROCKET SCIENCE Sheila Murthy ('17)

**HOMETOWN** Redmond, WA  
**MAJOR** Mechanical Engineering

### Why did you choose Caltech?

When I was about 13 years old, my dad recorded NOVA documentaries about astronomy. We would watch them together, and I noticed that the closing credits would always reference Caltech and JPL. After I asked him what this was, my dad explained that JPL was one of NASA's sites and that its parent institution was Caltech. He told me that JPL was the only NASA center founded by a school, so after confirming that attending Caltech would enable me to work at JPL, my plan was to apply and hopefully get accepted.

Having grown up in Redmond, I knew that many of my friends' parents worked for companies like Amazon, Microsoft, and Boeing, so I was also exposed to big tech companies and smaller software start-ups. This also piqued my interest in working in science and technology. Originally I wanted to study astrophysics, so I first came to Caltech for a college visit in my junior year of high school. During that time I met a graduate student who I kept in contact with, and he helped me get a summer internship at JPL just before my senior year. I absolutely loved the experience, and it solidified my interest in Caltech as my top school choice!

### What do you enjoy most about being a student at Caltech?

During the first two years as an undergraduate, most classes are part of the core curriculum, and they are very technical. All majors complete most of the same classes. This year, as a junior, I got to branch out and try some applied, practical, and specialized subjects in engineering. I was part of the FSAE racing team. We built a racecar from scratch, and this was the first year that Caltech got to participate in a competition, as we passed a lot of the engineering requirements. It was so much fun to be part of a team and see the theory I had been learning about in class being applied.

I also really enjoyed an introductory aerospace class—we did everything from learn about guidance, navigation, and control systems to actually work on the AAReST telescope, one of the few JPL telescopes managed by Caltech. We got to work in the dedicated Space Structures Lab with Dr. Pellegrino, and as part of the class, we worked on different components of the telescope. I was focused on the mirror-box system and ran vibration testing and set up optical testing procedures. I couldn't have done this without learning the theory in the previous years, and it was thrilling to see the theory come to life!

At Caltech, everyone is research oriented. We have the luxury as students that we can ask nearly any faculty member to do a research project and that faculty member will work with us. This is where the student-to-faculty ratio really pays off.

I am also invigorated by Caltech's collaboration policy. As a freshman, we all take all the same classes—basic chemistry, physics, and biology—and this forces us to work together. Caltech is unique in that it encourages us to collaborate on problem sets, not copying but teaching and working through process and problems together with our peers. Some sets are nearly impossible to complete alone, and it takes the approach of collective understanding to complete an assignment.

### Who are you working with for your SURF, and what is your project focused on?

I am part the robotics and mobility group at JPL, within a program called the NASA Innovative Advanced Concepts (NIAC) study, which is an incubator for rapid prototyping and feasibility studies on potential missions. My specific SURF project is called Transformers, in which I and another intern are trying to design a series of solar reflectors that could be mounted along the rim of Shackleton crater, located at the south pole of the moon. These reflectors would redirect any sunlight that hits them at the moon's azimuth, directly into the inside

of the crater, and thereby provide some indefinite energy source to lunar rovers and stations that are inside the crater, seeking to explore the crater's icy regolith. Currently, the main constraint with any lunar mission is that we do not have a sustainable energy source. Harnessing solar power at this location could yield fascinating advancements in human understanding of the moon's geological composition. An unlimited energy source would allow us to develop lunar stations within a crater that is normally engulfed in darkness, which I think is pretty cool!

My work, in particular, focuses on the deployment mechanisms that mount and orient these reflectors accurately. It is a tough job, considering that each reflector has at least a 35-meter diameter and is 400 meters high! This week I am designing a 1:20 scale model of the reflector using Mylar and adding rigidizers on the base of the reflectors. This project is in phase two of NIAC, which means there are still a lot of open questions and we have the freedom to explore. I am working with graduate student mentors and enjoy the opportunities to exchange ideas with them. Much of the work is experimental, and we are eliminating ideas as fast as possible. Despite the uncertainty, it is a fun and dynamic working environment because we can think outside the box and be very creative with rapid prototyping.

### What most excites you about your SURF?

Like at Caltech, the opportunity to talk about projects and collaborate with team members has been really motivating. I feel fortunate to be working in a rich, active environment, surrounded by so many smart people. One of the most rewarding aspects of our work is talking to people about what we are working on and coming up with new and fresh ideas.

### If you could have a superpower, what would you choose and why?

Not sure if this is a superpower, but I would love to go into space or fly anywhere without confinements or the need for a spacesuit. Maybe I could use this power to help connect people.

### What do you hope to do when you graduate?

I am still deciding between graduate school and industry. JPL, SpaceX, or Boeing could all be great companies to work for, so I will probably apply to both schools and jobs and see what offers I receive. However, I look forward to pursuing engineering. In the future, I would consider pursuing an executive MBA to work on the business side of things. I like to see how products can manifest themselves for the public to

use, and it would be rewarding to understand the big picture and how to effectively help people on a global scale.

### Closing sentiments?

The generosity of the Caltech Associates has allowed me to spend a summer at JPL and explore a field of engineering among world-renowned, literal rocket scientists. How cool is that? Truly, the endowment the Associates provides to curious young intellectuals is a gift, and one I will be passing along when I am at an age to give back to students who so desperately want to learn and contribute to the world around them. ■



## A PASSION FOR PARTICLE PHYSICS LED THE PATH TO CALTECH Gillian Kopp ('18)

**HOMETOWN** Boulder, Colorado  
**MAJOR** Physics

### Why did you choose Caltech?

I knew I wanted to be involved in research in college, and Caltech's focus on and support of undergraduate research drew me here. The small size means that students have access to many resources and opportunities and can easily reach out to and talk with professors. The fantastic research opportunities mean that at Caltech, students are encouraged to be both student and scientist, and the SURF program further makes this possible. My father actually attended Caltech, so I had heard about the school from him, too.

**What do you enjoy most about being a student at Caltech?**

I love the vibrant intellectual community and excitement about science shared by the entire Caltech community. The students I get to spend time with and how much I learn from them is one of the most valuable things about being at Caltech. Additionally, the focus on collaboration means that students are willing to work together to solve difficult problems. Combining the strengths of multiple people is often very insightful.

**Who will you be working with for your SURF this summer, and what is your project focused on?**

I am working in Maria Spiropulu's [Caltech Professor of Physics] high energy physics group. My research is focused on improving detectors for use at the Large Hadron Collider at CERN. Specifically, I am working with a detector prototype for the Compact Muon Solenoid experiment, working on improving the time resolution to precisely detect the collision point of two particles. I had the wonderful opportunity to spend the first four weeks of my SURF at Fermilab in Chicago working with the test beam there to take data, and I am now at Caltech to continue the analysis. The research in high energy physics is really exciting, and I'm thrilled to have this hands-on research opportunity!

**What are you most excited about as you begin your SURF?**

High energy physics is an area of research I have been interested in since high school. I read Sean Carroll's [Caltech Professor of Physics] book *The Particle at the End of the Universe* about the Large Hadron Collider, and I was so fascinated by the subject. To be working on the detectors that I read about is so thrilling! I am also really enjoying the combination of lab work and analysis for this research.

**If you could have a superpower, what would you choose and why?**

Flying—I really enjoy being outdoors, especially in the mountains, and flying would be a great way to explore areas like this.

**Closing sentiments?**

Thank you very much to the Caltech Associates for their generosity and support of undergraduate research through the SURF program! Research in high energy physics is what I hope to pursue in my career, and the opportunity of SURF has allowed me to explore different fields of physics research. It is an exciting time to be involved in high energy physics as we gain more knowledge and make many advancements. ■

HIGHLIGHTS OF  
**Summer**



**Undergraduate Research Week**

In 2010, the House of Representatives declared the week of April 11, 2011, as National Undergraduate Research Week. Since then, the Council on Undergraduate Research (CUR) has continued to celebrate this week annually as a way to draw attention to the important role research plays in the undergraduate educational experience. This past April, our SURF Ambassadors celebrated the week by handing out ice-cream and information to students, faculty, and staff outside the Red Door. Additionally, student Bianca Lepe (SURF '13, '14) wrote about her SURF experience for *The California Tech* as a way to encourage students to get involved in research, early and often. To see Bianca's article, visit: <http://caltechcampuspubs.library.caltech.edu/3086/1/Issue%2023%2C%202015-16.pdf>.

**Wednesday Seminar Series**

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

**2015**

**Domniki Asimaki**

*Professor of Mechanical and Civil Engineering*

How Kathmandu Dodged a Bullet on April 25, 2015: Lessons Learned From the M7.8 Gorkha Earthquake, and Their Significance in Understanding Infrastructure Risk in Southern California

**Konstantin Batygin**

*Assistant Professor of Planetary Science*

Jupiter's Grand Attack

**Mark Davis**

*Warren and Katharine Schlinger Professor of Chemical Engineering*

Fighting Cancer With Nanoparticle Medicines: The Nanoscale Matters!

**Michael Ewens**

*Associate Professor of Finance and Entrepreneurship*

Financing the Entrepreneurial Firm and Radical Innovation

**Katherine Faber**

*Simon Ramo Professor of Materials Science*

Coatings for 18th Century Porcelains and 21st Century Engines

**Fiona Harrison**

*Benjamin M. Rosen Professor of Physics; Kent and Joyce Kresa Leadership Chair, Division of Physics, Mathematics, and Astronomy*

From Spinning Black Holes to Exploding Stars: A New View of the Energetic Universe

**Elizabeth (Betty) Hong, SURF '98, '99, '00**

*Clare Boothe Luce Assistant Professor of Neuroscience*

Understanding the Functional Consequences of Synaptic Specialization in a Small Brain

**Charles Lawrence**

*Project Scientist, U.S. Planck Project; Chief Scientist, Astronomy, Physics, and Space Technology Directorate at JPL*

Measuring the Universe

**2016**

**Guillaume Blanquart**

*Professor of Mechanical Engineering*

Combustion Processes and Turbulent Flows

**George Djorgovski**

*Professor of Astronomy; Director, Center for Data-Driven Discovery Science in Cyberspace*

**Christian Frankenberg**

*Associate Professor of Environmental Science and Engineering; Research Scientist, JPL*

The 4-Corners Area: Where Does All the Methane Come From?

**Alexander Hirsch**

*Professor of Political Science*

Managing Political Organizations

**Carlos Lois**

*Research Professor of Biology*

Assembly of Brain Circuits and the Cellular Bases of Behavior

**Sarah Milkovich, SURF '97, '98, '99**

*Planetary Geologist and Science Systems Engineer, JPL*

Adventures in Planetary Exploration

**Thomas Miller**

*Professor of Chemistry*

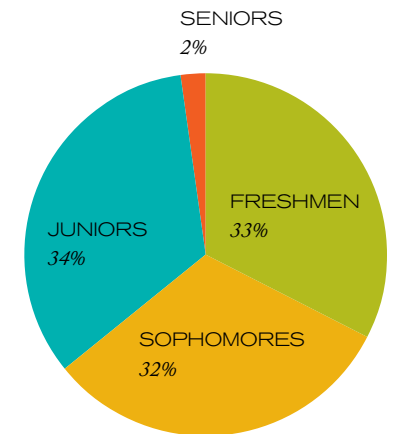
Signed, Sealed, Delivered: How Proteins Get Where They're Supposed to Go in Cells

**Chris Umans**

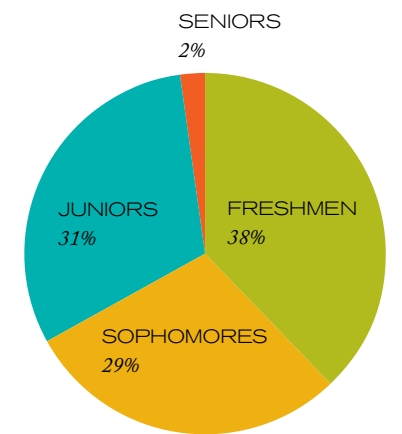
*Professor of Computer Science*

Algorithmic Magic: Behind the Scenes of Modern Computer Science

**2015 SURFers**



**2016 SURFers**



## 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.

### 2015

#### Decisions, Decisions!

Benson Christalin, Graduate Student in Control and Dynamical Systems  
 Christopher Kucharczyk, Graduate Student in Materials Science  
 Christine Morrison, Graduate Student in Chemistry  
 Emily Wyatt, Graduate Student in Chemical Engineering

#### What Do Faculty Look for in a Graduate School Applicant?

Ken Libbrecht, SURF '79, Professor of Physics  
 Oskar Painter, John G Braun Professor of Applied Physics and Fletcher Jones Foundation Co-Director of the Kavli Nanoscience Institute  
 Thomas Miller, Professor of Chemistry  
 Joe Shepherd, C.L. Kelly Johnson Professor of Aeronautics and Mechanical Engineering; Dean of Graduate Students

#### Letters of Recommendation: An In-Depth Look

Candace Rypisi, Director, Student-Faculty Programs Office

#### The Do's and Don'ts of Graduate School Essays

Mandy Casani, Assistant Director, Career Development Center

#### Setting Yourself Up for Success!

##### How to Take Full Advantage of College to Get the Future You Want!

James Berk, Career Counselor/Pre-Health Advisor, Career Development Center

#### Networking for the Introvert

James Berk, Career Counselor/Pre-Health Advisor, Career Development Center

#### What Are Your Transferrable Skills?

##### Transferring Your SURF to an Industrial Internship

Aneesha Akram, Internship Specialist, Career Development Center

#### Using Social Media and Managing Your Online Image

Mandy Casani, Assistant Director, Career Development Center

#### Tell Me About Your Research: How to Talk About Your Research to Various Audiences

Mandy Casani, Assistant Director, Career Development Center

### 2016

#### Decisions, Decisions!

Emily Blythe, Amgen '11, Graduate Student in Biochemistry and Molecular Biophysics  
 Emmanuel Garza Gonzalez, SURF '11, '12, Graduate Student in Applied and Computational Mathematics  
 Matt Getters, Graduate Student in Biology and Biological Engineering  
 Christine Morrison, Graduate Student in Chemistry

#### Setting Yourself Up for Success! How to Take Full Advantage of College to Get the Future You Want!

James Berk, Career Counselor/Pre-Health Advisor, Career Development Center

#### Letters of Recommendation: An In-Depth Look

Candace Rypisi, Director, Student-Faculty Programs Office

#### The Do's and Don'ts of Graduate School Essays

Mandy Casani, Assistant Director, Career Development Center

#### Applying to Graduate School?

##### All About Funding and Grad School Visits

Helen Duong, Recruitment, Outreach, and Admissions Coordinator, Graduate Studies Office

#### Networking for the Introvert

James Berk, Career Counselor/Pre-Health Advisor, Career Development Center

#### Using Social Media and Managing Your Online Image

Mandy Casani, Assistant Director, Career Development Center

#### Alternative Career Options

Mandy Casani, Assistant Director, Career Development Center

### SURFers' AVERAGE GPA\*

2015 **3.52** 2016 **3.65**

\* Caltech students only, excluding freshmen

### 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 exists at JPL.

### 2014

OCTOBER 6, 2014

**Moogega Cooper**, Planetary Protection Engineer  
**Matthew Shaw**, Microdevices Engineer  
**Kiri Wagstaff**, Senior Research Staff

OCTOBER 13, 2014

**Jessica Collisson**, Technical Group Supervisor, Systems Engineering Verification and Validation Group  
**Glenn Orton**, Senior Research Scientist  
**Steven Vance**, Habitability Team Lead, JPL Icy Worlds NAI

OCTOBER 20, 2014

**Eric DeJong**, Member of the Technical Staff  
**Doug Lisman**, Senior Engineer  
**Neal Turner**, Staff Scientist

OCTOBER 27, 2014

**Laurie Barge**, Caltech Postdoctoral Scholar  
**Aaron Parness**, Mechanical Engineer  
**Florian Schwandner**, JIFRESSE Project Scientist III

NOVEMBER 10, 2014

**Colleen Marrese-Reading**, Senior Engineer  
**Farisa Morales**, SURF '00, Astrophysics Researcher  
**Shouleh Nikzad**, Principal Member of the Technical Staff

NOVEMBER 17, 2014

**Charles Budney**, System Engineer IV  
**Emily Meany**, SURF '14, '15, Caltech Undergraduate in Bioengineering  
**Leigh Torgerson**, Senior Member of the Engineering Staff

### DEMOGRAPHICS

	2015	2016
Women	36%	40%
Minorities	12%	12%

### 2015

OCTOBER 5, 2015

**Sarah Milkovich**, SURF '97, '98, '99, Engineer, Planetary Geology and Science Systems  
**Rudra Mukherjee**, Research Technologist and Group Leader, Robotics Modeling and Simulation Group  
**Tatiana Roy**, SURF '13, '14, '15, Caltech Undergraduate Student in Applied Physics  
**Oleg Sindi**, SURF '04, Systems Architect, Information Systems Engineering Group

OCTOBER 12, 2015

**Laura Jones**, Engineer, Guidance and Control Systems  
**Glenn Orton**, Senior Research Scientist  
**Oleg Pariser**, Member of the Technical Staff at Multimission Image Processing Laboratory (MIPL)

OCTOBER 19, 2015

**Sabah Bux**, Technologist III, Thermal Energy Conversion Technologies Group  
**Serina Diniega**, SURF '02, Mathematical Planetary Geomorphologist  
**Annemarie Eldering**, Deputy Project Scientist, Orbiting Carbon Observatory - 2 (OCO-2)

OCTOBER 26, 2015

**Bonnie Buratti**, Senior Research Scientist and Technical Manager  
**David Thompson**, Research Technologist  
**Parag Vaishampayan**, Staff Scientist

NOVEMBER 9, 2015

**Morgan Cable**, USRP '04, Research Scientist, Instrument Systems Implementation and Concepts Section  
**Tim Eifler**, Research Scientist, Astrophysics Section  
**Benjamin Jorns**, Engineer, Electric Propulsion Group

NOVEMBER 16, 2015

**Yutao He**, Senior Technologist, Advanced Computer Systems and Technologies Group  
**Chris Mattmann**, Principal Data Scientist and Chief Architect, Instrument and Data Systems Section  
**Aaron Noell**, Technologist, Planetary Surface Instruments Group  
**Robert Sanchez**, SURF '14, '15, Caltech Undergraduate Student in Geophysics  
**Michael Tuite**, Isotope and Organic Geochemist and Manager, Astrobiogeochemistry Lab

### Strengthening Effective Communication Skills

Being able to communicate one's science is critical to one's success. Through SURF students have plenty of opportunities to practice and develop their writing and oral communication skills. This process begins during the application phase when students, in collaboration with their mentor, need to write and submit a research proposal. During the summer, SURFers must submit two progress reports, an abstract, and final paper. And, of course, they must give a final presentation. Here are some other ways in which students' oral and written communication skills are further 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 semi-final round held in November. Six to eight finalists advance to a final round held every January. The 2016 Perpall finals will be held in January 2017.

- 2014 Winners** Benjamin Wang, First Place  
Adam Jermyrn, Second Place, tie  
Sean McKenna, Second Place, tie
- 2015 Winners** Moriah Bischann, First Place  
Alec Brenner, Second Place  
Dominic Yurk, Third Place

**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.

- 2014 Winners** May Hui, First Place  
Kayane Dingilian, Second Place
- 2015 Winners** Chaitanya Malladi, First Place  
Beatriz Atsavaprane, Second Place, tie  
May Hui, Second Place, tie

**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.

**Summer 2015, Vol. 16, no. 2**  
*Editors-in-Chief:* Edward Fouad and Suchita Nety  
*Student authors:* Christina Daniel, Edward Huang, Patrick Yu

SURFers	2015				2016			
	Total # of Students	CIT Students	Non-CIT Students	Mentors	Total # of Students	CIT Students	Non-CIT Students	Mentors
Biology and Biological Engineering	51	42	9	25	36	29	7	17
Chemistry and Chemical Engineering	62	52	10	22	71	62	9	28
Engineering and Applied Science	100	70	30	38	95	62	33	40
Geological and Planetary Sciences	22	19	3	15	29	16	13	17
Humanities and Social Sciences	7	4	3	6	19	13	6	9
Physics, Mathematics, and Astronomy	95	57	38	58	98	56	42	61
Jet Propulsion Laboratory	60	40	20	37	62	34	28	43
Off Campus	33	33	0	33	32	32	0	29
International	7	6	1	5	7	7	0	6
<b>Total</b>	<b>437*</b>	<b>323</b>	<b>114</b>	<b>239</b>	<b>449*</b>	<b>311</b>	<b>138</b>	<b>250</b>

\*this includes LIGO and exchange SURF students



THE SURF BONUS—A COMMUNITY OF SCHOLARS

# FUNDING SURF

Each SURF student receives an award of \$6000 for the ten-week summer period, a total budget of \$2.4 million. Funds are raised from a variety of sources including endowments and annual gifts from individuals; foundations and corporations; faculty grants; NASA funds (for students working at JPL).

SURF depends upon the generosity of its many friends for annual gifts and for the establishment of new endowments. We thank the many donors who have supported SURF 2015 and 2016!

## Endowments

A strong SURF endowment helps ensure the future of the program and will help provide generations of Caltech students with the unparalleled opportunities to engage in research at the frontiers of knowledge.

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 several years, or specified in a donor's estate plans.

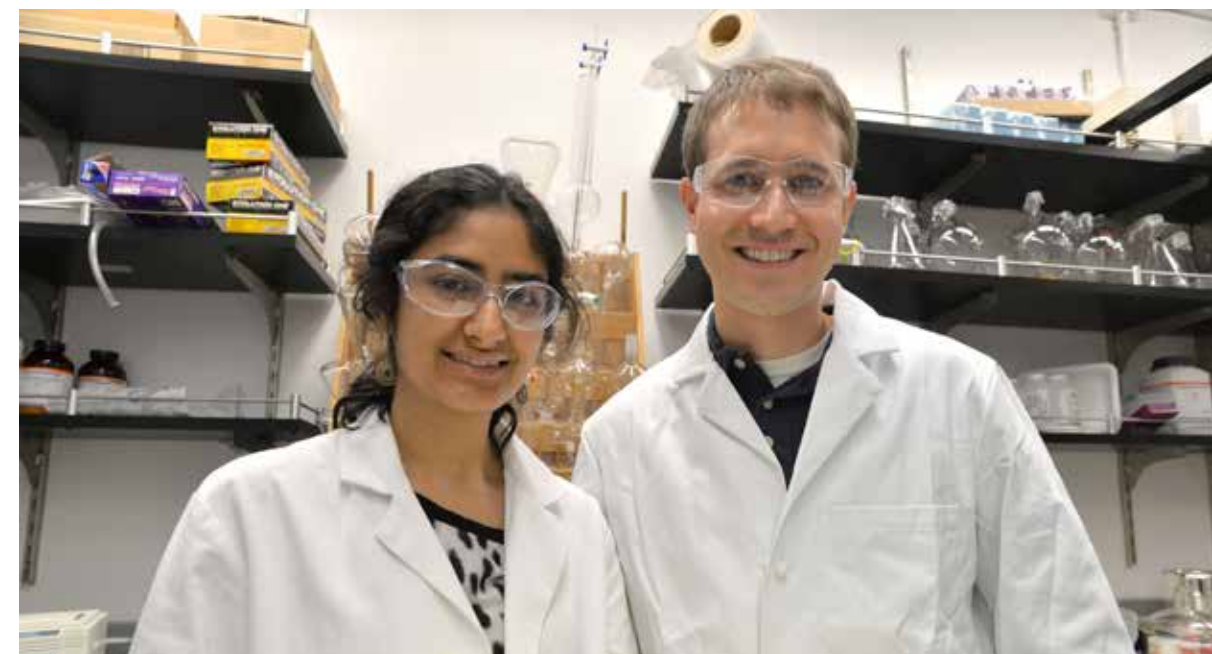
Each year a student will be selected to bear the endowment name, and the donor will receive a letter introducing the student and their research project. Donors have the opportunity to meet the students supported by their gifts at an annual student-donor dinner. Additionally, donors are invited to attend SURF Seminar Day to hear the students' final presentations.

## Annual Gifts

We deeply appreciate our donors who give annually to support SURF. We depend on these contributions to help build a robust financial foundation for each SURF year. Every gift is important!

We especially thank SURF alumni and parents who contribute to the program. These gifts are a strong testimony to the value they place on the SURF experience in the undergraduate curriculum.

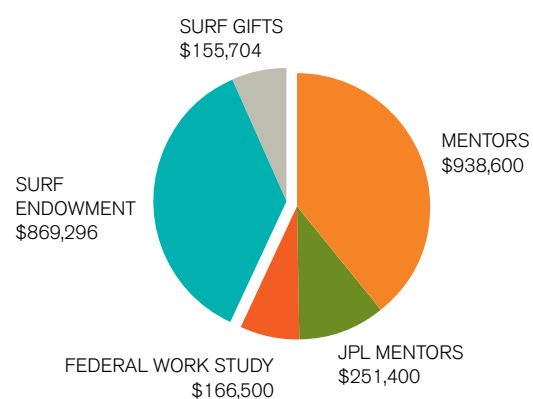
Gifts may now be given online at [fund.caltech.edu](http://fund.caltech.edu). After entering your donation amount, select "Choose specific designations." In the pop-up designations window, scroll to the "Research Support" section and select "SURF (Summer Undergraduate Research Fellowships)".



As the 2016 Robb and Eunice Rutledge SURF Fellow, freshman **Ashna Dhingra** worked with mentor **Harry Gray**, the Arnold O. Beckman Professor of Chemistry, on a project entitled *Fused Porphyrin Dimer for Proton Reduction*. The Rutledge SURF Endowment was established in 2015 by Caltech professor, Dave Rutledge, and his wife, Dale Yee. It was established in honor of Dave's parents and given to support a student in chemistry or chemical engineering. The Rutledge SURF endowment was matched by the John Stauffer Trust by providing an additional \$125K to support undergraduate research in chemistry and chemical engineering. Matching grants are still available.

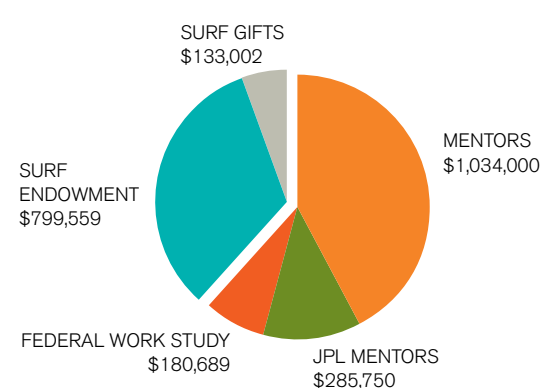
## 2015 SURF Award Funding

\$2,381,500



## 2016 SURF Award Funding

\$2,433,000

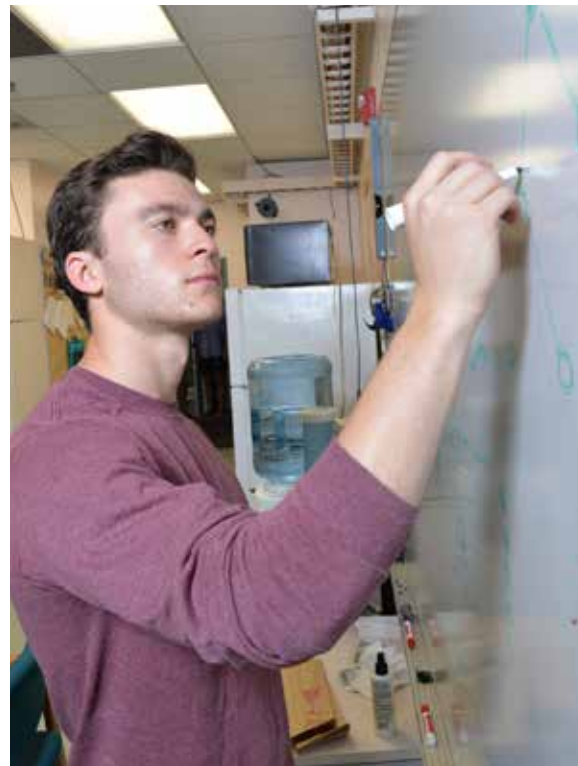


> Annual gifts of \$6,000 provide support for one student to do a SURF. In 2016, Caltech and SURF alum **Kevin Franklin's** generous donation provided support for freshman **Aaron Sartin** to conduct research with mentor **Michael Ewens**, Associate Professor of Finance and Entrepreneurship. While Kevin, as managing director at BlackRock, the world's largest asset manager, spends his days analyzing hedge funds, Aaron spent his summer exploring the interactions between legal and illegal marijuana markets.

Corporate donations not only provide vital funding for SURF, but they also provide students with a network of professional support outside of their campus research. In 2016, the Northrop Grumman Corporation supported three SURF students.

> **Evren Gokcen** (right), under the mentorship of Professor Pietro Perona, the Allen E. Puckett Professor of Electrical Engineering, examined methods of building adaptive deep neural networks.

✓ Working with Harry Atwater, the Howard Hughes Professor of Applied Physics and Materials Science, junior **Connie Robinson** (below left) and freshman **Kevin Tat** (below right) worked at the intersection of nanophotonics and energy.



## Honor Roll of SURF Donors

### ANNUAL GIFTS

#### \$6000 or more

Mr. Ian Agol, SURF '91  
 Mrs. Hannah Bradley  
 Mr. George L. Cassat  
 Ms. Maria Chan\*  
 Dr. Jane C. Chen\*  
 Mr. and Mrs. Kevin L. Crook\*  
 Mr. Vivek R. Dave, SURF '87\*  
 Mr. Kevin M. Franklin, SURF '98  
 Mrs. John D. Gee\*  
 Dr. and Mrs. Daniel C. Harris\*  
 Dr. Taylor W. Lawrence, SURF '85\*  
 Mr. and Mrs. Robert C. Loschke\*  
 Mr. Jackson Rhoades\*  
 Mr. and Mrs. David P. Rossum\*  
 Mr. Samuel N. Vodopia and  
 Ms. Carol Hasson\*  
 Dr. James C. Whitney

#### \$2500-\$5999

Mr. Matthias Blume  
 Mr. and Mrs. Paul G. Haaga, Jr.\*  
 Mr. and Mrs. Robert E. Holo  
 Mr. Mani M. Limlamai, Space Grant '03\*  
 Mr. Patrick Lincoln  
 Ms. Denise Nelson Nash  
 Mr. and Mrs. Richard M. Rosenberg\*  
 Mr. George Ruptier  
 Dr. Gary W. Stupian\*  
 Mr. and Mrs. Tandy Trower

#### \$1000-\$2499

Mrs. Kim Beaver  
 Mr. Daniel H. Chou, SURF '97\*  
 Dr. Jeanne M. Courval\*  
 Mr. and Mrs. Kirk M. Dawson\*  
 Mr. Hank Hall and Ms. Debra Dison Hall\*  
 Mr. and Mrs. Jay Farr\*  
 Mr. Leroy J. Fisher II and  
 Dr. Susan S. Murakami\*  
 Dr. and Mrs. Blair A. Folsom  
 Ms. Nancy H. Glanville\*  
 Dr. Philip M. Gschwend\*  
 Mr. and Mrs. Kenneth H. Hahn,  
 SURF '85  
 Mr. Jackson I. Ito  
 Mr. and Mrs. Arthur S. Jackson\*  
 Dr. and Mrs. Paul C. Jennings\*  
 Dr. Marilyn R. Kehry\*  
 Mr. and Mrs. James M. Kendall, Jr.\*  
 Dr. Robert M. Kieckhefer\*  
 Ms. Janice Lau Wee, SURF '92, '93, '94\*  
 Mr. Sangjun Lee, GIST Exchange '13

Mrs. Joanne Lester  
 Mrs. Jeanne G. Lewis\*  
 Dr. and Mrs. York Liao  
 Mr. Eric S. Lin, SURF '02, '03\*  
 Mr. Javed Mostafa  
 Mr. and Mrs. Timothy M. Norris\*  
 Mr. and Mrs. Don M. Pinkerton  
 Dr. Robert K. Roney\*  
 Mr. Stephen J. Salsler, SURF '86\*  
 Mr. and Mrs. Richard J. Soghoian\*  
 Drs. Tab A. (SURF '87) and  
 Keri Stephens\*  
 Dr. Derek M. Surka (SURF '92, '93) and  
 Ms. Charrissa Lin\*  
 Dr. John A. Thich  
 Mr. Thomas A. Tisch  
 Mr. Cumrun Vafa  
 Dr. George Wallerstein

#### \$500-\$999

Ms. Dian P. Anderson\*  
 Ms. Hoang M. Banh, SURF '04\*  
 Mr. Mark O. Barrett, SURF '98, '99, '00  
 Dr. Sunney I. Chan  
 Mr. Peter K. Clark\*  
 Dr. Andria Costello Staniec  
 Dr. and Mrs. Jan W. Dash\*  
 Dr. Peter L. Davis\*  
 Mr. Xiaoming Fan\*  
 Ms. Alta Y. Fang, SURF '10, '11\*  
 Mr. Hung Fai Fong, SURF '92, '93  
 Dr. David C. Gakenheimer\*  
 Mr. and Mrs. Kenneth Hui,  
 SURF '82, '83\*  
 Dr. Peter S. Hung, SURF '05, '06, '07  
 Mr. Ju-Min Ko and  
 Mrs. Fon-Chiu Mia Chen  
 Mr. and Mrs. Santosh Krishnan,  
 SURF '83, '84, '85\*  
 Dr. and Mrs. Phillip J. Laipis  
 Mr. Arthur Lee  
 Dr. and Mrs. Jack E. Leonard\*  
 Mr. and Mrs. James L. Lester\*  
 Mr. and Mrs. Timothy Lin  
 Dr. Aron J. Meltzner, SURF '97, '98, '99\*  
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