e&S
Engineering & Science

Caltech

VOLUME LXXVII, NUMBER 3, FALL 2014

e&S

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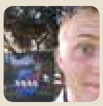
Caltech on Twitter

Follow us, retweet us, and let us know you're talking about us by including @Caltech in your tweets.

@huntermaats: Such a pleasure having Caltech's brilliant quantum physicist @quantum_spiros on The Bryan Callen Show!

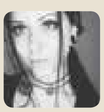
@MasonMac2014: Late night jam session in the Caltech studio…sure, why not



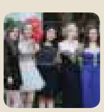
@OxyAstro: Quadcopter shenanigans on Beckman Lawn. A normal Tuesday night at Caltech

@thatethanlee: Trying to see the rest of the amazing @Caltech campus but family of five is engrossed by the turtles in their pond.

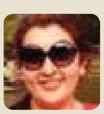
@discoverLA: There's something to do in LA every day of the year. Day 177/365: Take the @Caltech architectural tour bit.ly/1qf72xP #LA365



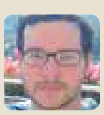
@Kaitlynraub: The things that I would do to go to @Caltech is unexplainable and honestly illegal. #onedaymylove #imcomingforyou #eventuuuuallly



@AnnabelleBarden: Caltech chic caught up to me. My pile of polo shirts grows taller like a germinating gametophyte with overexpressed paracrine growth hormone



@dollz87: Perks of having gone to Caltech—super smart friends to debug your code :)



@JasonMHenry: It's odd being on a college campus and not being in college. But man @Caltech is gorgeous.

@Miquai: Ahhhhhhhhhh first playoff summer softball game of my #Caltech intramural career. Go GPS Strike Slip!

Tweets may have been edited for spelling and grammar.

Caltech
Engineering & Science

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The Minds Behind the Matters

The faculty in Caltech's Division of the Humanities and Social Sciences are researchers and teachers, mentors and investigators. They delve into questions about our behaviors as individuals and in groups, about how we humans interact with one another, and how those interactions influence our social, political, and economic systems.

And they do this using the same kind of intellectual rigor that is one of Caltech's signature characteristics, applying innovative and precise methodologies to imaginative and bold questions.

For these and many other reasons, we're using this issue of *E&S* to consider just how Caltech's humanists and social scientists work to deepen our knowledge and understanding of our world.

It's hard to figure out what to say about faculty members who are so much better than I am at explaining why what they do matters—to themselves, to their students, and to society—and why it matters that they're doing it at Caltech. And so, I won't try. Instead, I'll leave you with their voices, as heard throughout this issue, in a series of essays, profiles, and interviews.

"What I value most about Caltech is its commitment to intellectual freedom and its trust in its faculty to fulfill the Institute's purpose, which is to produce outstanding research."

—John Brewer, Eli and Edye Broad Professor of Humanities and Social Sciences and professor of history and literature (p. 14)

"Caltech students are brilliant and sharp-eyed, and teaching them has made me a better humanist."

—Christopher Hunter, assistant professor of English (p. 16)

"Caltech has taught me that combining different approaches to knowledge enables a much richer picture of the human experience."

—Catherine Jurca, professor of English (p. 15)

"The interdisciplinary collaboration that many universities hold as a desideratum, we practice on a day-to-day basis."

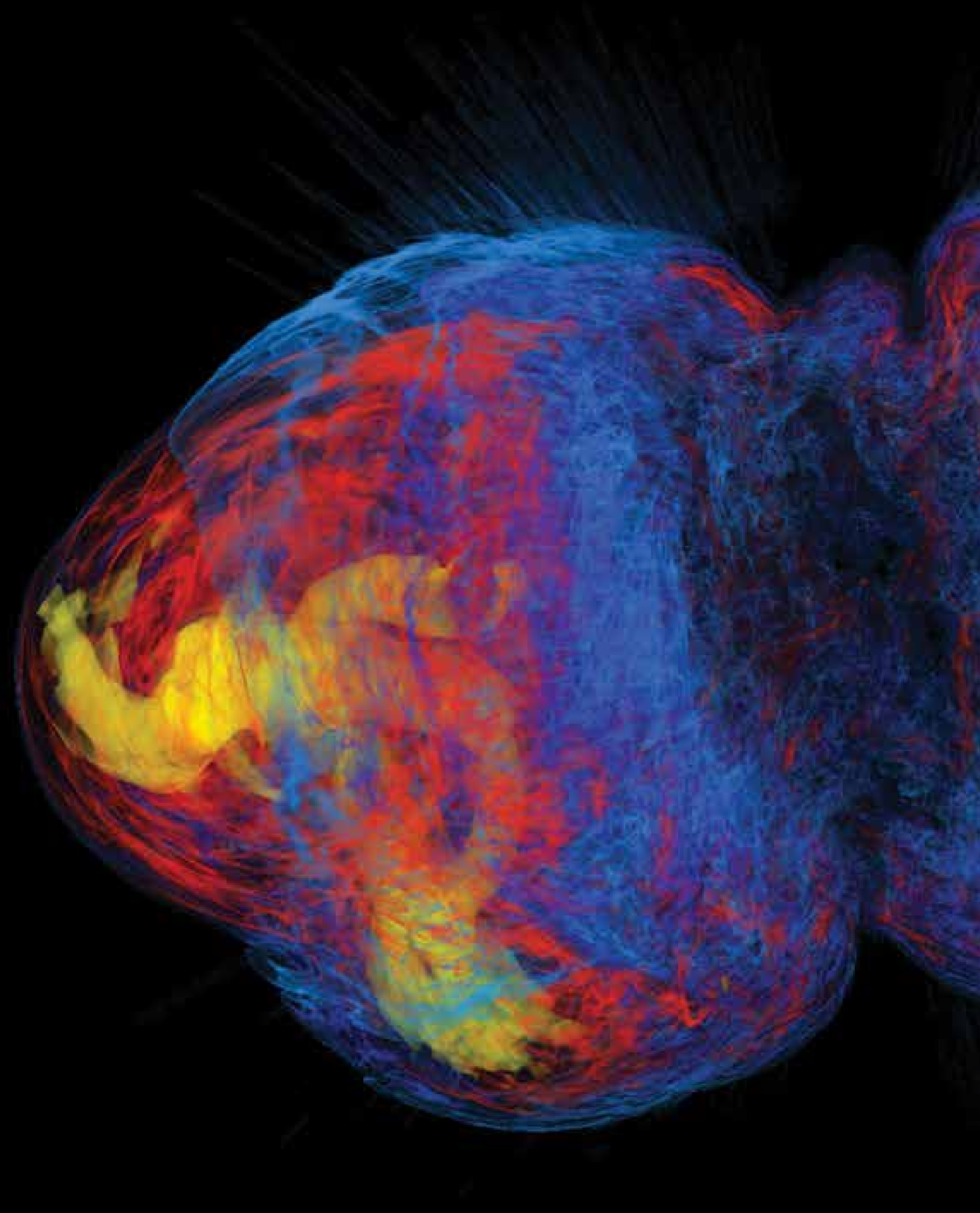
—Jennifer Jahner, assistant professor of English (p. 13)

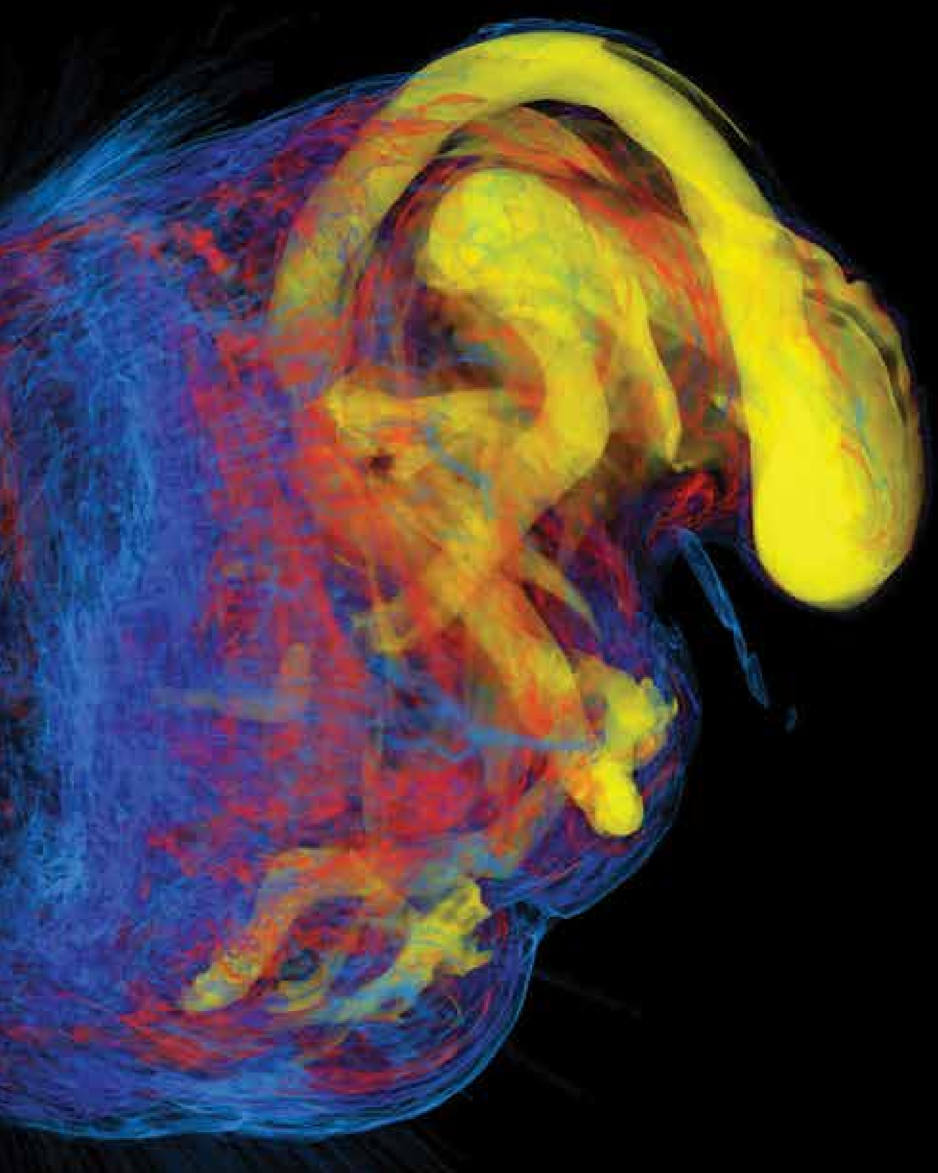
"If you don't have access to all the disciplines that shape our world, then you can't be an active citizen."

—Christa Robbins, Mellon Caltech-Huntington Postdoctoral Instructor in Art History (p. 22)

—Lori Oliwenstein, Editor

Random Walk





CORE INSTABILITY

When massive stars collapse, as they inevitably do, they often then explode into a supernova—but not always. For astrophysicists, it has been a challenge to figure out what drives the explosion after the initial collapse of the core of a massive star. Recently, Caltech postdoctoral scholar Philipp Mösta and professor of theoretical astrophysics Christian Ott simulated the collapse of a three-dimensional rapidly rotating star with a strong magnetic field. They introduced a tiny asymmetric perturbation around the core's axis of symmetry to see if it had an effect on the star's explosion. In the simulation illustrated here, the perturbation triggers a "kink instability" that results in two lobes of twisted and highly magnetized material that do not show signs of a runaway explosion—a supernova—at the end of the simulation. "As the material expands, it gets wound in tubes around the spin axis of the star, like water being expelled vigorously from a twisting garden hose left lying on the ground," says Mösta. More and longer simulations on more powerful supercomputers will be needed to determine the final fate of core collapse in such a rapidly rotating magnetized star.

Insider Info

Our art department temporarily affixed

142

Scrabble tiles to the wall of Dabney Lounge for the photo on page 24.

31

fables were included in the original 1966 edition of professor emeritus Oscar Mandel's *Gobble-Up Stories* (see page 14).

500

pieces of scrap paper were used by British artist Patrick Bremer to create the colorful collage that graces the cover of this issue.

Agents of Change

In the lab of chemist Jim Heath, Caltech's Elizabeth W. Gilloon Professor and professor of chemistry, researchers are working to develop new capture agents for cancer—chemicals that could bind to a particular cancer biomarker, allowing the protein to be identified and studied more easily. The goal is to replace antibodies, the current gold standard for capture agents, with something cheaper and more stable.

The biomarkers that the researchers want to target are hundreds of amino acids long. Yet it is often the case that a single mutation within that sequence is enough to cause cancer. So graduate student Kaycie Butler Deyle (PhD '14) and her colleagues have been trying to zoom in on just the chunk of protein where a mutation is known to occur. For example, Deyle focused on a point mutation on the protein AKT1, where the amino acid E at position 17 is known to change to amino acid K, allowing the protein to stay attached to a cell membrane four times longer than usual—a signal that tells the cell to continue to grow, triggering cancer.

In the lab, she first synthesized the chunk of AKT1 that holds the mutation. Then she needed to come up with a chemical that could grab and hold onto that five-amino-acid-long chunk.

To figure out what that chemical might be, she used something called click chemistry, which relies on the ability of two types of molecules, or click handles, to click together when near one another. Typically this requires the incorporation of a copper catalyst, but the Heath lab came up with a new approach. Deyle first inserted one of the click handles two amino acids away from the mutation in her synthesized chunk of AKT1. Then she screened a million-member library to find a short sequence of amino acids with the other click handle attached that would bind to the AKT1 and click together with the first handle. That sequence of amino acids makes up a new capture agent for AKT1. "Essentially, we use the cancer protein to catalyze the formation of its own capture agent," Deyle says.

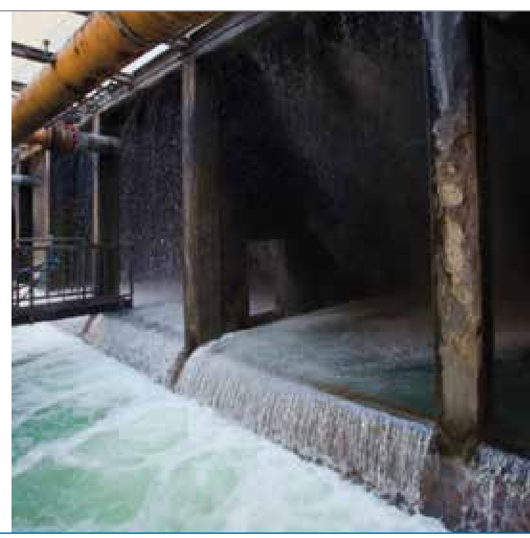
Next, Deyle attached a cell-penetrating peptide to her capture agent, and she used a dye to spy on its progress, making sure that the agent was getting through. It was. "Even in cells, our capture agent is still really selective for the mutation," Deyle notes.

With that work in hand, the researchers began trying to block the action of the mutant protein completely. What they've found is that an expanded version of their capture agent can successfully stop the mutant protein from binding to the cell membrane.

Thus far, the work has only been done on the benchtop. The next step will be to try it in cells. "We hope this is a route to a unique therapeutic for cancer," Deyle says. —*KF*

On the Grounds

This sump, located somewhere on campus, is part of an elaborate chilled-water system that helps lower temperatures in buildings at Caltech. It collects water sprayed out through dozens of nozzles at the top of a series of cooling towers. Large fans pull air up through the water as it falls, creating an evaporative cooling effect. Once cooled, the tower water can absorb heat from a separate volume of water that circulates around campus and winds up back at the tower, where it transfers some of the heat it picked up along the way. So where at Caltech can you see these waterfalls in action?



Answer: The sump and the cooling towers shown in the picture are part of the Central Utility Plant.

“I was sitting there at breakfast, and my laptop computer told me that shaking was coming, and then I felt it, and it was nice.”

—Caltech seismologist Thomas Heaton, about the prototype earthquake early-warning system he pioneered, which went off during a 4.4 temblor in the Santa Monica Mountains on March 17.

Beating the Heat—and the Stacks

It’s not every day that you find a group of students traveling through campus dressed as minions from the movie *Despicable Me*. However, such sightings are par for the course on Ditch Day, an annual spring tradition at Caltech. On that day, Caltech seniors challenge underclass students to solve puzzles or complete complex tasks, called stacks, while the seniors leave campus for the day. This year’s challenges included calibrating a catapult to fling tomatoes at a target, rappelling off the side of Firestone Laboratory, and solving a complex vertical version of sudoku. In the stack pictured above, the underclass “minions” had to fashion a raft out of nothing but cardboard boxes, balloons, and duct tape—and the raft had to successfully float one passenger down the entire length of the Gene Pool. Although falling in the pool meant failing the stack, it was a welcome cooldown: the temperature on May 15—this year’s Ditch Day—was a sweltering 100 degrees Fahrenheit. *—JSC*

Smart Hops

Diego Benitez had a unique graduate-school experience at Caltech. By day, he studied the ins and outs of olefin metathesis in the laboratory of Victor and Elizabeth Atkins Professor of Chemistry Robert Grubbs—work that resulted in a PhD in chemistry in 2005, as well as a trip to Sweden that same year when Grubbs was awarded the Nobel Prize. However, when Benitez wasn’t studying reactions in the lab, he was enthusiastically pursuing another interest: craft beer.

“Pasadena is a good destination for craft beer, so in addition to chemistry, I guess you could say that I also had the chance to study beer while I was at Caltech,” Benitez says. The tasty after-hours research eventually led to home brewing, a hobby he continued to pursue through his postdoc in nanotechnology at UCLA and a few years working in industry.

In 2012 Benitez and fellow chemist and beer enthusiast Kevin Ogilby decided to take the plunge and quit their day jobs to pursue their hobby full time—that’s how Progress Brewing was born. The brewery, located in South El Monte—about 10 miles southeast of Caltech—specializes in what Benitez calls “drinkable beers that the majority of people will like—not just beer geeks.”

Although the applied chemistry of crafting a new brew strays from his formal laboratory training, it has allowed Benitez to accomplish another life goal: entrepreneurship. “I come from a family of entrepreneurs, so I always knew I kind of wanted to branch out on my own. Beer seemed like a really fun way to do that,” he says. *—JSC*

A WEBBY UNIVERSE

Look up at the sky on a moonless night, and what do you see? If you are feeling poetic, you see “the lovely stars, the forget-me-nots of the angels” (Henry Wadsworth Longfellow). In a different mood—or if you’ve spent much time around Caltech—you might be more likely to say that you see galaxies, nebulae, quasars, binary star systems, supernovae. But let’s face it: to the naked eye, it’s just stars and more stars, so matchless in their beauty that it is easy to imagine that we see the entire universe spread out before us.

The past century of astrophysics has taught us that what we see is but a tiny fraction of what is out there. Dark matter and energy compose 96 percent of our universe. “Bright matter”—the stuff we see—is no more than 1 percent. The rest lies in the intergalactic medium (IGM): what Caltech physicist Chris Martin calls “dim matter.”

Over the past several decades, theorists have predicted that the dim matter of the IGM is a “cosmic web,” with gas flowing through its filaments to feed matter into galaxies. Now, courtesy of Caltech’s Cosmic Web Imager (CWI), designed and built by Martin and his team, we have seen it. Mounted on the 200-inch Hale Telescope at the Palomar Observatory, the CWI has already delivered some appetite-whetting images of the IGM swirling around a quasar and a Lyman-alpha blob (a protogalaxy filled with hydrogen gas).

A new, improved version of the CWI is being prepared for the 10-meter telescopes at the W. M. Keck Observatory in Hawaii. Using these CWI enhancements, Martin hopes to point the imager at what looks like nothing, and see there the filaments of the cosmic web spread far and wide. —*CE*

MICROGRAVITY

Recent graduate Lisa Lee (center) from the class of 2014 participates in a medical-technology experiment aboard NASA’s reduced-gravity aircraft, based at the Johnson Space Center’s Ellington Field in Houston, Texas. Sometimes referred to as the “vomit comet,” the plane performs a series of dives, giving those onboard periods of weightlessness for up to 25 seconds at a time. Lee teamed up with students from Stanford University (including Diniana Piekutowski, left, and David Gerson, right) to test a hemodynamic transesophageal echocardiogram (hTEE) in zero gravity for possible health monitoring in space. “Astronauts experience a lot of medical complications in space because there’s no gravity, so there’s a need to constantly monitor how they’re doing,” explains Lee, who received her degree in physics. “But a lot of current monitoring technology is very bulky, and there’s a very steep learning curve to learning how to use it. This hTEE is very easy to learn how to use, it’s small, and it’s portable . . . and it would provide an easier way to monitor heart conditions.” —*KF*

BY THE NUMBERS: Class of 2014

As a new school year begins, and we welcome a new class of freshmen to campus, we thought we would give the class of 2018 some nonacademic statistics to study—and possibly try to beat! Over their four years at Caltech, the students from the class of 2014:

Pulled **12** major pranks

Consumed **24** pounds of food each at Midnight Madness

Heard the cannon fired **25** times

Attended **32** Interhouse and House parties

Participated in or planned **120** Ditch Day stacks

Ate **620** pies on Pi Days

The Write Stuff

> Ezekiel, meanwhile, was convinced
> that Creative Writing, still in its infancy,
> would amount
>
> to a bona fide
> academic pursuit only if students weren't spoon-fed
> but came to think of literature
> as magical rather than magisterial.
>
> *Paul Muldoon, "Saffron"*

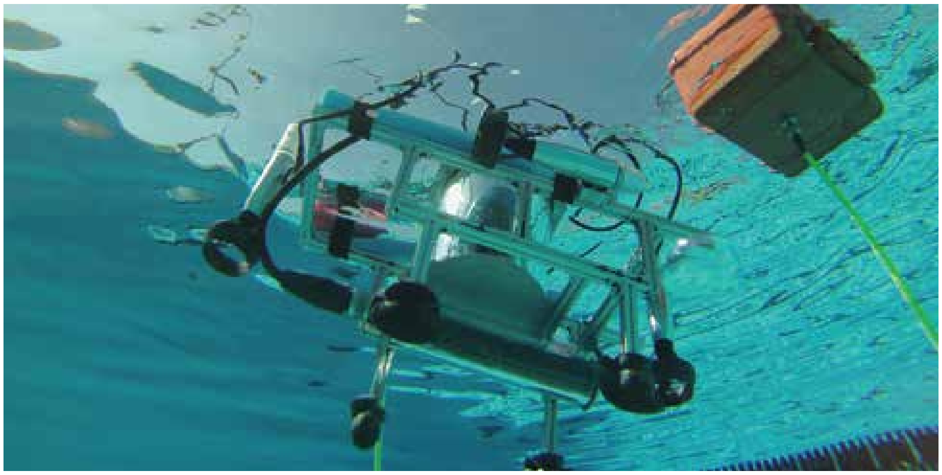
Launched in 2007 by English professor Cindy Weinstein, the creative-writer-in-residence program most recently welcomed Irish poet and Pulitzer Prize winner Paul Muldoon to campus, as a complement to English professor Kevin Gilmartin's course on modern and contemporary Irish literature. The program, which has existed through support from the Provost's Innovative Teaching Fund, now has ongoing support from the Division of the Humanities and Social Sciences through the James Michelin Distinguished Visitor Program.

"Students know the challenges of understanding the universe, from the point of view of chemistry or physics. The writers who come to Caltech will show students how literature addresses these challenges as well," says Weinstein. "The creative process is both different from and analogous to doing an experiment in a science lab," she adds. "Students welcome the opportunity to meet someone like Paul who explains how one writes poetry."

For Muldoon, who visited Gilmartin's classes and met with students in humanities classes, the experience was equally rewarding. "For writers the idea that anyone might be interested in reading their work at all always comes as a bit of a surprise, and the idea that some of these students might actually have been prepared for the visit is quite heartening," he says.

Weinstein hopes to have a few visitors each year—one per quarter—to teach or sit in on classes, do public readings, or come for a week and write.

"My hope is that Caltech will become known as an excellent place for writers to come and be exposed to really smart students. The goal of this program is that Caltech becomes a destination for creative writers, especially writers whose work demonstrates a link between science and literature," says Weinstein. *—AA*



Making a Splash

If you were to visit the swimming pools on campus any weekend last spring, you would have found a team of Caltech students diligently preparing for competition—but they weren't tweaking their flip turns and backstrokes. Instead, the members of the Caltech Robotics Team were meeting to fine-tune their latest project—a robotic submarine named Bruce—for the 17th Annual International RoboSub Competition.

At the competition, which took place in San Diego in late July, the team was scored based on how many tasks Bruce could complete in 25 minutes. The complex challenges—such as traveling through an underwater gate, finding and hitting different colors of buoys, firing a tiny torpedo at a target, and tracking down the location of a sonar pinger—required collaboration between Bruce's programming, electrical, and mechanical subteams.

As an added challenge, instead of acting as a remote-controlled vehicle, Bruce had to perform all of these tasks completely autonomously—meaning that the students couldn't have any communication with their robot during the competition. Before the competition, Bruce was handed over to a professional diver, who switched the robot on and placed it in the water. Then the team had to sit back and wait to see how many tasks Bruce would complete—and if those hours of practice in the Caltech pool were going to pay off.

Although Bruce wasn't a finalist this year, the rookie Caltech team did well, earning the title of "Best New Team" at the competition. And because Bruce is a reusable robot, team members hope that with another year of programming and pool practice they can achieve an even better result next year. *—JSC*

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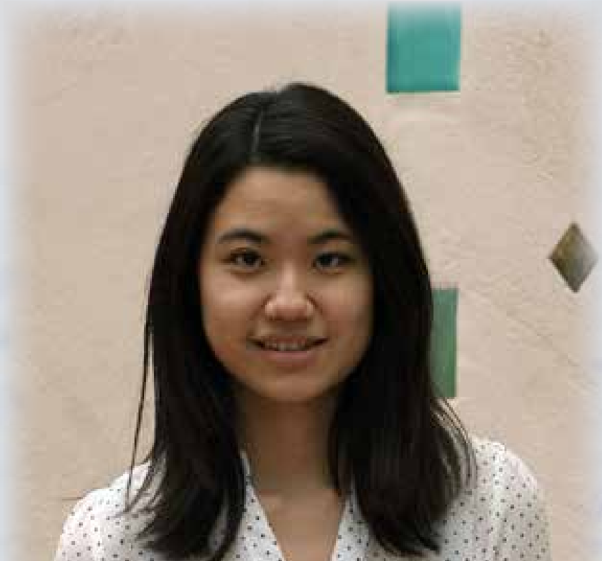


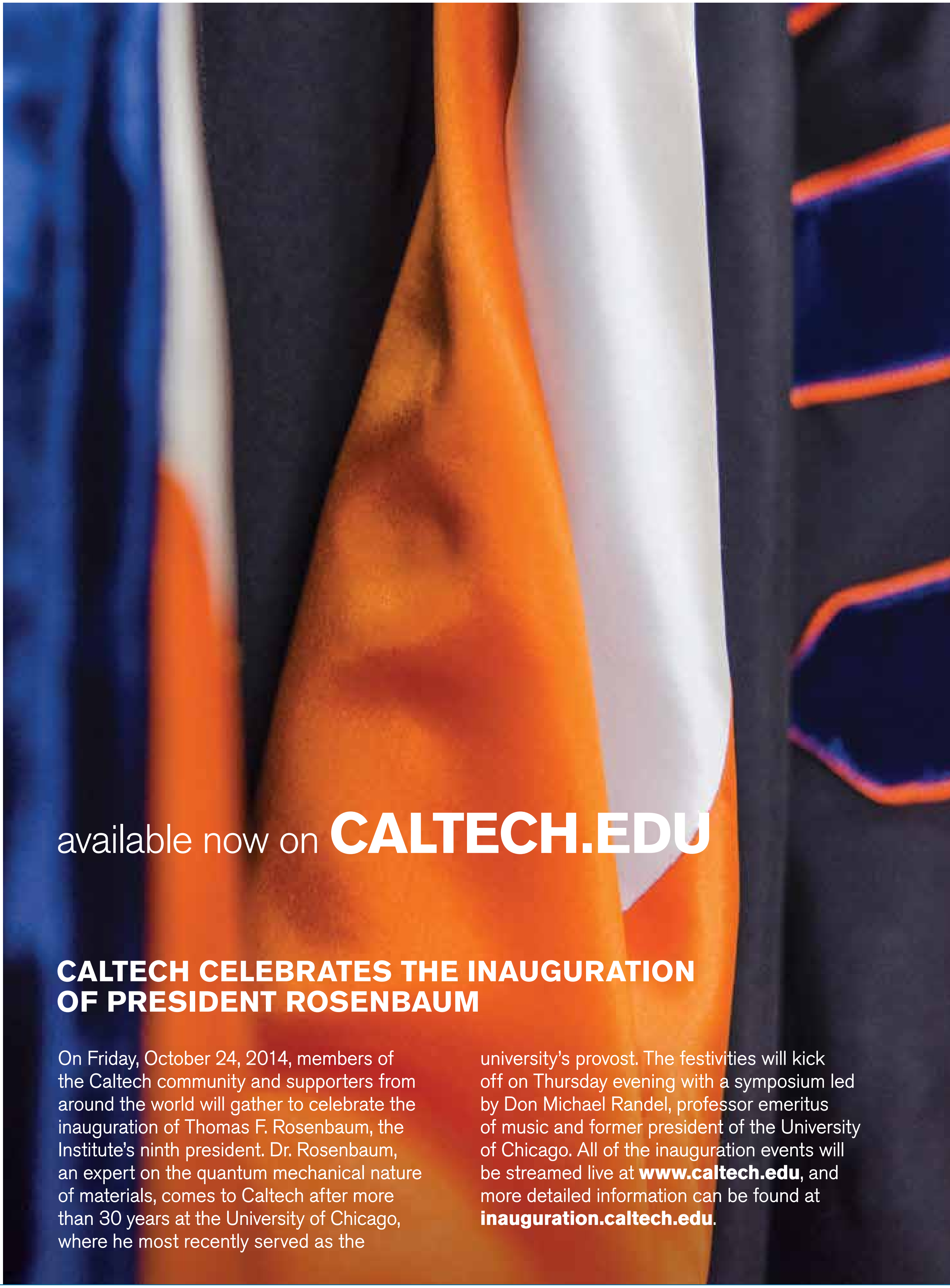
Alison Tan '14

Harrison Miller '15 + Sonia Kim '17

Kenneth G. Libbrecht '80

every year every gift any amount

Caltech Fund



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CALTECH CELEBRATES THE INAUGURATION OF PRESIDENT ROSENBAUM

On Friday, October 24, 2014, members of the Caltech community and supporters from around the world will gather to celebrate the inauguration of Thomas F. Rosenbaum, the Institute's ninth president. Dr. Rosenbaum, an expert on the quantum mechanical nature of materials, comes to Caltech after more than 30 years at the University of Chicago, where he most recently served as the university's provost. The festivities will kick off on Thursday evening with a symposium led by Don Michael Randel, professor emeritus of music and former president of the University of Chicago. All of the inauguration events will be streamed live at **www.caltech.edu**, and more detailed information can be found at **inauguration.caltech.edu**.

The Humanists

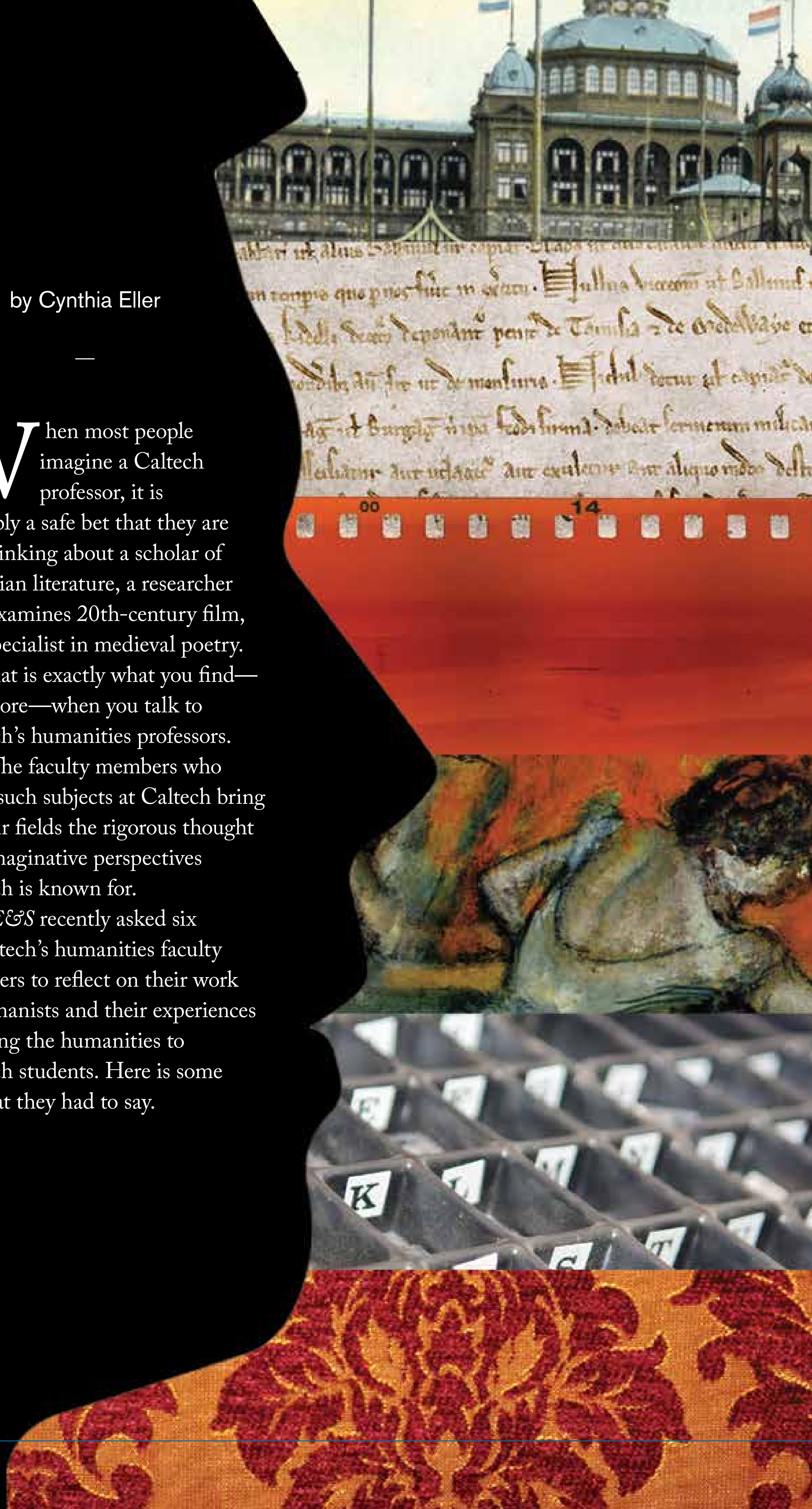
by Cynthia Eller

—

When most people imagine a Caltech professor, it is probably a safe bet that they are not thinking about a scholar of Victorian literature, a researcher who examines 20th-century film, or a specialist in medieval poetry. But that is exactly what you find—and more—when you talk to Caltech's humanities professors.

The faculty members who teach such subjects at Caltech bring to their fields the rigorous thought and imaginative perspectives Caltech is known for.

E&S recently asked six of Caltech's humanities faculty members to reflect on their work as humanists and their experiences teaching the humanities to Caltech students. Here is some of what they had to say.



JENNIFER JAHNER

—

assistant professor of English

Jahner arrived at Caltech in 2012, immediately after completing her PhD in English at the University of Pennsylvania. Her specialization in medieval poetry has taken her through the study of history to an examination of multilingualism, as she strives to understand how the poetry of that era was a vehicle for political and legal discourse. Her current book project, tentatively titled The Conjured Realm: Poetry and Political Formation in the Era of Magna Carta*, examines 13th-century British poetry and its connection to the political reforms of the day.*

Before I had set foot in an actual Caltech classroom, I imagined humanism and empirical science as remote islands, and my task as that of a literary tour guide, explaining our strange customs and ways. Upon starting here two years ago, I quickly realized that I needed to revise my metaphors. First, as it turns out, we are all denizens of the same small island—Caltech—and across the disciplines we share a common dedication to discovery, analysis, and intellectual integrity. Second, it became clear that Caltech students are hardly strangers to literature, nor to the questions of ambiguity and interpretation that literary texts inevitably raise. Teaching literature at Caltech, then, is simply the work of teaching literature: providing students with the context necessary to ask good questions about texts, and the tools necessary to pursue and demonstrate their answers.

One of the most dramatic differences between Caltech and more traditional research universities, however, is the fact that those of us in the humanities belong to a department combining English, history, and philosophy. The interdisciplinary collaboration that many universities hold as a desideratum, we practice on a day-to-day basis. This proximity to other methods and types of training shapes how we think about the boundaries of our respective fields.

For instance, part of my research looks at how scholars in the Middle Ages put their university training to work in the service of political causes, penning propagandistic verses for and against documents like Magna Carta. Medieval writers did not recognize the same disciplinary divisions that we do today, and those of us who study the medieval past regularly confront what, to modern readers, are startling conjunctions of genre and subject matter: poetry that conveys philosophy, history that explicates natural science, or philosophy that speculates on literary fiction. Caltech promotes a similar sense of intellectual capaciousness and juxtaposition, allowing those of us who work at the seams of various fields to develop truly interdisciplinary projects. All of us cultivate relationships beyond the Institute as well, through local partnerships and international collaborations. We are fortunate to have the scholarly community and resources of the Huntington Library only a mile away.

Since the advent of the universities in the Middle Ages, the humanistic disciplines have been at the core of higher learning, teaching students how to articulate and interpret what they see, and how to situate bodies of knowledge in relation to each other. The humanities constitute a vital part of the Caltech mission as well. Literature, history, and philosophy teach us how to communicate our expertise to others and to translate our research across specialties and beyond the boundaries of academe. Even more fundamentally, the humanities teach us about the histories of knowledge and creative endeavor, allowing us to see that truths are products of their time and place as well as products of the minds and methodologies that discern them. ◆

JOHN BREWER

—

Eli and Edye Broad Professor of Humanities and Social Sciences and professor of history and literature

Brewer was educated at Cambridge University with a specialization in 18th-century British history. He has been educating others ever since, in locations ranging from Los Angeles to Chicago, Florence to Paris. He came to Caltech in 2002. In his research, Brewer takes provocative themes—the interaction of culture and money in the art world, for instance, or the origins of tourism—and investigates them across cultures and down through time. Brewer's most recent book is The American Leonardo: A Tale of Obsession, Art and Money *(Oxford University Press, 2009). An earlier volume,* The Pleasures of the Imagination: English Culture in the Eighteenth Century *(Farrar, Straus and Giroux, 1997), was nominated for the National Book Critics Circle Award and won the Wolfson History Prize.*

Caltech offers unique advantages: an academic structure that not only permits but encourages cross-disciplinary research, an intimacy that stems from its small size, an unswerving commitment to the creation of an environment conducive to high-quality research, and undergraduates who may not know a lot about the humanities, but whose smarts are second to none.

The mechanics of research in the humanities is both similar to and very different from work in the sciences. I don't have a lab on campus; instead, I use libraries and archives dispersed in different countries—the United States, Britain, Germany, France, and Italy. In this sense, my working habits are probably closer to those of a geologist; I spend lots of time in the field. But I focus my attention on writing books, not papers. Words—lots of them—rather than numbers are the tools of my trade.

My last book used the history of a forged painting to investigate how the old-master art world worked; my current project examines the region around Naples in the 19th century. This project involves the history of archaeology and geology, art history, the history of migration and exile, politics, and economics in order to understand how the area around Naples acquired a specific identity.

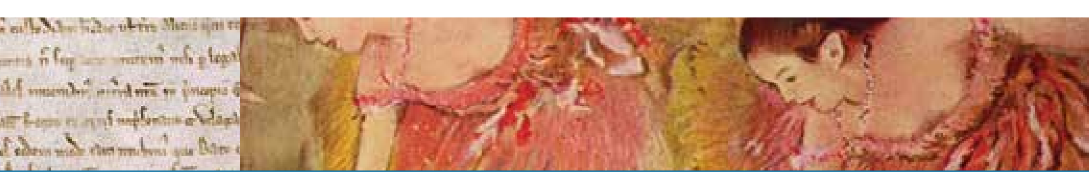
During my time at Caltech I've taught and run research projects with colleagues in related disciplines such as the history of science, art history, and literature. I've also made use of the expertise of Caltech scientists—with biologists for a project on modeling in the sciences and the arts; with George Rossman and Provost Ed Stolper for information on Vesuvius and volcanology. I am currently organizing a conference that will bring together humanists and social scientists with technical experts at the Resnick Sustainability Institute.

What I value most about Caltech is its commitment to intellectual freedom and its trust in its faculty to fulfill the Institute's purpose, which is to produce outstanding research. Such confidence, which is in rapid decline in many educational institutions, is what makes for good scholarship. ◆

OSCAR MANDEL — *professor of literature, emeritus*

Mandel taught English at Caltech for over 40 years. Born in Belgium, he is a bilingual French/English author of poetry, fiction, and plays, as well as a translator and analyst of all these genres, plus art history. His Gobble-Up Stories, *a series of brief morality tales with inventive animal and human characters, were recently performed by Theater Arts at Caltech (TACIT). A collection of his fiction, including the* Gobble-Up Stories, *was released this year by Prospect Park Books under the title* Otherwise Fables.

I have been privileged to work at Caltech under every Caltech president but two. When I was hired in 1961, the chairman of the Division of the Humanities and Social Sciences was a professor of literature: Hallett Smith, a distinguished Shakespeare scholar. The way Hallett Smith hired me is worthy of note. I had met the division's French instructor, Paul Bowerman, at a dinner party. I was looking for a job after a year as a Fulbright lecturer in American



CATHERINE JURCA

—

professor of English

Jurca came to Caltech in 1995, though her connection to the Institute goes back much farther (see below). A professor of English, Jurca specializes in 20th-century American novels and classical Hollywood films. Her most recent book, Hollywood 1938: Motion Pictures' Greatest Year *(University of California Press, 2012), looks not just at the movies, but at the entire culture that sprang up around them: how the film industry operated to produce, distribute, and exhibit films and how consumers made them a part of their lives.*

My connection to Caltech goes back more than 80 years. My maternal grandfather, an engineer, matriculated here one month before the stock market crash of 1929. My father graduated 30 years later and worked as an aerospace engineer until he retired. As a humanist, I am the family oddity.

Nevertheless, Caltech was my dream job: a chance to return home, do my research with maximum resources and minimum interference, and teach bright, disciplined scientists and engineers other interesting, necessary ways of understanding and communicating about the world.

My dad gave me pause, though, when he told me the story of a fellow student—one of the smartest in his year—who politely listened to an excellent English lecture on the first day of a freshman humanities course and afterward asked: "What do I need to do in this class to get a D?"

I wondered, would my students feel that way about American literature and film? Do they? No way. Caltech students are overwhelmingly engaged and often quite enthusiastic, both with the specific content of our courses and with the process of developing new tools for analyzing and appreciating the things we study.

My most rewarding classroom experience is a two-term course in classical Hollywood film. The black and white movies we watch, with seamless continuity editing and shamelessly happy endings, are scarcely recognizable as movies to my students. Through a combination of industry history and close analysis of individual films, I get them to consider how and why movies looked the way they did then—and how and why they have changed over time.

My teaching relates closely to my research. A recent project involves an extensive analysis of daily box-office records from the Stanley-Warner theater chain, a unique dataset that is allowing me to discover more about audience choices and how film distribution and

exhibition responded to and shaped those choices in the mid-1930s.

I would never have dreamed of using the word "dataset," let alone embarking on a collaboration with an economist, if my Caltech colleagues had not given me the opportunity to learn about the methods and insights of social science history. Certainly I bring an appreciation of the qualitative aspects of audience behavior to these box-office figures; numbers can't tell us everything about phenomena. But Caltech has taught me that combining different approaches to knowledge enables a much richer picture of the human experience. In this case, it allows me to not only uncover what historical moviegoers did, but also to see, perhaps, why they made those particular choices. ◆

poetry in Amsterdam. Professor Bowerman introduced me to Professor Smith. The latter interviewed me, took into account the recent publication of my *A Definition of Tragedy* (New York University Press, 1961) and an article or two (perhaps he even read them), invited me to lunch at the Athenaeum together with Cushing Strout, a professor of history, and decided to hire me. It was a year's appointment to replace someone on leave of absence. That someone became a dean elsewhere, and as I seemed to have done no harm during that year, I was made permanent. That is approximately how Caltech—or at any rate HSS—functioned in those years.

Caltech in general, and the division in particular, remained kind to me and rewarded me as a teacher, scholar, and writer. By teaching the basics of English literature, drama from the Middle Ages to the mid 20th century, and fundamentals of the art of poetry, did I produce a generation of Caltech graduates who are cultivated scientists who read Jane Austen when not tweaking electrons or synapses, subscribe to chamber music series, and frequent art museums and theaters? We cannot know, but we do our duty by opening doors to realms of thoughts and passions neighborly to those that the sciences offer. ◆

CHRISTOPHER HUNTER

—

assistant professor of English

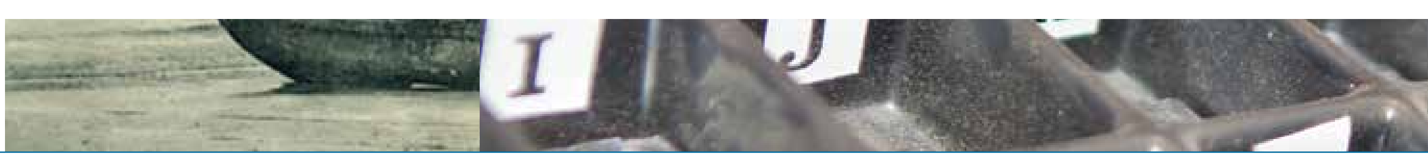
Hunter came to Caltech in 2010 as an assistant professor of English with a specialization in American literature of the 18th and 19th centuries. He is interested in how the genre of autobiography developed historically, and is preparing a book titled A New and More Perfect Edition: Reading, Editing, and Publishing Autobiography in America, 1787–1850. *Hunter has been heavily involved in the study of Benjamin Franklin's autobiography, which he describes as "the most published, read, and studied memoir of all time." Hunter is part of a team of scholars now working on a facsimile edition of the original manuscript.*

As a high school student I spent a summer at MIT taking classes in calculus, physics, chemistry, engineering, and writing. I was an aspiring astrophysicist—in fact, on a few occasions I came with the Santa Monica Amateur Astronomy Club to talks and star parties here at Caltech. In college I decided to concentrate on comparative literature instead of physics, but I returned to MIT for the next five or six years, first to tutor and later to teach the same summer writing course I myself had taken. Little did I know it was preparing me to return to Caltech! I jumped at the chance when it came, and it has been wonderful to find myself once again in front of classrooms full of STEM majors. Caltech students are brilliant and sharp-eyed, and teaching them has made me a better humanist.

My own work focuses on the history of the book, which means that I'm interested in how the physical form of books, letters, newspapers, and the like affected the meanings of the texts they contain. This approach really resonates with Caltech students, in part because it considers technical and economic questions alongside the cultural and interpretive ones they might expect from an English class.

Books are products; they are objects. In Colonial and post-Revolutionary America they were made by craftsmen and craftswomen using tools that would have been recognizable to Johannes Gutenberg, the 15th-century Mainz goldsmith who perfected printing with moveable type. The 19th-century technological innovations that transformed those trades into an industry also dramatically changed the look, availability, and price of books. These changes mattered as much to scientists as they did to writers and readers of literature. One of my goals is to teach my students to see the technical processes at work in the books we study.

That is why, as much as possible, I like to expose my students to rare books and artifacts from the time periods we study. After a few weeks of training in basic bibliography, they can go into the Caltech Archives and generate new insights about its small but extraordinary collection of rare books. Often, they work on texts by scientists they've studied in their STEM classes: people like Newton, Kepler, Galileo, and Darwin. These encounters with the history of their own disciplines should help make them better scientists by making them more aware of how knowledge is produced and how it circulates.



DEHN GILMORE

—

assistant professor of English

Gilmore specializes in 19th-century British and European literature and has a special interest in the relationship between Victorian literature and visual culture. This focus is evidenced in her first book, The Victorian Novel and the Space of Art: Fictional Form on Display *(Cambridge, 2013), and her book-in-progress,* "Large as Life": The Victorians' Disproportionate Reality, *which considers the Victorians' avid interest in the "life-sized." In 2013, Gilmore won the Nineteenth Century Studies Association Article Prize for the best article from any scholarly discipline focusing on any aspect of the 19th century. She came to Caltech in 2009.*

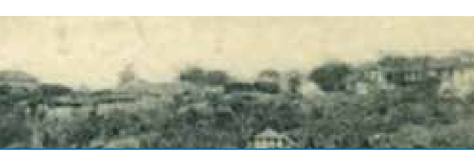
When I began teaching, I was a graduate student at Columbia University, where undergraduate students are required to undertake a rigorous "great books" curriculum. This meant that by the time they entered my literature sections, they were primed to murmur knowingly at references to Shakespeare or Herodotus, Euripides or Austen, and to make such references themselves.

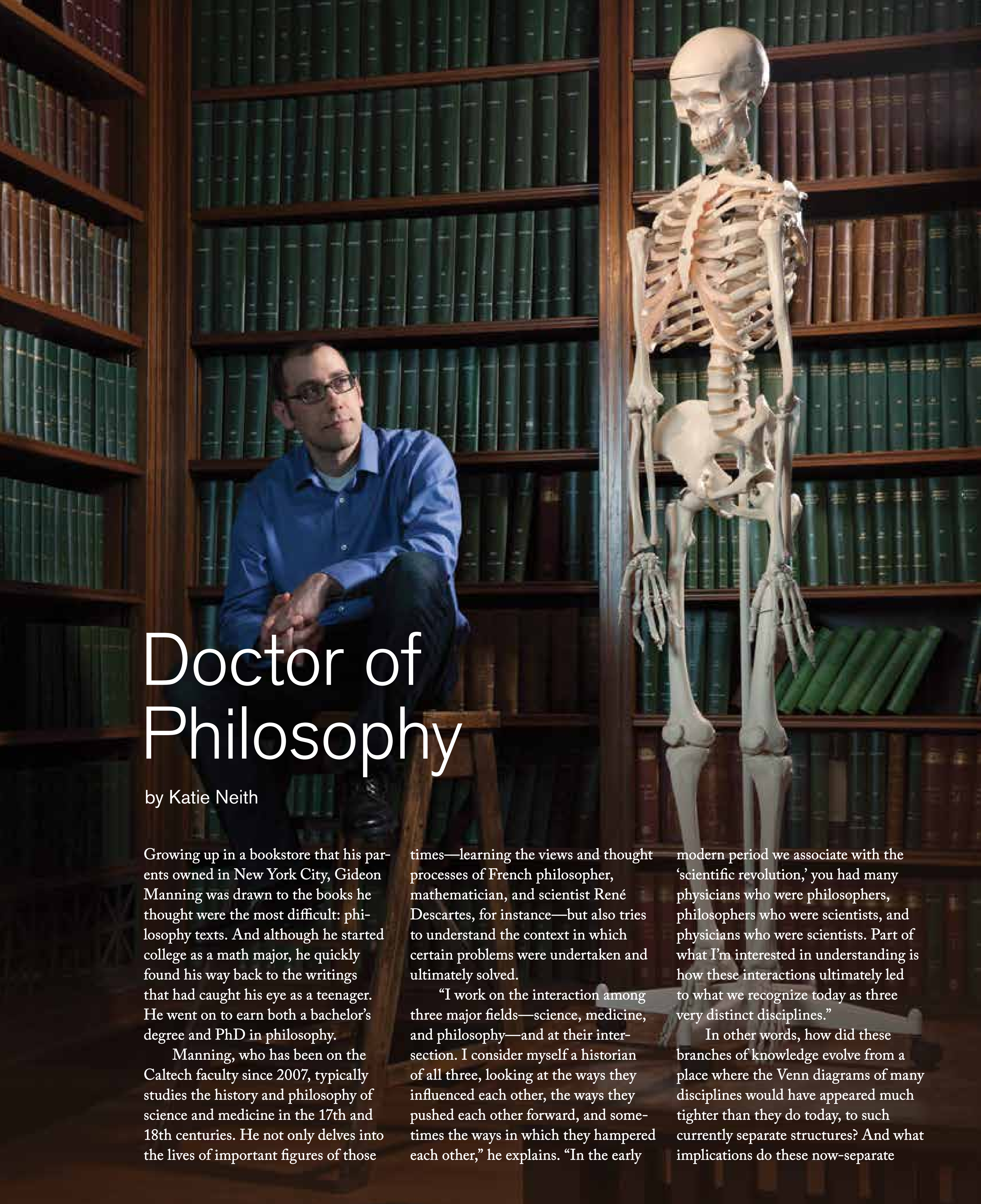
Arriving at Caltech, I rapidly discovered that my new students' knowledge base was entirely—and, in retrospect, unsurprisingly—different. Their most rigorous preparation had usually been scientific and mathematical, so it no longer helped to compare a particular poem to an Elizabethan sonnet, or to say that a novel had been inflected by the author's reading of Greek tragedies. Though from the outset I appreciated Caltech students' intense concentration and focus, I initially had difficulty figuring out how to build a web of context and recognition for them. In time, however, I came to appreciate a wholly new set of avenues along which to make connections, and from which I have learned a great deal myself.

It may have been the memorable day when a discussion of Yeats's poem "Sailing to Byzantium" turned from consideration of themes of aging and poetic immortality to heated talk of automata, and whether one could in fact make a nightingale "of hammered gold and gold enamelling / To keep a drowsy Emperor awake." Or it may have been the time a student knocked on my door to shyly admit that he had been trying to work out how Dickens's complicated multiplot novels would work as computer programs. But regardless of exactly when it happened, at some point the works studied in all my classes—often works I had taught many times before, or even written about—started to seem newly alive to me, full of new dimensions, dynamics, and correspondences.

The results of these teaching experiences have become embedded in my syllabi. My class on major British authors has migrated, over time, into a survey of "the scientific imagination" from Marlowe to McEwan, with stops along the way for writers like Darwin and books like *Frankenstein*. And my 19th-century classes now *always* include Sherlock Holmes, whom my students all invariably know better than I do myself.

I have come to appreciate and to value highly my students' affinities with the great detective of Baker Street—their insatiable curiosity and mastery of what to the outsider can seem like arcane knowledge, and their restless determination to crack the case and to nose out all the clues they can along the way. With the classroom as mystery space and the game afoot we plunge on together. e&s





Doctor of Philosophy

by Katie Neith

Growing up in a bookstore that his parents owned in New York City, Gideon Manning was drawn to the books he thought were the most difficult: philosophy texts. And although he started college as a math major, he quickly found his way back to the writings that had caught his eye as a teenager. He went on to earn both a bachelor's degree and PhD in philosophy.

Manning, who has been on the Caltech faculty since 2007, typically studies the history and philosophy of science and medicine in the 17th and 18th centuries. He not only delves into the lives of important figures of those times—learning the views and thought processes of French philosopher, mathematician, and scientist René Descartes, for instance—but also tries to understand the context in which certain problems were undertaken and ultimately solved.

"I work on the interaction among three major fields—science, medicine, and philosophy—and at their intersection. I consider myself a historian of all three, looking at the ways they influenced each other, the ways they pushed each other forward, and sometimes the ways in which they hampered each other," he explains. "In the early modern period we associate with the 'scientific revolution,' you had many physicians who were philosophers, philosophers who were scientists, and physicians who were scientists. Part of what I'm interested in understanding is how these interactions ultimately led to what we recognize today as three very distinct disciplines."

In other words, how did these branches of knowledge evolve from a place where the Venn diagrams of many disciplines would have appeared much tighter than they do today, to such currently separate structures? And what implications do these now-separate structures have for those who work and study in these spaces today?

By the time Manning had arrived at Caltech, shortly after defending his dissertation at the University of Chicago, his work had already started to push beyond the traditional boundaries that many philosophy departments set. He says that Caltech felt particularly suited to him because "it seemed to promote and be willing to encourage that kind of flexibility in my thinking and my work."

Now, to build on his historical knowledge of medicine by steeping himself in present-day information, he's setting out on a new journey beyond critical thinking to spend a year in medical school. With the help of a New Directions Fellowship from the Mellon Foundation, he is studying at the Keck School of Medicine of USC, where he started classes in August.

"One of the really great features of this fellowship is that, in the humanities, there are not that many opportunities to get support to learn something new, let alone funding to attend medical school," says Manning. "The Mellon fellowship is unique in that it's an investment in me as a scholar, and shows the Mellon Foundation's understanding that my research will benefit from my learning more technical details about biomedical science than I otherwise would be able to do."

"My research will benefit from my learning more technical details about biomedical science than I otherwise would be able to do."

To learn the skills needed to do research in medicine—and therefore better understand the challenges that physicians and scientists faced in the past—he has enrolled as a first-year medical student and will study everything from gross anatomy to genetics.

"You can read the old medical texts and they offer these magnificent descriptions, but the organ, or bone, or system may have had a different name at the time that doesn't correlate to present day medical terminology," Manning says. "You need to know what it is they're describing; otherwise you can't know what they're talking about. Learning just gross anatomy will help me connect these dots."

For example, he says that it's easy for someone with zero anatomical knowledge to read medical literature from the 17th century that says something like "the knee bone is connected to the ankle bone" and just assume that it's correct. So among his goals for the school year are to get a better sense of how the body looks to an anatomist, to learn the core concepts of health and disease in human beings, and to understand how medical practice navigates its competing interests in maintaining health and increasing longevity. Then he will turn his attention back to exploring how medicine, science, and philosophy interacted with one another in the early modern period with a better understanding of the specific challenges that contemporary physicians face when they interact with the body and try to achieve certain results.

"You can emphasize the value of history by realizing that it brings out contrasts with today's way of doing things, and those contrasts may show you the good reasons for a practice being the way it is, or show that it doesn't have to be that way," says Manning. "It's worth reflecting on—medicine has not always been this self-standing discipline. It was an achievement for medicine to become what it is today, just as it was for physics or biology. Coming to understand that achievement is a way of understanding where we are now."

In addition to gathering information that will help him better understand the history of medicine, Manning sees the basic science underlying biology as one of the real routes to aiding medical practice—something he hopes to study further after his time at the Keck School.

"If you think of medicine as securing and preserving health, or providing health to people when they lose it, one of the really exciting things to explore for the future is how basic science may help manipulate and intervene in living things to promote the goals of medicine," he says.

To equip himself for medical school, Manning has spent some recent time relearning foundational disciplines that will be important for his studies: kinematics, physics, statistics.

"Caltech is a great place to do this kind of prep work because whenever I have a question there is always somebody I can call," he says. "Not only do they really encourage thinking outside of the traditional confines of the discipline in which you are initially trained, but because we're in such close proximity to one another, I've had the opportunity to interact with exceptionally gifted people who work in other fields and can help me answer my questions."

When Manning isn't prepping to make the jump from professor to med school student, he's also active in a group he helped found four years ago, the Early Modern Circle. With the support of the Division of the Humanities and Social Sciences, the group brings together graduate students and more established scholars throughout Southern California to discuss the history of philosophy and encourage each other's work.

"Even as my research has progressed beyond the traditional confines of what many people think philosophers do, I've remained interested in the relationship between mind and body, how it is that we talk about consciousness, what's distinctive about human beings, what's in the world and how do we know it—those questions still interest me," says Manning. "But it will be great fun to take some time to learn what it really is that connects the knee bone to the ankle bone." e&s

Gideon Manning is an assistant professor of philosophy.

Tracing the Path of Corruption

by Jessica Stoller-Conrad

When economic anthropologist Jean Ensminger started her research in a rural African village in 1978, she couldn't have anticipated the surprising turn her work would take three decades later.

Ensminger—who is interested in the impediments to development that stem from poor governance and weak economic institutions—began her work by studying society from the bottom up among the Orma people in Kenya. This work involved several decades of quantitative data gathering on the economic fortunes and actions of the same households as they reacted to changes in their political economy and as they gradually engaged more with national political institutions and the global market.

Some years after her arrival at Caltech in 2000, a seemingly benign goat-restocking project in the area where Ensminger conducts her studies ultimately caused an unanticipated shift in her research. She was not then aware that the microproject was under the umbrella of a large $230 million World Bank project funding thousands of similar microprojects in villages over most of Kenya.

"This local project was small enough that it was not particularly on my radar, but I kept hearing from villagers that it was causing a lot of conflict because it was riddled with corruption," she says.

Based upon prodding from villagers, Ensminger decided to dig further. Fortuitously, she had just completed her once per decade survey of the local population. Armed with several decades' worth of socioeconomic data on the same people, she was able to link people's positions in the socioeconomic hierarchy, including their social network position, to the benefits received as a result of corruption in the project.

"I never set out to study corruption, but I recognized this as a quite rare opportunity to gather actual payoff data at the individual level and link it with 30 years of economic and demographic data on the same individuals," she says.

Still, Ensminger did not perceive this small research effort as a career-changing move. "I was at the time deeply involved in co-administering a collaborative project running economic experiments around the world in small-scale societies. When I wrote that first paper on corruption I saw it as a one-off exercise," she says.

But then something rather dramatic happened: Within three weeks of presenting the paper to the research department of the World Bank, the operations staff running the large funding project sent a convoy of six vehicles out to the village where Ensminger had reported corruption. Says Ensminger, "There were many aspects of that 'investigation' that were highly irregular, not the least of which was the fact that the people that the World Bank in Washington sent to do the investigation were potentially implicated."

Ensminger traveled back to Kenya to assess the situation and quickly deduced that it was worth asking whether the corruption she had observed in this one microproject was representative of similar problems elsewhere in the larger World Bank project. The drama of the World Bank's reaction to her research led her to wonder if where there was smoke, there was fire, she says.

> "Along the way, I conducted more than 1,000 interviews on corruption in the larger World Bank project."

"I began to reorient the course of my future research, though for several years my time was divided as I wrapped up the cross-cultural experimental project," says Ensminger. "Along the way, I conducted more than 1,000 interviews on corruption in the larger World Bank project, talking to project staff, village beneficiaries, World Bank staff in Washington, and prominent Kenyan members of civil society, human-rights groups, and Parliament."

Her goal was to understand the extent of the corruption—in a project that spans over 75 percent of Kenya and ran for 17 years—by getting to the root of how it all worked, including how project funds were siphoned off for use in election campaigns and for personal consumption. As Ensminger says, "It became a classic 'follow the money' exercise, but in the process, I learned a lot about the aid business, and the incentives that explain why these problems persist.

"It is no surprise to most people that there is a lot of corruption in aid funds, but just what order of magnitude and what types of aid are most at risk is important to understand," she says. Toward this end, Ensminger is currently working to develop a quantitative method of detecting fraud in aid data.

"Faking numbers that resemble true distributions is actually quite difficult for people, and there are digit analysis techniques that we can use to detect such fraud," she says.

In collaboration with Caltech undergraduate Jetson Leder-Luis (pictured with Ensminger on the previous page), a double major in economics and applied math who graduated in 2014, Ensminger adapted and developed approximately one dozen statistical tests used to detect fraud in the reported data of the World Bank project. At the same time, the World Bank was conducting its own forensic audit of the Kenyan aid program. The results of their two-year investigation concluded that 66 percent of the thousands of financial transactions they analyzed were suspected of being fraudulent or were questionable.

"What we demonstrate from the results of our method is that they match fairly well with those of the forensic audit," says Ensminger, who is continuing to refine her tests. "That is good for aid, because those who wish to monitor problems in real time, and from anywhere in the world, now have a method for doing so that is more timely and cost-effective than a full-blown forensic audit. Donors should be able to identify risky areas more quickly and respond to stem the damage."

A research agenda focused upon corruption isn't what she set off to study as a young anthropologist 30 years ago, but Ensminger says research is always about adapting to the unexpected twists, turns, and opportunities that present themselves.

"The most rewarding thing about this particular turn in my research is that the people of Kenya—from the village where I have lived for over 30 years, to the leaders of civil society in Nairobi—are more engaged with this aspect of my research than anything else I have done," she says. "We are learning together about the who, what, when, where, and how of corruption, and that collaboration is the most satisfying of my career to date."

Jean Ensminger is the Edie and Lew Wasserman Professor of Social Sciences.

At the Intersection of Art and Science

by Andrew Allan

As a teenager, Christa Robbins began her college career intent on becoming a painter. But after a few years toiling in oils on canvas and earning her bachelor of fine arts degree in painting and printmaking, she realized she was more interested in studying art than in making it. So Robbins left the studio behind to become an art historian—a rare transition for someone in her shoes. "I made the conscious decision to stop making art," she says.

Three years later, she landed at the University of Chicago, studying under art and media theorist W. J. T. Mitchell; she focused on modern abstract painting and criticism and earned her PhD in 2010. After teaching appointments at the University of Illinois, Chicago; Cornell College; and Texas Christian University, Robbins came to Caltech in 2013 as the Mellon Caltech-Huntington Postdoctoral Instructor in Art History, a position created by John Brewer, Caltech's Eli and Edye Broad Professor of Humanities and Social Sciences and professor of history and literature.

Even though she says she "fits in by not fitting in" at Caltech, the flexibility and freedom that the Institute gives its researchers, as well as the region's cultural resources, were a real draw for Robbins.

Her research focuses mainly on 20th-century abstract painting, but, according to Robbins, she doesn't just write about paintings and provide a biographical account of what an artist does and how he or she goes about making objects.

"My work distinguishes itself by focusing on the art object as rhetorical—an object that's capable of making arguments and intervening in theoretical, philosophical, and political discourse," she notes. "I think of the objects as discursive, meaning they intervene in conversations and thinking processes that are unfolding around them."

For example, Robbins is currently working on a book that deals with how midcentury—late 1940s to mid 1970s—American paintings offer arguments about the definition of self and how that definition figures into legal, psychological, and philosophical contexts.

"I write about painting in the postwar period because it was the dominant art form at that time—it's what a work of art was for the majority of people," she says. "As such, it is where important arguments were made in the cultural sphere that were simultaneously being made in the social sphere."

She translates her research not only into the written word, but also into her teaching practices at Caltech. During the last academic year, she taught three courses: an introduction to modern art, a survey of West Coast art since the 1960s, and an exploration of collaborations between artists and scientists from the 1960s to the present.

> "My work is inspired by trying to figure out how we can make science more accessible to a larger body so that people can make better informed decisions when it comes to dealing with scientific issues."

"I like to look at artists and scholars who have attempted to do something where these two disciplines—art and science—are brought together," she says. "My work is inspired by trying to figure out how we can make science more accessible to a larger body so that people can make better informed decisions when it comes to dealing with scientific issues, like genetically modified foods, vaccines—items you see in the news all the time."

So she uses her time in the classroom to expose a new generation of students to artists working at the intersection of science and art, shining a light on people like Steve Kurtz, one of the founders of the Critical Art Ensemble (CAE), an artist-activist group concerned with corporate and state uses of the sciences.

"The CAE wants to put knowledge in people's hands," says Robbins. "They want to mitigate the lack of conversation that we have in the public about legislation or corporate decisions that direct where research goes, or how science enters our lives. That was at the heart of my wanting to do the collaborations class."

Robbins adds that she feels strongly that those creating advances in technology need to be responsible to the public, especially because scientific and technological research is trending toward privatization. To that end, she explores topics—both in her research and in the classroom—that include data sharing, data use, and "hacktivism," or artists who take a more activist stance in relation to the sciences.

"I am interested in contemporary art that claims to be participatory or relational—works that are research based and are more about an artist going out into a community and enacting some sort of program or some research project that results not in an object, but rather in a situation or an experience," says Robbins.

In her collaborations class, she and her students discuss artists such as Eduardo Kac, who performs his own genetic experiments in a creative manner and brings conversation about genetic manipulation to the public in a new way, she says. They end the quarter on the topic of electronic disturbance, looking at artists who actively intervene in scientific practice for political and cultural reasons.

Exposing Caltech students to such topics is of critical importance to Robbins because she wants to see future scientists effectively navigate their cultural and social worlds.

"If you don't have access to all the disciplines that shape our world, then you can't be an active citizen," she says. "The conversations we're having in my classes are very much about not just whether science can talk across disciplines, but what its obligation is to a larger public. A lot of the artists we talk about try not to take a stance on what science should do, but rather take a stance on how scientists should speak to us about what they're doing." e&s

Christa Robbins is the Mellon Caltech-Huntington Postdoctoral Instructor in Art History. Her book on midcentury American paintings and the definition of self is slated to be published in 2015.

Talking the Talk

by Katie Neith

When you consider the transformation of modern human beings over the past 250,000 years, it is clear that both biological evolution and human invention have contributed to our ongoing development as a species. The use of complex language is, of course, a key skill that sets us apart from other animals, and one that many scientists believe is primarily a product of natural selection. But Caltech professor Fiona Cowie, who studies evolutionary biology and linguistics through the lens of philosophy, believes that language is a tool that was originally a product of human ingenuity.

"My approach is different from that of almost everyone else who works on the evolution of language, the majority of whom think that language arose initially through mutation and natural selection," she explains. "And you can see how, if language arose in a species, it would be favored by natural selection because it's really useful. But you can only have selection for language once people are using it. So I tend to view language more as an invention, or technological advance, rather than as if it were some extra limb that grew as a result of selection on genetic mutations."

To support her unconventional theory, Cowie is working to figure out what happened in our lineage after humans split off from the other great apes around seven million years ago. What gives us the capacity for the kinds of language skills we have that others do not?

"I consider myself to be a big-picture philosopher, one who tries to take a whole bunch of information that doesn't seem to make sense or add up, and synthesizes it into a broader view of something," she says.

Her case for language as a human invention rests on the concept of imitation. Early humans were living in groups, more or less just like our closest relatives, the chimps. But while chimps spend a lot of time on their mothers' backs, human infants spend a lot of time face-to-face with their mothers. In addition, human babies have much longer periods of helplessness during which they are literally looking to their parents for aid and information, Cowie says.

"There is evidence that imitation is actually a learned skill," explains Cowie. "Many people have thought that it's inborn, but if it's learned, then those years of face-to-face contact with the mother would be really crucial, because a prolonged period of imitating facial and body expressions in humans would set the ground for the idea of using symbols to represent things, which is one of the fundamental features of language. If you can imitate another individual, then that serves as a way of bringing that person to mind."

For example, if someone has a funny walk, and you do the funny walk, then other people around you will start thinking of the person you are imitating. And that's exactly what a name does: it brings to mind a specific person. So babies who imitate their mothers become adults who can bring their mothers to life in other peoples' minds by using a symbol to represent

"If you can imitate another individual, then that serves as a way of bringing that person to mind."

or name a thing, which is the essence of language.

But there's more to it. After all, vervet monkeys have certain calls for particular predators, and dolphins have signature whistles that we could equate to names, and surely many other animals communicate. What makes us unique in the animal kingdom is the fact that we are able to go beyond these simple naming tools.

"The ability to introduce new words to name new things is really what distinguishes human language from the symbol systems of other animals," says Cowie. "That is the really critical innovation that we came up with."

Which brings us back to imitation. Once humans learned to imitate each other and perhaps use mimicry to name each other, the new "technology" took off, Cowie believes. People began to deliberately invent new symbols to communicate.

"You can imagine that once they have this idea that they can name things, they will start imitating sounds, like thunder, a hyena's laugh, whatever," she says. "The imitations using sound become more and more abstract until they are more like words, which don't imitate anything at all, and a language is born."

Cowie, who grew up and did her undergraduate studies in Australia, first came to Caltech in 1992 after receiving a PhD in philosophy of science from Princeton. At the time, she says, Caltech was not known to be a school with philosophical interests, which put her on the ground floor for helping to build a philosophy of science group.

"Now, for history and philosophy of science, Caltech is a fabulous place to be," she continues. "It's very supportive of whatever research you do. You can do what you like here."

What Cowie has done over the past 20-plus years is explore philosophical ideas about language: how we as individuals learn it, and where we as a species got it. Today, as she works on a new book on the evolution of language, she spends a lot of time taking long drives—it is, she says, her method for synthesizing the information she's gathered into an original argument before sitting down to write, which she calls "the hardest part of my work."

"I have a story in my head, but as I write things down, I need evidence to support every statement," says Cowie. "There are always disagreements in any branch of science, and my research is no different. The writing keeps ballooning out underneath. You want to say one simple thing, but then behind that thing is an entire scientific debate."

"What I like about the picture of language that I've developed—language as a discovery or invention—is that you can then understand it as a massive and transformative cognitive technology, which makes it appropriate for Caltech," says Cowie. "When people say, 'Obviously language had to be a product of mutation and natural selection,' or, 'We're too dumb to figure it out for ourselves,' I compare that to the idea of people 30,000 years in the future looking at the Internet and thinking, 'Oh my gosh, a huge cognitive transformation happened because of the Internet. There must have been some massive evolutionary breakthrough that enabled people to type.' I just don't see evidence that that's the case—now or in the past." e&s

Fiona Cowie is a professor of philosophy. In addition to her current book in progress, she is the author of What's Within? Nativism Reconsidered, *which won the Gustave O. Arlt Award in the Humanities in 1999.*

Factoring in Behavior

by Jessica Stoller-Conrad

New medicines may seem to pop up overnight on pharmacy shelves, but the drugs that make it to market have actually gone through a long period of testing. Today, one of the most important steps in this process—the gold standard for testing the efficacy of a treatment—is the randomized controlled trial, or RCT. By *randomly* assigning eligible patients to either an experimental group that receives the drug or a control group that doesn't, researchers try to factor out some of the variables that differ among patients—and glean more accurate information about the actual effects of the drug. But the effects of human behavior can still seep into the results of such trials, says Caltech economist Erik Snowberg.

Snowberg, who first came to Caltech in 2008, is interested in understanding how economic theory can be used to understand human behavior outside the realms traditionally considered by economics. When he arrived at Caltech his research focused on using economic models to predict political behavior, but more recently—along with his collaborator, Sylvain Chassang of Princeton—he has focused on the challenge of using the economic view of behavior to improve the randomized controlled trials commonly used in medicine and public health.

"Over the years, people have come up with different methods to remove bias in clinical trials—biases caused by people's behavior in the trial," he says. Randomization was one such method, first implemented to eliminate differences between patients who receive the experimental treatment and those in the control group—that is, those who do not receive treatment. However, as

RCTs have evolved, they've developed issues of their own, Snowberg says. For example, some patients who end up in the control group may really want the treatment and may subvert the experimental protocol to get it.

"We thought that, rather than trying to eliminate the effects of behavior, it would be better to understand these effects—so that we can harness them to develop better therapies," he says.

To do that, Snowberg and collaborators have developed experimental designs that identify motivated patients, while also randomizing their treatment status. They reason that if the test group of patients is motivated and interested in participating, they will more likely follow the instructions. This will ultimately give doctors a better idea of exactly how well a drug works when taken as recommended, and how well it works when a patient's behavior does not conform to the experimenter's desires.

"A randomized controlled trial is like a lottery; in a trial, you might have a 33 percent chance of getting treatment," Snowberg explains. "But what if there is a patient who really believes in the trial and is really motivated to follow through with the treatment regimen? What if they can get what is essentially an extra lottery ticket?"

In one example of their innovative trial designs, every such "ticket" is drawn at a rate of one out of three. However, patients are given the opportunity to earn another ticket and thus identify themselves as motivated to complete the treatment—even through negative side effects. They might earn this ticket through spending their time in a boring and tedious task, or through a cash payment, but as long as the patients are selected to receive treatments through a lottery, the trial is still randomized.

Snowberg believes this type of design could yield more precise information than more traditional RCTs, regarding the efficacy of a properly used treatment. For example, if the treatment only works for people who earned an extra ticket, it indicates that they believe in the treatment, and this caused them to behave in a way conducive to the therapy, he says.

> "If a community is given a pump, but most of the people don't believe that using the pump will keep them from getting sick, a majority won't use it—and they'll continue to get sick."

Although the "earning" aspect of this selection process may seem controversial for trials involving a last-hope treatment for a terminal illness, Snowberg says that it's important to realize the design is not one-size-fits-all—and RCTs are used for all sorts of experimental trials, many outside of medicine. For example, the researchers are also hoping to learn more about human behavior in experimental trials involving the adoption of a new technology—an improved water pump for agriculture in Africa.

"Right after college, a friend of mine joined the Peace Corps, and her job was to help prevent dysentery outbreaks by convincing people to drink water from a safe, clean water pump rather than from an often-contaminated open well. But she was frustrated because no one wanted to drink from the pump," Snowberg says.

Interested in the situation, Snowberg visited his friend in Mali.

"I thought it was weird that an organization just came and installed the pump without making sure anyone in the community wanted or would use it," he says.

By distributing water pumps to anyone, whether or not they believe the pumps will be beneficial, "you're giving people the opportunity to reinforce their prior beliefs about what is or isn't going to be effective," he says. "If a community is given a pump, but most of the people don't believe that using the pump will keep them from getting sick, a majority won't use it—and they'll continue to get sick. Before, they believed the pump would be ineffective, and now they have evidence, 'See, everybody is just as sick now as they were before,'" he says.

To see if a new type of trial design could help organizations better allocate resources to where they will do the most good, Snowberg and his collaborators are now testing several of their trial designs using agricultural water pumps in Kenya. In this ongoing study, at least one person in every village in the study area will get a pump, but how that person is chosen will change from village to village. In some villages, the pump will be distributed in the traditional way—randomly. But in others, villagers will have the option to earn another ticket by weeding a field in a neighboring village, or even to receive extra tickets from their neighbors—a form of voting the researchers hope will allow the village to identify who they think would be the best person to experiment with this new technology.

The researchers will then follow up with each village to see if the residents of those villages where a pump was given to someone who earned an extra ticket have more favorable opinions of the pump. The researchers hope that the results from this study will enable more effective distribution models for aid organizations.

Snowberg says that almost anything evaluated using a randomized controlled trial is probably also affected by behavior. "There may be differences in behavior based on culture, but economics, and our research, is focused on identifying the behavior that is common to all of us," he says. e&s

Erik Snowberg is professor of economics and political science at Caltech. His work on the design of clinical trials is supported by the National Science Foundation and Caltech.

Valuable Decisions

by Kimm Fesenmaier

You've just finished eating a healthy, balanced meal and are now faced with two dessert options: a slice of ooey, gooey chocolate cake or a nutritious fruit cup. After considering your choices, and with a bit of a sigh, you reach for the fruit cup.

It's not the most exciting decision you will ever make—you make many like it every day. Still, your brain received sensory information and, after a bit, you acted on it. But what happened in between? What transpired in your brain before you actually picked up the more healthful option?

That mysterious in-between is the focus of a fledgling field known as neuroeconomics, or decision neuroscience. Neuroeconomists recognize that while decision making is complex and a bit messy, it is also so central to our daily lives that a better understanding could greatly enhance our grasp of human nature.

Neuroeconomists contend that, when weighing the value or worth of various choices, people do not always behave as standard economic theories would suggest. Rather than always acting rationally and in their own best interests, people can be unduly influenced by emotions, unusual experiences, and automatic reflexes, which can lead to poor choices. For that reason, neuroeconomists say it's time to begin using the most advanced tools for analyzing the biological response to choice in order to update our models of decision making.

The field got its start—at least in part—at Caltech, growing out of the discipline of behavioral economics as researchers like Colin Camerer began to wonder if they could dig deeper and try to update economic theory using not only psychology and sociology to inform its economic models but the actual workings of the human brain. Today, a little over a decade after this new approach began to be pursued on campus, a core group of researchers, including Camerer, Ralph Adolphs, John O'Doherty, and Antonio Rangel, is approaching the question of decision making from many angles, using experimental economics and studies of the brain to peer into that ultimate of black boxes to see what truly happens when you select the fruit cup—or double down on a bet or opt to buy shares of a particular stock.

"Caltech has been at the forefront of creating this new field," says Jonathan Katz, Caltech's Kay Sugahara Professor of Social Sciences and Statistics and the former chair of the Division of the Humanities and Social Sciences (HSS). Part of the reason is Caltech's size and concentration of specialties, he says. "Caltech is unique in that it's the only place where under one roof, in one department, there are both card-carrying neuroscientists and card-carrying social scientists interested in neuroscience." But beyond that, he says, is the fact that HSS has always been successful at seeking out interesting fields that need a bit of intellectual trailblazing. "We've always chosen areas that sort of fall between disciplinary cracks and that are a bit risky," Katz says. "Neuroeconomics is the latest incarnation of that."

"It's quite a radical combination of methods," agrees Camerer. "Our view is that anything which we, as economists, used to just infer—like whether people think something is going to happen in the future or how much they value something—we should try to measure biologically."

That is a radical viewpoint in light of the fact that, for most of the last 100 years, standard economics has held that the choices we make provide all the information needed to understand how much we value something. So although economists spend a lot of time building formal models of how they think economic decision making happens, the only variable they typically use is the choices that people make. Neuroeconomists, on the other hand, consider what actually happens in the brain when we make those choices.

O'Doherty, whose background is in psychology and mathematics, explains the differences between the two methodologies by comparing the decision-making brain to an electrical generator that runs on water. Water goes into the generator, something happens inside, and electricity comes out. You could look at what comes out at the end—the electricity—in order to try to understand how the generator works, he says. But that's not going to cut it if you want to understand exactly what's going on inside the generator, so that you can predict why it keeps breaking down.

Similarly, simply looking at the economic choices people make will give you an overview of their preferences. But it doesn't help you understand exactly how the brain generates those choices. It is necessary to know this if you want to have an accurate model of how people make decisions, which among other things you could then use to make predictions about when people might be vulnerable to making poor or suboptimal decisions. The neuroeconomics approach, then, is akin to actually opening up the generator, looking inside, and seeing the different components that are transforming the water into electricity.

"In decision neuroscience," says O'Doherty, "we start with a model of what we think might be happening during decision making. Then, using techniques like neuroimaging and electrophysiology, we find out what the neural circuits are actually doing as they transform information and generate decisions. That allows us to compare and contrast different models and to find out which model is the best predictor of actual behavior."

That last bit about using and testing models is known as a computational approach—or, as Camerer refers to it, the Caltech group's "secret sauce." It's what sets true neuroeconomics apart from other types of neuroscientific work in which researchers simply try to figure out which areas of the brain are active, or "light up," during a particular task. Instead, neuroeconomists aim to produce and/or test mathematical models that represent how the brain assesses components of value, such as temptation, risk, and social consequences, and integrates them in order to produce decisions. Then they work to make sure that these models jive with the behavioral data—the records of what people actually *do*—and with the brain's actual activity, as measured through imaging and other techniques.

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For example, Camerer has conducted several studies looking at the choices people make when risk is involved. In these studies, subjects might lie in a functional Magnetic Resonance Imaging (fMRI) machine that measures the blood flow in their brains as they are offered a risky choice, such as buying a lottery ticket, which has a varying chance of paying off different amounts of money. (In fMRI, blood flow is a proxy for neural activation; the more blood, and therefore oxygen, in a particular part of the brain, the more active it is. An area that is active likely plays a role in whatever decision is being made.)

The model Camerer has developed for this set of decisions suggests that people compute values for the rewards that they believe they are likely to receive if they take a financial risk and also if they do nothing. Then they compare the two and choose the option that yields the highest value. In the risky case, the model says that people multiply the value of possible outcomes by the likelihood of those outcomes to arrive at an overall valuation.

Over the course of a study, it might become clear that one participant doesn't value high payoffs enough to compensate for the high risk involved in betting on those low likelihood outcomes. Another might be putting too large a value on a huge payoff given the low chance of winning the jackpot. Camerer and his colleagues look through the fMRI data to see if they can identify one or more brain regions that are "encoding" these different values, meaning that neurons in those areas are activated to an extent that is proportional to the values that the individuals are assigning. And with risk-taking, the areas the researchers have pinpointed are the striatum and the insula.

Camerer emphasizes that fMRI is just one of many tools the Caltech team uses to investigate the biology of decision making. They also use EEGs, single-neuron recordings, studies of brain-lesion patients, and skin-conductance and eye-tracking tests. "Every method is fantastic in some way and weak in some other way," Camerer says. "So we basically use whatever tool is best. That often means combining techniques so the strength of one compensates for the weakness of another."

The Making of a Decision

Camerer's most recent work focuses on financial bubble markets—markets in which prices rise well beyond the intrinsic value of the assets in question. The American housing bubble that ultimately caused the recent Great Recession is an example of such a market. By creating experimental markets in the lab—where value, risks, and the number of trading sessions can be controlled and known—Camerer and his colleagues have been able to track the development of bubble markets.

What they found was that the highest earners in such markets were the participants who sold shares while prices were still on the rise. Looking at the behavioral data, the researchers formulated a model that suggested that some kind of brain activity must have prompted these high earners to sell even though the market had not yet peaked. By scanning the brains of some of the participants during the experiment, the researchers were able to see that, several periods before prices reached a peak, the high earners indeed had high levels of activity in the insula, which is associated with negative bodily sensations such as being choked, as well as with social uncertainty and exclusion. For high earners, the insula was serving as a kind of early warning signal, making the high earners feel nervous and uncomfortable and thus causing them to sell off their shares. Meanwhile, the low earners—whose brains showed no signs of increased insula activity—ended up buying shares when prices were far too high, and thus got stuck with shares that were no longer valuable once the bubble burst.

In reflecting on the findings of the study, which was published in July in the journal *Proceedings of the National Academy of Sciences*, Camerer says he and his coauthors were reminded of an unconventional bit of advice once offered by investment guru Warren Buffett to "be fearful when others are greedy and greedy only when others are fearful."

"If you could replace 'fearful' with 'nervous,' his advice would match closely what we see in the brains of successful traders," Camerer says. "This is a case where the brain imaging tells us something very close to what we think is unconventional wisdom in the stock market. These high earners bought early, timed the market a little bit, and sold into a rising market. That's a hard thing to do, and they did it because this warning signal in their brains told them to do it."

Back to Basics

Despite the findings of these kinds of complex economic studies, we still know very little about what happens in the brain when we make even the most basic kinds of decisions. That's why many decision neuroscientists, like Rangel, are focusing on the basics.

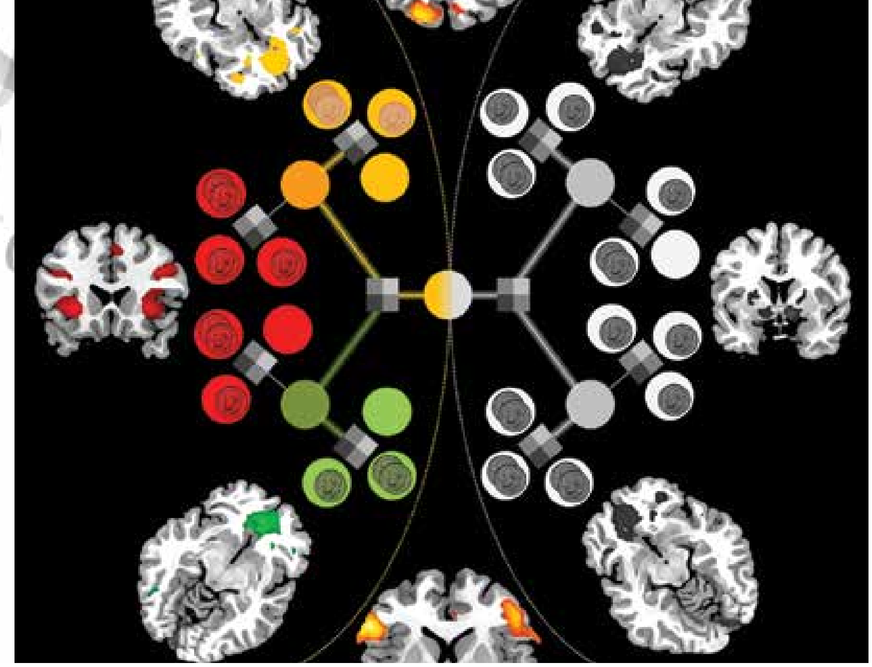
"I'm interested in the simplest type of decision that we can study in the laboratory in a precise way," says Rangel. "Our goal is to understand *exactly* what variables are computed in the brain from the moment you notice that you have a very simple choice—for example, between an apple and an orange—to the moment you actually move your hand to implement the choice. What are the computational models that best describe this process? I want to understand that in exquisite detail."

Some of those details are starting to become clear. Through fMRI and EEG studies—as well as single-neuron recordings of epileptic patients—Rangel's group has found that a region of the brain called the ventral medial prefrontal cortex (vmPFC), which sits about an inch behind the midbrow, assigns a value to each of the choices available at the time of decision, indicating how attractive your options are. The higher the value the brain assigns to a particular choice, the more often a group of neurons in the vmPFC will fire when you evaluate that choice, and thus the more likely it is that you will select it.

Rangel began his career as a classical economist—he was an assistant professor of economics at Stanford University when he took his first steps toward neuroeconomics. At the time, he was working on a project to try to come up with the optimal public policy toward addictive substances, including how the substances should be regulated or taxed, how addicts should be treated, and whether public-health campaigns should be implemented. Part way through the project he realized that if he was to find the best solution he needed to know more about how addicts decide to continue using drugs. Looking for answers, he turned to psychology and neuroscience.

The standard view in economics had been what's called rational addiction. It says that as long as people are capable of understanding the possible consequences of drug use, addiction can be perfectly rational. This is very much in line with the thinking that humans make rational decisions, seeking out information and doing what's in their own best interest at all times. "But this is highly inconsistent with what we now know about how the brain is affected by addictive substances and how they impair decision making," Rangel says. After researching the neural basis of addiction, he and a colleague published an influential paper that argued that drug use can be rational but is often a mistake based on a malfunction of the brain's decision-making circuitry.

Today, Rangel is a neuroscientist, and much of his work focuses on the seemingly simple realm of food choice. In one study, his group showed self-reported dieters photos of 50 foods ranging from cauliflower to Snickers



bars. The subjects were first asked to rate the foods in terms of how tasty they thought they would be and, separately, how healthful they considered the foods to be. Using those ratings, the researchers then pinpointed one food for each subject that that subject had ranked in the middle of the pack on both scales. The subjects were then put into an fMRI scanner and shown all of the foods again, answering this time whether they would rather eat their middle-of-the-pack food versus each of the other items. The researchers found that the dieters fell into two groups—those who chose mostly healthy foods over their middle-of-the-pack food were deemed "healthy eaters" based on their higher level of dietary self-control; those who made unhealthy decisions were "unhealthy eaters."

The researchers found that the brains of the healthy and unhealthy eaters differed in a significant way at the time of decision: although in all of the subjects the vmPFC encoded a value signal that seemed to guide their food choices, the healthy eaters had additional activity in a part of the brain called the dorsolateral prefrontal cortex (dlPFC), which adds to the basic value signal in the vmPFC, allowing it to take into account more abstract attributes, such as long-term health. The model that Rangel and his team created to represent this decision system involves the brain mapping out a series of such attributes for each food choice, assigning a value to each attribute, and then integrating those values into an overall decision. Bad dieters, the model says, simply do not integrate the more abstract attributes, such as the health consequences of eating a particular item, into the final valuation. This leads those dieters to make choices based mostly on taste—a hypothesis borne out by the fMRI experiments.

In a follow-up experiment, Rangel's group did the same fMRI study with self-proclaimed nondieters. In half of the trials, the researchers asked the participants to make whatever decisions they liked; in the other half, the subjects were asked to make their decisions while paying attention to how healthful the items were. Interestingly, that simple instruction led to the subjects making healthier choices; the imaging results showed that it activated the same dlPFC/vmPFC network as in the good dieters. The stronger the connection between the two, the researchers found, the healthier the dieters' choices became. "That was interesting to us because it suggests that this difference between dieters is not something that is hardwired but something that can be modified," Rangel says.

Bad dieters, the model says, simply do not integrate the more abstract attributes, such as the health consequences of eating a particular item, into the final valuation. This leads those dieters to make choices based mostly on taste.

A Decision to Learn

While Rangel is particularly interested in what happens in the brain at the moment of decision, O'Doherty has focused on how the brain learns, over time, to make different types of decisions. His group has determined that there may be multiple systems in the human brain that drive decision making: one system that operates at the Pavlovian level; another that responds based on habits learned over time; and yet another, more sophisticated, system that is goal-directed, involving planning and the weighing of possible consequences. O'Doherty notes that each of those systems involves different brain regions to varying degrees. (For more on these systems, see "From Dendrites to Decisions," *E&S*, Fall 2011, p. 14).

O'Doherty is also interested in considering how social situations—where concepts such as trust, altruism, and retribution come into play—impact the process of decision making and learning. "After all," he says, "much of what we learn as children we learn by watching someone else."

In this area of focus, O'Doherty is certainly not alone. In fact, in 2012, the National Institute of Mental Health awarded Caltech a five-year grant of $9 million to create the Conte Center, which involves a group of researchers working together in a sort of virtual hub for studying the neurobiology of social decision making. Work by researchers involved in the center—Adolphs, O'Doherty, and Rangel, as well as Assistant Professor of Biology Doris Tsao and James G. Boswell Professor of Neuroscience Richard Andersen—is concentrated on four projects that look at decision-making scenarios of increasing social complexity through the use of electrophysiology and fMRI.

In one such experiment, you would be asked to lie down on the tubelike bed of an fMRI scanner and to repeatedly select one of two onscreen slot machines to play. In the beginning, you would just pick one or the other; but after switching off between the two for a while, you might learn that one machine pays out more than the other and develop a preference for that one. The researchers would first want to know what happened in your brain as you learned to choose one machine over the other, and then they would want to know how your choices might change over time, especially with the added complications of social interactions and interpersonal relationships. "So if you've learned that one machine is a better choice, can you unlearn that and switch over if the other machine begins paying out more?" says Ralph Adolphs, the director of the Conte Center. "How does that work? What if you're not doing anything, but you're watching someone else do this task? Will you learn in the same way? Now what if you think the person you're watching is really stupid, or you believe they're an expert, or, worst of all, you think they're trying to deceive you?"

A key finding that has emerged from the center's work thus far is that a common core system of reward regions in the brain seems to be activated in all of these decision-making situations, "whether you learn how to make decisions through your own experience or you learn by watching someone else do something," Adolphs says. That core includes two brain regions—the posterior cingulate cortex and the ventral striatum—as well as a portion of the vmPFC. Additional brain systems seem to work with and feed information to these core regions when social rewards are added to the decision-making mix.

Of course, scientists still have much to learn about the core reward system. For example, although fMRI may show a relatively large blobby region being activated during a particular task, researchers would like to find out if all or only some of the neurons in those areas are activated. For that, they need to use additional techniques and consider new, inventive models. Only then will they be able to work out the details of how the core regions are interconnected.

By figuring out how people make decisions when everything is working typically, Caltech's neuroeconomists and their colleagues hope one day to be able to determine what exactly is happening when people make bad decisions—and then to devise strategies to help us all make better choices, whether that be to stop taking drugs, to stay in school, or to behave altruistically.

"If you had to boil it down to 'What's the number one problem in the world?' well, it would be poor decision making," says Adolphs. "It's very hard to make complex decisions, especially when the consequences of those decisions will occur far in the future. Understanding how to improve that kind of decision making, that's the big challenge. And neuroeconomics is the only scientific way to really crack it." e&s

Ralph Adolphs is the Bren Professor of Psychology and Neuroscience and professor of biology. He is also the director of the Caltech Conte Center for Neuroscience. His work is funded by the National Institutes of Health (NIH) and the Simons Foundation.

Colin Camerer is the Robert Kirby Professor of Behavioral Economics. He is supported by the National Science Foundation (NSF), the Gordon and Betty Moore Foundation, the Lipper Family Foundation, and the Neuroeconomics Discovery Fund.

John O'Doherty is a professor of psychology and the director of the Caltech Brain Imaging Center. The NIH, the NSF, the National Center for Responsible Gaming, and the Moore Foundation contribute funding to his work.

Antonio Rangel is the Bing Professor of Neuroscience, Behavioral Biology, and Economics. His neuroeconomics work has been supported by the NSF, the NIH, the Moore Foundation, and the Lipper Foundation.

Blue-Sky Thinking

Cyrus Behroozi (BS '97)

Cyrus Behroozi wants to connect the whole world to the Internet. "Two-thirds of the world's population still doesn't have access," says Behroozi, an engineer with Google[x], the Internet giant's experimental division. "It's easy to think of the Internet as a luxury, but it's now so deeply tied to economic development."

Considering that Google[x] is most widely known for engineering the driverless car, its solution to global connectivity might seem charmingly low-tech: balloons.

But these aren't everyday balloons. Behroozi leads the network engineering for Project Loon, an ambitious experiment by Google[x] to create a global wireless network of transmitter-laden balloons floating around the world in the stratosphere, 12.5 miles above ground, which is twice the elevation flown by commercial airlines. "At that altitude, we gain the coverage advantages of satellites, but at a fraction of the cost to launch and maintain," he says.

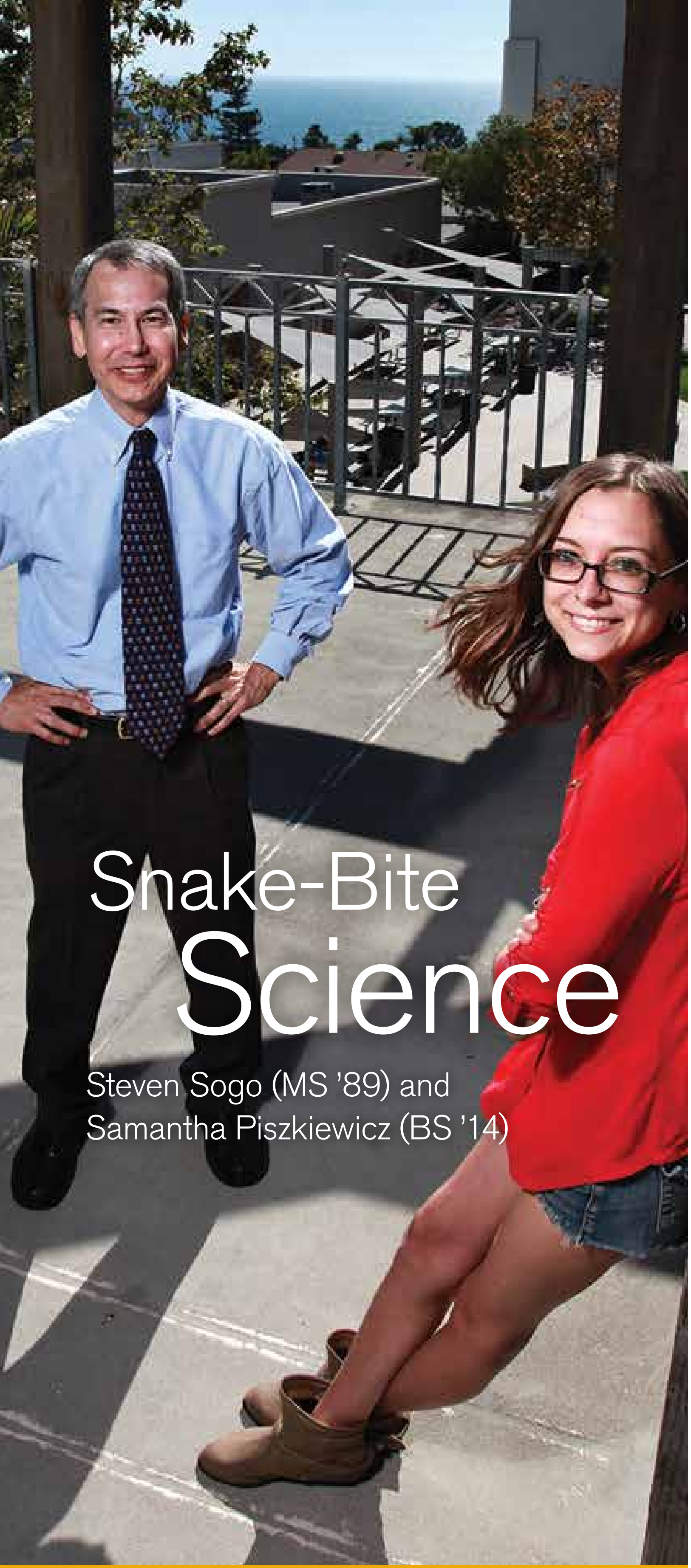
The project carries enormous engineering challenges. To be a viable alternative to satellites, the balloons must first be able to stay aloft for an extended period (Google[x] currently targets 100 days, enough for three trips around the globe). To meet that goal, engineers have developed balloon materials to withstand extremely wide variations in pressure and temperature.

Next, there is the issue of navigation—how exactly do you direct an unmanned balloon? In the stratosphere, winds tend to flow in a single direction, depending on elevation. Google[x]'s balloons loosely navigate by changing altitude to catch a ride with a current headed in a desired direction.

Having conquered these challenges, the team needs the balloons to deliver the Internet, which is where Behroozi comes in. His team has developed an array of lightweight transmitters and receivers powerful enough to connect the balloons to provider stations, one another, and end users—customers in rural, remote locations.

"One of our challenges is that the balloons constantly rotate," Behroozi explains. "We've designed special antennas so that no matter which way the balloon is oriented, you can get a signal."

Behroozi believes that his training at Caltech prepared him for the scope and diversity of Project Loon. "A lot of us at Google[x] tend to be what we call 'T-shaped' people," he says. "We have exposure to a wide variety of disciplines (the top of the T), with a deep expertise in one particular field (the stem). That's very much how Caltech trains us, and this makes it possible for us to combine our disciplines to tackle enormous challenges."



Snake-Bite Science

Steven Sogo (MS ’89) and Samantha Piszkiewicz (BS ’14)

Alumni stories provided by the Caltech Alumni Association. For more about these stories and to read about other alumni in the news, visit alumni.caltech.edu.

Steven Sogo, a science teacher at Laguna Beach High School, had become frustrated by his chemistry curriculum. On paper, his students performed well in science placement exams, but still, he was troubled. “The type of students who scored high knew how to memorize facts and take tests, but they weren’t necessarily good scientists,” Sogo says. “I wanted to teach a class that rewarded curiosity, experimentation, and the risk of failure.”

So in 2007, Sogo partnered with Ken Shea, a professor of chemistry at nearby UC Irvine. Shea had developed new processes for molecular imprinting—a technique used to create nanoparticles capable of latching onto organic molecules. “We call them ‘plastic antibodies,’” Shea explains. One of the first applications was a synthetic antidote to bee venom.

Sogo enlisted Shea’s help to establish a similar lab at Laguna High, but the high schoolers needed a target. One of Sogo’s students, Samantha Piszkiewicz, voiced her fascination with the Mozambique spitting cobra, which (as its name suggests) spits its venom, a noxious cocktail of protein toxins that break down the lining of cell walls.

Starting in the fall of 2008, Sogo led Piszkiewicz and her fellow students in adapting and applying Shea’s techniques for molecular imprinting to the snake venom. The following spring, they had successfully synthesized an antibody. “The first test result we got was so beautiful and encouraging,” Piszkiewicz said. “We saw 85 to 95 percent inhibition of cell destruction.”

In 2009, the students presented their research at a science competition held at Caltech. “That felt like a homecoming of sorts,” Sogo says. “It was a chance to show off the research, and also to introduce my students to a place that made such an impression on me.”

It also made an impression on Piszkiewicz—who went on to enroll at Caltech, graduating this past spring with a bachelor’s degree in chemistry.

Sogo, meanwhile, continued to work on the snake venom project. New classes of Laguna students carefully refined and documented their procedures, and in 2013 their work was published in *Chemical Communications*, considered one of the field’s leading journals.

“They weren’t published just because they were high school students,” Shea says. “They made a valuable contribution and their work serves as a model for other high schools.”

“It’s hard to imagine that my first published project is for work I did when I was 16,” says Piszkiewicz, who was listed as lead author. Now pursuing her PhD in biophysics at the University of North Carolina, Chapel Hill, she dreams one day of leading her own research lab. “I wouldn’t be the researcher—or the person—that I am today without that class.”

And perhaps that’s where Sogo’s real success lies. In addition to creating an antivenom, he is helping scientists like Piszkiewicz to discover themselves.

DREAM COURSE

Looking forward to the return of students to campus, we asked alumni to create their Caltech dream course, complete with a title and short course description. Here are some of the classes they dreamed up.

DITCH DAY 1a Stack-building,

a *systems engineering* approach. Project management, design, risk management, and testing. Offered fall term only.

OUR MOON

This course studies our moon and uses this study to introduce elements of **science, history, observation,** and **the arts**.

DESIGNING BOARD GAMES FOR FUN AND PROFIT

Elements of board game design, including common pitfalls to avoid **(runaway leader problem, first turn advantage, "broken" strategies**) as well as proper weighting of various elements to keep game balance.

WTF PHYSICS!

A refresher for rusty alumni who have *not done anything relativistic, quantum-mechanical, or particle-physical since graduation*, who are reading the latest news about Higgs bosons, inflation, and dark energy, and who are asking themselves . . .

WTF?!?!?!?

DREAM PHYSICS: Neural net probe technology induces into the participant's brain the **full panorama of presently known physics knowledge** via artificially induced dreaming.

RATIONAL GOVERNANCE

Defines the scientific basis for government and explores the question of whether and how **governments can evolve** into greater rationality.

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The meaning and implications for our world of the concept of infinity **in both directions**.

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