



inquiry@

UC SANTA CRUZ
RESEARCH MAGAZINE

2016-17

**Tracking
toxic tides**



The spirit of **inquiry@UC** Santa Cruz



The Office of Research and University Relations are very pleased to present the second annual issue of *inquiry@UC Santa Cruz*! This UCSC research magazine highlights the broad scope of outstanding research being conducted on our campus, and has descriptions of recent results from some of our award-winning faculty, whose honors include Packard, Guggenheim, and Carnegie fellowships. From the arts to engineering, the research described here captures the imagination and vision that characterizes our researchers on the Santa Cruz campus, with investigations that span and combine the basic search for knowledge

with addressing societal and health issues. From using the structure of an endangered language to illuminate how the brain processes communications, to devising portable and inexpensive tests for the Ebola virus, to using modern digital techniques to reconstruct ancient archaeological sites, to monitoring toxic algae blooms in our near-coastal oceans, our UC Santa Cruz research is united around a common theme: pushing the boundaries of knowledge in the service of humanity.

Welcome to the 2016–17 edition of *inquiry@UC Santa Cruz*. We hope that it gives you a flavor of the creativity and excitement that characterizes our campus research enterprise!

A handwritten signature in blue ink that reads "Scott Brandt".

Scott A. Brandt
Vice Chancellor for Research
and Professor of Computer Science

BRIEF inquiries page 4

FEATURES

Tracking toxic tides

Ocean sciences professor forecasts toxic algae events page 10

Total recall

Do digital footprints alter our relationship to the past? page 14

Seeing past stereotype

Art historian probes racial dynamics through visual media page 17

Thinking in tongues

Uncommon language hints at linguistic logic page 18

Unwinding the clock

Carrie Partch breaks circadian rhythms page 21

The future of the past

Archaeologists use digital tools to dig into an ancient site page 24

A lab in the hand

High-tech creates low-cost medical tests page 26

Following the law

Chronicling politics, religion, and law from Africa to California page 29

Cloudy with a chance of life

Astrophysicists probe inside distant planets page 35

PEN&INQ page 38

INQUIRINGminds page 39

About the cover: Phytoplankton are microscopic marine plants that play huge roles in the ocean's food chain. Despite their contributions to life, these tiny organisms can also produce deadly toxins.

PHOTO: COURTESY OF NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA)

BRIEF inquiries

UNIVERSITY OF CALIFORNIA
SANTA CRUZ

Chancellor
George Blumenthal

**Campus Provost and
Executive Vice Chancellor**
Alison Galloway

Vice Chancellor, Research
Scott Brandt

Vice Chancellor, University Relations
Keith Brant

inquiry@UC Santa Cruz
2016-17

Editor
Elizabeth Devitt

Creative Director
Lisa Nielsen

Art Director/Designer
Linda Knudson (Cowell '76)

Associate Editors
Quentin Williams, *principal*
Jeanne Lance
Tedd Siegel
Lynne Stoops

Photography
Carolyn Lagattuta

Contributors
Eileen Campbell (SciCom '83)
Elizabeth Devitt (SciCom '13)
Blake Edgar (SciCom '89)
Kerry Klein (SciCom '15)
Greta Lorge (SciCom '03)
Jyoti Madhusoodanan (SciCom '14)
Lisa Marie Potter (SciCom '15)
Heather Rock Woods (SciCom '94)
Rina Shaikh-Lesko (SciCom '13)
Kim Smuga-Otto (SciCom '15)

**Produced by UC Santa Cruz
Communications & Marketing**

1156 High Street
Santa Cruz, CA 95064-1077
Email: inquiry@ucsc.edu
Web: research.ucsc.edu
ucsc.edu
5/16 (1516-245/5M) IM6



COMPUTER SCIENCE

Open source resource



After UC Santa Cruz alum Sage Weil earned his doctoral degree in computer science he didn't let his thesis work languish. Instead, he spent seven years refining the open source storage solution, Ceph, and then created a startup for the platform, which sold to Red Hat last year. Now, with major gifts that total \$3 million for research in open source software, Weil is creating similar opportunities for other UC Santa Cruz students.

"Sage was a brilliant student and deeply committed to open source software as a model for how to move computer science forward," said Scott Brandt, vice chancellor for research and computer science professor. "His success was quite extraordinary, and he wanted to give back to the university."

With matching funds from the UC Presidential

Match for Endowed Chairs, Weil's gift of \$500,000 established a \$1 million endowment for the Sage Weil Presidential Chair for Open Source Software. An additional \$2 million supports the Center for Research in Open Source Software (CROSS), directed by computer science professor Carlos Maltzahn.

"CROSS will bridge the gap between student research prototypes and successful open source software products," said Maltzahn. "We're the first graduate-level program that offers this completely new way for students to get involved in a very sophisticated professional community," he added.

The newly minted CROSS has already attracted three founding member companies: Toshiba, SK Hynix Memory Solutions, and Micron.

ENVIRONMENTAL TOXICOLOGY

Heavy metals

Last year, the California ban on lead-based ammunition drew on scientific evidence developed by UC Santa Cruz toxicologists Donald Smith and Myra Finkelstein. With a unique "fingerprinting" technique, they directly linked the ammunition to deadly levels of lead poisoning in California condors.

Although lead gets lots of attention, it isn't the only metal that Smith worries about. In people, manganese toxicity from contaminated water, soil, or dust is an emerging problem in many countries—including our own.

Essential for our bodies at low levels, excessive amounts of manganese can impair cognitive function and cause conditions similar to Parkinson's disease.

In two separate NIH-funded studies, Smith documented manganese levels in the body and corresponding changes in neurological behavior: one in children with high environmental exposure; another in experimental animal models exposed to manganese as neonates.

The results of the animal study, described in *Environmental Health Perspectives*, showed that developmental exposure to manganese causes lasting attention and fine-motor deficits. The deficits in the animals parallel those observed in the study on children.

Smith is now exploring the underlying mechanisms of manganese toxicity

in the brain and how medications, such as Ritalin, might mitigate those impacts.

UC SANTA CRUZ NATURAL RESERVES

Green gifts

Outside the classroom doors, UC Santa Cruz provides stewardship for five natural laboratories located along the Central California coast. These protected ecosystems belong to a network of undisturbed sites that are set aside for research in the UC Natural Reserve System.

Each of these pristine places will benefit from a \$500,000 gift from the Helen and Will Webster Foundation, which, with matching funds from the UC Regents, will establish a \$1 million endowment for the Wilton W. Webster Jr. Presidential Chair for the UC Santa Cruz Natural Reserves.

Four of the UC Santa Cruz reserves are part of 39 areas managed by the University of California, encompassing over 750,000 acres across California. These UC Santa Cruz reserves include Año Nuevo Island Reserve, Fort Ord Natural Reserve, Landels-Hill Big Creek Reserve, and Younger Lagoon Reserve. A fifth, the Campus Natural Reserve, is also managed by UC Santa Cruz.

The reserves offer research opportunities for students of all ages, ranging from K–12 programs at Fort Ord, overseen by Gage Dayton, the administrative director of the UC Santa Cruz Natural Reserves, to

the multi-reserve project led by UC Santa Cruz biologist Barry Sinervo for the Institute for the Study of Ecological and Evolutionary Climate Impacts.

“Getting students out in the field is transformative,” said Donald Croll, the faculty director of the UC Santa Cruz Natural Reserves and professor of ecology and evolutionary biology. “This gift will help us inspire the next generation of conservationists.”

FILM & DIGITAL MEDIA

Oscar nominee

A first-ever film effort by Dee Hibbert-Jones, UC Santa Cruz associate professor of art and digital art and new media, earned an Academy Award nomination for *Last Day of Freedom*, a short-subject documentary. Her work also garnered a 2016 John Guggenheim Memorial Foundation fellowship for film and video.

Six years in the making, in collaboration with San Francisco artist Nomi Talisman, the film tells the story of a man who turned in his war-haunted brother for committing murder.

“We wanted to reach behind the headline news and look at the effect of the death penalty on the families and communities left behind,” said Hibbert-Jones, a fine artist by training. They used animation to put psychological distance between the viewer and the powerful story, she explained.



White-nose syndrome was named for appearance of the fungus (*Pseudogymnoascus destructans*) around the muzzles, ears, and wing membranes of affected bats.

ECOLOGY & EVOLUTIONARY BIOLOGY

Bat plan

Four new grants, totaling almost \$300,000, are helping UC Santa Cruz biologists Marm Kilpatrick and Winifred Frick advance research on white-nose syndrome, a malady that has killed more than 6 million bats since 2006.

The pathogenic fungus makes the bats wake from hibernation too frequently. They exhaust their stores of fat and starve to death, explained Kilpatrick, associate professor of ecology and evolutionary biology.

Last November, with grants from the U.S. Fish and Wildlife Service, Bat Conservation International, and the Nature Conservancy, Kilpatrick and Frick started field trials with potential treatments.

Earlier work by UC Santa Cruz graduate student Joseph Hoyt showed that some bats have skin bacteria that inhibit the fungus.

In the trials, groups of bats roosting in a mine got their skin sprayed with one of three things: Hoyt's fungus-killing bacteria, an anti-fungal extract made from chitosan (a protein in the outer skeleton of insects), or a treatment-free control.

The bats were tagged with a device to record when each animal left the mine. If the treatments work, the bats will survive until spring when flying insects return.

“If this works,” said Kilpatrick, “we could help species heavily impacted by disease.”

BRIEF inquiries

MOLECULAR, CELL & DEVELOPMENTAL BIOLOGY

Why Wolbachia?

Cell biology studies could offer high-impact solutions for neglected tropical diseases that afflict the “bottom billion,” the poorest people in the poorest countries, wrote UC Santa Cruz biologist William Sullivan in an essay published in *Molecular Biology of the Cell*.

For example, when researchers discovered that a bacterial parasite of worms caused the debilitating inflammatory reactions of African River Blindness—not the roundworms that migrated into human tissue—the door opened for treatment with common antibiotics.

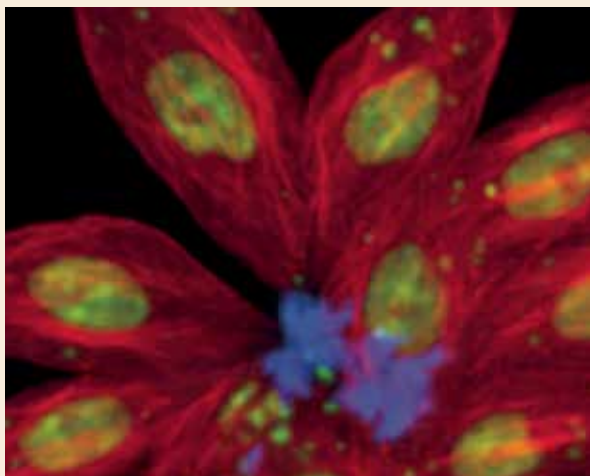
Sullivan’s team developed the high-throughput screening method to hunt for drugs that might kill this sneaky bacteria, called Wolbachia. In collaboration with the UC Santa Cruz chemical screening center, they found an FDA-approved

drug that killed Wolbachia. The same drug also kills the long-lived worms because they need the bacteria to survive.

Now Sullivan’s team, in collaboration with the California Institute for Biomedical Research, is screening more than 170,000 compounds for even more potent anti-Wolbachia treatments. With further study, Sullivan hopes to better understand how the parasitic bacteria manipulates its host worm, and find drugs to disrupt those interactions.

“The goal is to find a drug that could be used once, or yearly; something suitable for a mass drug administration campaign,” said Sullivan.

Below: Oocyte of disease-causing heartworm from a dog. Wolbachia (green dots) are bacteria symbionts essential for worm survival.



“My arts research has always crossed genres and borders. When I teach public art I explore the politics of public space, and I’m interested in the ways public and private lives impact and intersect,” she said.

Last Day of Freedom is the first in a trilogy of films planned about the criminal justice system. The documentary qualified for the nomination after winning the 18th annual Full Frame Documentary Film Festival jury award for Best Short film.

AGROECOLOGY

Insect diversity

From coffee plantations to urban gardens, UC Santa Cruz environmental studies professor Stacy Philpott has been digging around dirt for decades.

“I look at ways to create win-win situations that protect insect biodiversity and help agriculture thrive,” said Philpott, who holds the Ruth and Alfred Heller Chair in Agroecology and directs the UC Santa Cruz Center for Agroecology & Sustainable Food Systems.

On coffee plantations, her studies have shown that clearing too many trees makes ant diversity decline. Without that biodiversity, plantations lose valuable resources, such as pest control.

Closer to home, Philpott and her students spent three summers studying 19 different Central Coast gardens to learn which factors enhanced insect biodiversity. As

urbanization increases, these small green spaces can provide important insect habitats.

Not surprisingly, growing a wider variety of garden plants supported a greater range of insect species. But they also found the surrounding landscape—trees, grasslands, cement, or ground cover—affected biodiversity. For example, in research published in *Environmental Entomology*, UC Santa Cruz alum Michelle Otoshi showed that spiders were more abundant with garden mulch.

In the future, Philpott will return to coffee plantations to study how changes in bee and ant diversity affect the microbiome of coffee flowers.

SOCIOLOGY

Citizen gain

The term “denizen” is used to describe an inhabitant who is not a formal citizen, but not necessarily an undocumented immigrant either. It’s a word that fits more than 60 million refugees who have fled their homelands, according to UN Refugee Agency data.

“What does it mean to be a denizen in a world that is organized around, and by, nation-states?” asked Catherine Ramirez, associate professor of Latin American and Latino studies and director of the Chicano/Latino Research Center at UC Santa Cruz.

Such questions will be explored during a year-

long “Non-citizenship” seminar, planned by Ramírez and four other UC Santa Cruz professors: Juan Poblete, literature; Felicity Amaya Schaeffer, feminist studies; Sylvanna Falcón, Latin American and Latino studies; and Steven McKay, sociology. The seminar is funded by a \$175,000 grant from the Andrew W. Mellon Foundation John E. Sawyer Seminar on the Comparative Study of Cultures.

Ramírez hopes to foster conversations across the borders of academic disciplines, geographical regions, and even time periods—by including historical perspectives as well as current events.

EDUCATION

Personal ed

Big data could help close achievement gaps between underserved students and their peers in the Silicon Valley region.

Educational intervention often takes a blanket approach, noted Rodney Ogawa, UC Santa Cruz professor emeritus of education. But a regional database that draws information from public schools, online educational program providers, and health and human service agencies could enable detailed analyses that lead to personalized education plans.

With a \$356,542 National Science Foundation grant, Ogawa and his colleagues built partnerships for the Silicon Valley Regional Data Trust, a database for

San Mateo, Santa Clara, and Santa Cruz counties.

One impetus for this project was a study, published in the *American Journal of Education* by Ogawa, Betty Achinstein, and Marnie Curry, of three predominantly Latino high schools with high rates of college-bound students. Despite intensive efforts, those at-risk students often weren’t prepared to academically thrive in college.

There were organizational barriers to students’ success, said Ogawa. He thought: Why not use data the way they do in medicine or astronomy to breakdown boundaries and answer intractable questions?

“The goal is to begin personalizing educational services so that the kids and families most at risk for poor outcomes in schools and elsewhere can be able to begin to turn the corner,” said Ogawa.

ASTROPHYSICS

Mistaken identity

Dark matter comprises more than 85 percent of matter in the universe. Still, no direct hints about its particle nature have been conclusively detected.

Recent attempts to confirm a dark matter decay signal from the dwarf galaxy Draco came up empty handed, reported UC Santa Cruz physicists, Stefano Profumo and Tesla Jeltema.



COMPUTER ENGINEERING

Hybrid vigor

Flying robots might not appear to have much in common with energy grids. To function smoothly, however, both use hybrid systems that combine stop-start action with continuous movement. Developing algorithms for these systems is a specialty of Ricardo Sanfelice, associate professor of computer engineering.

“I enjoy solving applications that combine physics and computational components,” said Sanfelice.

One of those applications enables “smart grids” to link off-and-on sources of renewable energy, such as solar power, with the continuous electric currents of standard electricity. A patent is pending for that hybrid control algorithm.

With a \$432,000 National Science Foundation grant, Sanfelice and a colleague from the

University of Arizona are now developing a system to enable groups of unmanned vehicles to work together under uncertain conditions.

A key problem is that computer calculations could take longer to make than actual movements—potentially putting vehicles and people at risk. Introducing a metric, called uncontrollable divergence, allows the computer to calculate tradeoffs between accuracy and speed to determine its best trajectory. Sanfelice’s team described this “computationally aware cyber-physical system” in the journal *Autonomous Robots*.

Sanfelice hopes to gather an interdisciplinary group of his campus colleagues to advance the development of these complex cyber-physical systems.

BRIEF inquiries

The signal claims, by two separate research groups, were based on observations of an anomalous bright line among X-ray spectra emitted from clusters of galaxies considered to be the largest dark matter-dominated systems in the universe.

A bright line was found at 3.5 keV, a result predicted by one model in which a sterile neutrino would decay into a 3.5 keV photon and an ordinary neutrino. However, ordinary potassium ions can create similar spectral lines. A follow-up

study, in an area without potassium, detected no bright line. This ruled out the sterile neutrino dark matter hypothesis at a 99 percent confidence level, explained Profumo.

“We’re back to the drawing board, but there’s no shortage of dark matter candidates,” he added.

“If a signal is found, and confirmed, then we’ll learn something fundamental about particle physics theory, which doesn’t include dark matter right now,” said Jeltema.

PLANETARY SCIENCE

Moonmaker

The rotational forces on spinning heavenly spheres creates bulges at their equators. A faster spin exerts a stronger force and bigger bulges. However, the Earth’s moon only rotates about once a month. So, for centuries, astronomers wondered: With so little spin, why the lemon shape?

Billions of years ago, the Moon was made of rock sheets floating on a sea of magma, said Ian Garrick-Bethell, assistant

professor of Earth and planetary sciences at UC Santa Cruz. The Moon’s distorted shape resulted from the combined effects of early tidal forces on a hot Moon, plus rotational forces as the surface later cooled unevenly, according to his paper published in *Nature*.

Garrick-Bethell drew insight from similar ideas about the shape of Europa, the cool and watery moon of Jupiter. A detailed topographical analysis of the Earth’s moon, based on data from laser altimeters and

OCEAN SCIENCES

Seal-ective hearing

Rising levels of man-made noise in the Arctic are degrading the acoustic habitat of ice-living seals.

To learn more about how noise pollution affects these animals, researchers at UC Santa Cruz’s Long Marine Laboratory partnered

with two pairs of rarely studied Arctic species—spotted seals and ringed seals—to test their hearing.

The results of those studies, published in the *Journal of Experimental Biology*, showed that both species are highly sensitive to sounds

both above and below the water’s surface, said Jillian Sills, lead author and a doctoral degree candidate in the Department of Ocean Sciences.

Moreover, the amphibious animals didn’t lose land-based hearing in favor of

underwater sound, noted lab director Colleen Reichmuth, a coauthor on the papers.

The research team tested the seals’ hearing under quiet conditions and against background noise, from frequencies as low as 100 Hz to ultrasonic frequencies higher than 70 kHz. Interestingly, the seals showed a wider hearing range under water compared to on land, suggesting that the hearing mechanisms differed in each environment.

Next, the investigators will create auditory profiles for the rarely studied bearded seal. All the data will help establish regulatory criteria for noise exposures to protect free-ranging marine mammals.



The two spotted seals at Long Marine Lab, Amak and Tunu, were orphaned as pups in the Arctic. NMFS Permit 14535

studies of gravity-field perturbations, supported these conclusions. Also involved in the study was UC Santa Cruz professor of Earth and planetary sciences Francis Nimmo.

This work expanded on earlier studies, published in *Science*, which used tidal forces to explain unusual features on an area of the Moon called the farside highlands.

COASTAL SUSTAINABILITY

Sea change

The kelp forests along the Pacific coastline provide a rich habitat for marine species, ranging from microscopic algae to marine mammals. They also offer a dynamic place to study environmental change for Kristy Kroeker, assistant professor of ecology and evolutionary biology at UC Santa Cruz, who received a five-year, \$875,000 Packard Fellowship for Science and Engineering.

In previous research Kroeker found that increasing acidification and temperature altered algae populations. In turn, these changes affected the animals that live and feed on the algae and, ultimately, the resilience of rocky reef ecosystems.

Now, she'll place ocean sensors from Baja California to Alaska to track changing carbonate chemistry, oxygen, and temperature levels. She'll follow the corresponding changes in the algae and marine herbivores.

In addition, Kroeker is experimenting with small granite tiles that provide blank slates for algae, coralline algae, and small grazers to establish



Local girls from Babile fill yellow water jugs at the area's main water source

SOCIOLOGY / ENVIRONMENTAL STUDIES

Tapped out

Water can be the currency that builds wealth or reduces poverty. However, access to water doesn't always command the same attention—or intervention—as the money gap between rich and poor.

Such inequities led UC Santa Cruz sociology professor Ben Crow and his collaborators to draft "The Santa Cruz Declaration on the Global Water Crisis." The document built upon the 2013 Equitable Water Governance workshop, led by Crow and Colleges Nine and Ten provost Flora Lu.

"Although limited water supply and inadequate institutions

are indeed part of the problem, we assert that the global water crisis is fundamentally one of injustice and inequality," noted the declaration.

Studies by Crow and Lu have shown these disparities are everywhere: in Global South populations excluded from water sources; in northeastern Ecuador where indigenous Amazonians struggle daily to find clean water in oil-contaminated communities; and in Central California where farmworkers compete with crops for uncontaminated water.

Safe drinking water isn't enough to eliminate

disparities, argued Crow, in a paper coauthored with UC Santa Cruz alum Matt Goff and published in *Water International*. Crow's two-year Kenya study, which included putting GPS devices on "jerry cans" to track the work of collecting water from vendors' taps, showed that time spent getting water—mostly by women—detracts from child care, small enterprise, and freedom for community involvement.


Instead, providing "liberatory capabilities," such as water taps inside households, could be more effective to reduce poverty.

themselves. Watching these communities build themselves will improve understanding about how kelp beds come back after big storms, and the ways

environmental changes might affect these dynamics.

"These are simple ecological experiments in

succession and species interactions—except that we're doing them across thousands of kilometers," said Kroeker.



Tracking toxic tides

Ocean sciences professor
forecasts toxic algae events

Cells of *Pseudo-nitzschia*, a genus of microalgae that includes several species which can make deadly toxins. Each cell is smaller than the width of a single hair. Measured in microns, 1/1000 of a millimeter, these organisms can be 2–8 microns wide and 40–175 microns long. These samples were collected during an algae bloom off the West Coast last summer that forced the closure of numerous shellfish and crab fisheries.

► When a giant algal bloom turned Pacific coastal waters poisonous from Santa Barbara to Alaska in May 2015, **Raphael Kudela** was ready.

His team from the Biological and Satellite Oceanography Laboratory not only stepped up their routine ocean water sampling, they also worked with collaborators to deploy more sophisticated instruments—including an underwater molecular biology lab, affectionately called “lab in a can,” to measure toxin levels and types of algae, a remote-controlled glider to gather information from different water depths, and wave-powered “wire walkers” loaded with recording devices.

A professor of ocean sciences, Kudela studies and tracks harmful algal blooms (HABs). He uses a variety of tools and collaborations that make it faster and easier to detect problems and work with health and fisheries agencies.

“From a scientific perspective, we were happy to see the bloom because we could collect the data we need to actually predict what’s going on,” said Kudela.

That’s the goal—to predict when and where toxic events are likely to emerge and, in turn, inform policy and management decisions that can minimize the impacts. Kudela’s lab and an alliance of researchers and public agencies are making rapid progress after almost a decade of building upon local trials.

The sooner the better. HABs are responsible for progressively higher economic losses, health threats, and damage to ocean and freshwater life. The 2015 West Coast bloom closed the commercial and recreational Dungeness crab fishery for the first time ever in Northern California, and temporarily took anchovies and rock crab from several California counties off the menu.

The troublemaker? A neurotoxin named domoic acid, produced by the blooming microalgae *Pseudo-nitzschia*. As well as the fisheries, the toxin also

afflicted sea lions, seabirds, and other marine animals causing amnesia, seizures, comas, and death.

Many species of microalgae produce different toxins that attack the liver or nervous system and cause illnesses, including paralytic shellfish poisoning and diarrhetic shellfish poisoning. Even nontoxic blooms can be harmful by clogging fish gills or draining all the oxygen out of the area as they decompose, killing a variety of aquatic creatures.

The microalgae, also called phytoplankton, are dynamos: In bloom conditions, their numbers surge so quickly that some species color miles of ocean red and whole lakes bright green. As photosynthesizers, they remove carbon dioxide from the water and vent oxygen into the atmosphere—up to half the oxygen we breathe comes from phytoplankton.

At the bidding of currents and winds, thousands of phytoplankton species sail the oceans, their single-celled bodies turning sunlight into food for everything from the smallest shrimp to the widest whales. Which means the toxins produced by HABs percolate through the food chain.

As the world heats up, and oceans and freshwater along with it, the duration and intensity of HABs will escalate,

posing increasing risks to aquatic and human health, fisheries, and drinking water.

“After years of seeing harmful blooms, that naturally led us to wonder ‘is there something we can do?’” Kudela asked.

He has answered “yes” in many ways.

Working with the National Oceanic and Atmospheric Administration (NOAA) and others, Kudela’s lab harnessed research and data to create a demonstration forecasting model.

Now active on the Central and Northern California Ocean Observing System, the demo draws from



Above: Kudela’s team uses “lab in a can,” to measure toxin levels and types of algae

PHOTO: COURTESY NOAA/VERA TRAINER; LAB IN A CAN COURTESY KUDELA LAB

TENACIOUS AND TOXIC

In 2015, normal spring upwelling combined with the arrival of the “blob”—an anomalous, excessively warm clump of Pacific water—created the biggest, longest-lasting, most toxic algal bloom ever seen along the West Coast.

Instead of dissipating after a few weeks, the bloom continued from May into October. Although individual cells only live a few days, the dead cells still contain domoic acid and accumulate in the bottom sediment, creating a reservoir of toxin that lasts for months.

Long after the bloom ended, Raphael Kudela’s lab found domoic acid in mussels. For the first time, the toxin also turned up in the muscle tissue of several kinds of fish. While those fish were still safe to eat, it was a sign of how extensively the toxin contamination spread during the 2015 bloom.

“There was so much toxin that we found it dissolved in the water, not just in the bodies of animals,” Kudela said.



Above: On July 28, 2015, the Operational Land Imager (OLI) on Landsat 8 captured these images of algal blooms around the Great Lakes. The bloom is visible as swirls of green in western Lake Erie.

Tracking toxic tides

satellite data on algal concentrations, real-time observations of biological activity and water conditions, calculations of circulation patterns, and statistical programs for prediction.

Maps based on current and future conditions show the probabilities of finding *Pseudo-nitzschia* blooms and domoic acid events along the California coastline. (For unknown but hotly investigated reasons, *Pseudo-nitzschia* doesn’t always make the toxin.)

“A complete predictive model will be a valuable resource for researchers and ocean users,” said David Caron, professor of biological sciences at the University of Southern California who contributes data for the model.

The maps currently advise: “Experimental Data—Use Cautiously.” But the information is already being used by marine mammal rescue groups to get a sense of how many sea lion strandings to expect in particular locales. Shellfish growers are beginning to pay attention, too; ultimately, insights from the maps should help them choose where and when to seed and harvest.

The model is also serving as a template for groups in Great Britain, Oman, and the United Arab Emirates. The latter two get at least 70 percent of their drinking water from desalination plants. Algal blooms obstruct plant filters; local HAB prediction could tell operators when to pull ocean water from deeper inlet pipes (phytoplankton live near the surface) or a different location.

“The research has gone almost all the way from a demo to a product that will be useful for policy, management, and the public,” Kudela said. The project, later to include Oregon and Washington, is scheduled to become part of NOAA’s National Weather Service and the National Ocean Service.

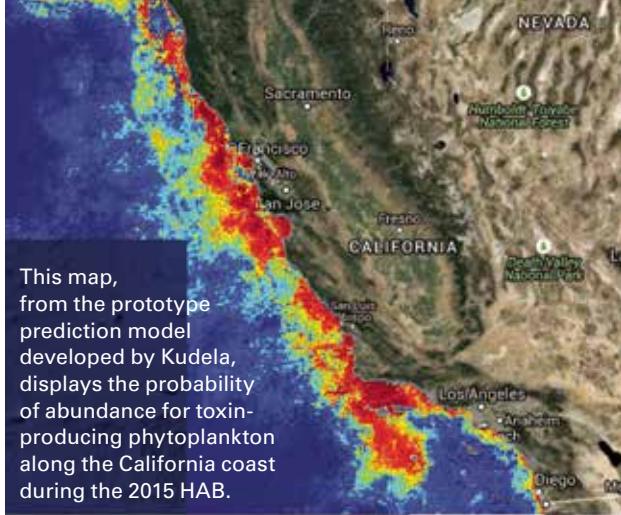
Looking for the big picture

Advances in science and technology have been crucial to building these predictive capabilities, and to analyzing the biology, chemistry, and physics of the tiny organisms and their watery world.

Satellites now play a major role in phytoplankton research. Kudela received a NASA grant for HAB forecasting, and his lab uses the space agency’s satellite data in a variety of ways.

“With remote sensing you can see the big picture, and take that information and move it into models so you can make predictions,” he said.

High-resolution satellites can precisely measure the amount of biomass, light scattering, chlorophyll, and



This map, from the prototype prediction model developed by Kudela, displays the probability of abundance for toxin-producing phytoplankton along the California coast during the 2015 HAB.

other pigments in the water. In a 2015 journal article, Kudela's team showed they could use this information to distinguish toxic and nontoxic freshwater algae blooms from space. Further, Kudela can specifically track *Pseudo-nitzschia* by the "signature" it presents to a satellite.

Freshwater HABs are also a concern. Now reported in every state, they can cause health problems ranging from allergic skin reactions to liver failure or sudden death, in both people and pets. Studies show that chronic exposure can even increase risk of cancer. One freshwater toxin, microcystin, sickens Monterey Bay sea otters when blooms flow to the ocean from inland water sources. It has also contaminated the drinking water of more than half a million people in the United States.

Soon, a newly launched satellite may be able to scan smaller bodies of water for telltale signs of dangerous blooms. Kudela's lab is vetting the satellite to make sure the data it picks up from space matches the samples researchers take from the water.

In Santa Cruz, they verified that the satellite could "see" with 10-meter resolution exactly where a freshwater HAB and a saltwater HAB, each producing a different toxin, were mixing in the San Lorenzo River in the quarter-mile stretch between the ocean and the train-trestle bridge.

Kudela then advised city officials to let the peaking algal blooms subside before removing a sand berm and letting the river flow to the ocean. Otherwise, the algae could have seeded new blooms in coastal waters.

Satellites aren't the only practical way to observe and gather evidence for decision making. In a pilot project with the California Department of Public Health, Kudela's lab developed inexpensive, rapid test kits that can be used in the field to check for shellfish toxins. Each kit probes for a different toxin, with a simple stick showing a plus or minus sign, just like a pregnancy test.

Another Kudela-cultivated method that might prove helpful and more economical than traditional assays works by extracting pigments from a water sample to determine its algal constituents. His lab is teaming

up with the U.S. Geological Survey to learn whether this technique can divulge enough information to assess the health of the San Francisco Bay.

"The impact of climate change is a huge open question," Kudela said.

In the short term, higher water temperatures will provoke more HABs, he explained. The 2015–16 El Niño weather system brought both warmer waters and winter storms that washed chemicals from fertilizers, pesticides, and even leaking septic systems into the ocean, where they acted as algal nutrients and increased the chances for a massive spring bloom on the Central Coast for a third year in a row.

In the long term, climate disruption will alter water temperature, precipitation, wind, nutrient availability, light intensity, and ocean acidification. All of which will change—in still speculated-upon ways—the activity and community composition of phytoplankton. For instance, the day-to-day productivity of nonbloom phytoplankton might drop, jeopardizing the aquatic food chain and increasing carbon dioxide levels in the ocean and atmosphere.

Preventing HABs while protecting active—but not hyperactive—microalgae might be possible one day. In the meantime, Kudela said, "monitoring, early warnings, and well-coordinated research is clearly an important investment in food and water safety and in our marine and freshwater environments."

HITCHCOCK & HABs

Alfred Hitchcock's film classic, *The Birds*, was based on a short story by English writer Daphne du Maurier.

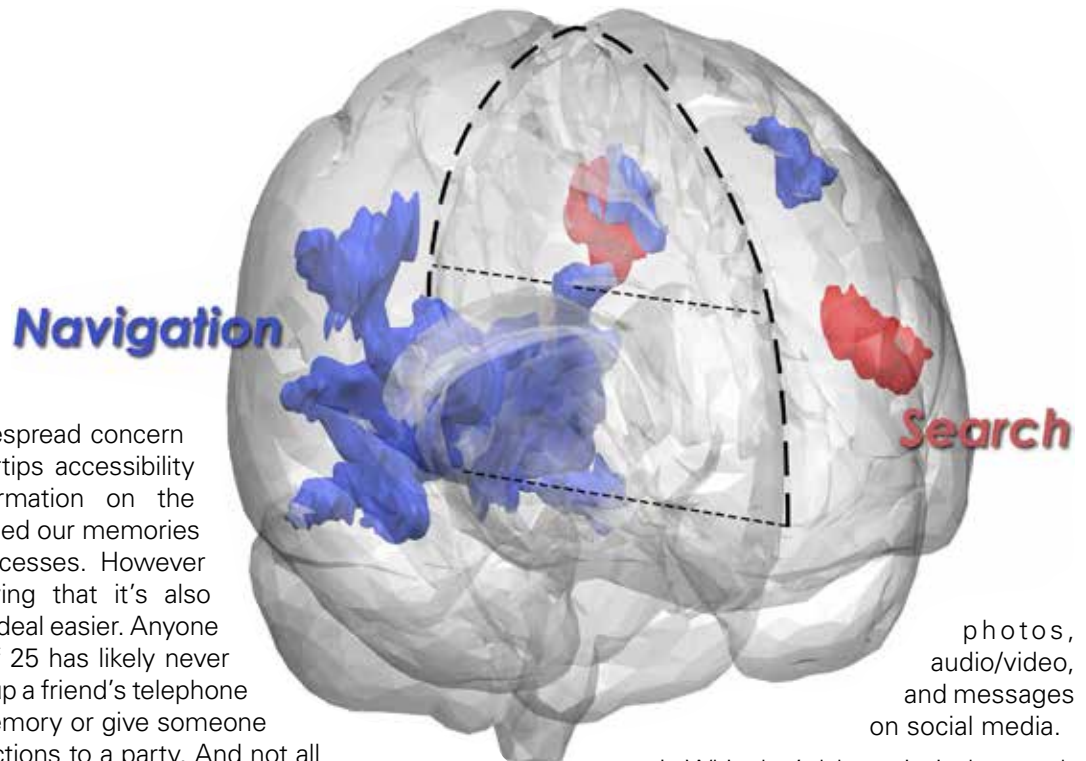
But Hitchcock was also inspired by a 1961 news story about flocks of suddenly berserk birds that slaughtered themselves by dive-bombing buildings in Capitola, a town on Monterey Bay near his vacation home.

Raphael Kudela studied zooplankton cells preserved after that event and found they contained *Pseudo-nitzschia*, a marine algae that can make domoic acid. And the behavior of the disoriented birds, he noted, is consistent with the toxin's neurologic effects.



Total recall

Do digital footprints alter our relationship to the past?



► There is widespread concern that at-our-fingertips accessibility to all the information on the Internet has eroded our memories and thought processes. However there's no denying that it's also made life a good deal easier. Anyone under the age of 25 has likely never had to summon up a friend's telephone number from memory or give someone turn-by-turn directions to a party. And not all scholars share this dim view of the changes digital technology has wrought.

"There's a bunch of ways that technology is absolutely transforming all of these human [thought and social] processes," said **Steve Whittaker**, UC Santa Cruz professor of psychology, who specializes in the study of human computer interaction, the intersection of psychology and computer science. "I'm very interested in trying to document and understand those effects," he said. "But I'm also very interested in how we might better design technologies to help us with things that we have problems with."

One of the problems stems from the sheer amount of digital "stuff" we accumulate. The average person produces six newspapers' worth of information per day—a nearly 200-fold increase compared to two decades ago, according to Martin Hilbert, professor of communication at UC Davis. This figure encompasses digital documents, emails, blog posts,

photos, audio/video, and messages on social media.

In Whittaker's lab, a principal research theme concerns the ways people organize their digital archives, and how the structure (or lack thereof) affects their ability to retrieve a specific piece of information when needed. "A lot of this stuff about organizing file systems, what you're doing is basically trying to guess what the information needs of your future self will be. And we're not very good at that."

Search patterns

Having worked in the tech sector for nine years, Whittaker holds more than 30 patents for communications and user interfaces. He noted that despite improvements in search—and the apparent advantage, in terms of flexibility, of using keywords to locate a computer file—most people use search only as a last resort.

It's no accident that graphical user interface design draws on analogies to the physical world: the icon for a text document looks like a sheet of paper, the icon

for a folder looks like a manila file folder, and so on. Whittaker hypothesized that when we navigate these virtual representations, it engages parts of our “animal brain” involved in locating an object in physical space.

“I don’t want to judge squirrels, but they’re probably not the most intelligent,” he said wryly, “Yet they seem to be pretty good at re-finding things that they’ve hidden.”

Whittaker collaborated with colleagues at England’s University of Sheffield and Bar-Ilan University in Tel Aviv on a study that used functional MRI to compare activity in the brains of 17 students while they retrieved target files from their own laptops, either by navigation or by search. The success rate didn’t differ significantly between the two methods, but the patterns of brain activity were distinct.

When you search, Whittaker explained, you have to think about characteristics of the target document—when it was created, the type of file it is, words it contains, the file name—and intuit what query terms will lead you to it. In contrast, navigation is a lower-level thought process that doesn’t compete for resources with higher faculties. Whittaker concluded that, given the choice, people usually opt to use the less cognitively demanding, if more primitive, method.

Character counts

Of course, the degree to which people attempt to organize their digital information varies. For instance, some individuals create deeply nested hierarchies, with subfolders containing relatively few items that are closely related, while others create a handful of superficial folders into which they lump a larger number of items that are related only loosely. And then there are those who just leave everything exposed on their desktop with no attempt at organization. While many factors likely account for these differences, Whittaker demonstrated that some of these tendencies can be reliably linked to personality traits.

In academic circles, “personality” refers to the way a person consistently thinks, feels, and behaves. Psychologists have identified five major dimensions of personality—openness, conscientiousness, extraversion, agreeableness, and neuroticism. Research has shown that for physical spaces, such as a dorm room or an office, certain cues can reliably predict these traits; for example, the variety of media the inhabitant owns is an indication of greater openness to experience.

Whittaker and his colleagues wrote a program that analyzes where all the personal files on an individual’s computer are stored and how they’re structured. The program strips the folder and file names that might reveal their contents, but shows where in the file

hierarchy they’re located (e.g., on the Desktop, or in a subfolder within Documents).

The research team found that relationships were somewhat different for Mac and PC users, but for both, the personality trait of conscientiousness was related to active organization in Documents and Desktop, reflected in the average number of files per folder.

However, the relationship only held when the overall number of files was low. A more unexpected finding, said Whittaker, was that individuals who scored high in neuroticism tended to have a larger number of files on their Desktops, particularly as their workloads increased. He speculated this might be due to anxiety over forgetting something that needs to be acted on.

Urging caution over reading too much into the results, Whittaker stressed: “These are not amazingly strong effects, but they’re tendencies.” Still, he mused, such insights could be helpful in developing new digital-information-management tools that take personality into account.

Past perfect

Another major theme in Whittaker’s research is the impact of digital memory on people’s emotional well-being. People who routinely use social media platforms such as Facebook, Twitter, and Instagram to share aspects of what they’re doing, thinking, and feeling from moment to moment are creating rich and enduring—albeit somewhat skewed toward positive self-projection—records of the minutiae of their day-to-day lives.

“We’re quite interested in whether that’s changing our relationship to the past,” he said.

Unaided by technology, our recollections of our own histories are not entirely accurate. Human memory positively edits the past via a couple of well-studied phenomena, explained Whittaker. For instance, a vacation may start with long security lines at the airport, getting wedged into the middle seat on the plane, and lost luggage. At the time, these negative experiences seem very salient to the traveler.

After the trip, these incidents may not be mentioned, or even remembered. Psychologists call that positivity bias; people recall two to three times as many positive events as negative ones. And a year later, that hapless vacationer likely won’t remember that the bad stuff happened at all, thanks to the tendency of negative emotions to subside more quickly than positive ones—the so-called fading affect bias.

But what happens, Whittaker wondered, when you go back and read an unimpeachable account (your own!)

Total recall

of the raw emotions—pain, anger, loss—you felt at the time you were going through something difficult? Does it interfere with the mellowing effect of time? The answer, happily, seems to be no.

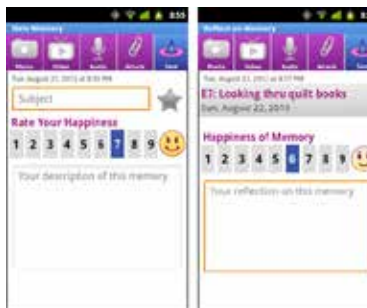
Self-determination

His team designed a smartphone application that allows users to capture what they're doing, thinking, and feeling throughout each day by writing a brief description of an event—including photos, audio, or video if they choose—and rating their emotional reaction on a scale of 1 to 9 (negative to positive). Essentially posting private “status updates” to themselves.

In developing the app, Whittaker randomly assigned 33 study participants to receive one of two versions. In one, the “recorders” were asked to complete at least three entries per day. They could view and edit their posts only until the end of the day, after which point the posts were hidden. In the alternate version, in addition to logging three new events each day, “reflectors” were presented with three previous entries and asked to write down their thoughts and rate their current feelings about the past events.

At the beginning of the study, all participants were given a battery of psychological surveys designed to gauge well-being. The tests were repeated after a month, during which time app users recorded mundane events such as drinking a cup of coffee, major events such as interviewing for a job, negative events such as quarreling with a loved one, and positive events such as enjoying a social outing. Users of both versions of the app showed improved well-being scores with no significant difference between the two.

Both improved over controls who reflected about emotionally neutral events.



Above: The current version of the Echo app, available for Android phones, is intended for people who are basically mentally healthy and just want to improve their well-being.

“Crudely expressed,” Whittaker said, “people get happier just through that experience of recording or thinking through their past experiences.” That finding is in line with research by others in the field of positive psychology who have shown that recording and reminiscing can have health and social benefits. However, technology-mediated reflection may provide additional benefits beyond those of simple recording. It can help people see patterns in their emotional responses to situations and alter their behavior, or gain perspective on negative experiences and reframe them as “redemption narratives” of resilience.

The current version of the Echo app, available for Android phones, is intended for people who are basically mentally healthy and just want to improve their well-being. It doesn't direct users to analyze past events in a structured way. But, Whittaker said, future versions could incorporate prompts based on techniques from cognitive behavioral therapy to help people work through negative feelings by approaching them from a problem-solving stance.

“What's interesting to us from the point of view of designing these types of systems,” remarked Whittaker, “is that people don't know what's good for 'em. We say to people: ‘What kind of information would you like us to present?’ And they say ‘Oh, just keep it positive.’ But in order to get some of the benefits of these applications, it's good to have negative stuff.

We don't know our futures and these technologies are giving us insights into how little we know about what's going to happen to us,” Whittaker added.

Seeing past stereotype

Art historian probes racial dynamics through visual media

▶ Clasp white-gloved hands, swaying side to side, the singer's exaggerated pale lips stand out against his jet-black face. At first glance, actor Al Jolson crooning "My Mammy" in *The Jazz Singer* depicts an offensive image of a black performer.

"It's pretty much impossible for a 21st-century viewer to look at that film and not squirm. How could anyone at the time not see Jolson's performance as a gross stereotype?" wondered **Martin Berger**, UC Santa Cruz professor of history of art and visual culture. But while critics debated aspects of the first feature-length talkie, Jolson's makeup didn't spark controversy among whites or blacks when the box-office hit premiered in 1927.

Berger has long been intrigued by how subtle social forces affect Americans' perceptions, and by the way historical events are represented—and later remembered differently—through such media as movies, paintings, or photographs.

In his analysis of news photos from the civil rights movement, published in his books *Seeing through Race* and *Freedom Now!*, Berger concluded that certain, oft-seen images became canonical scenes because they reinforced prevailing preconceptions of violent Southern whites victimizing powerless blacks.

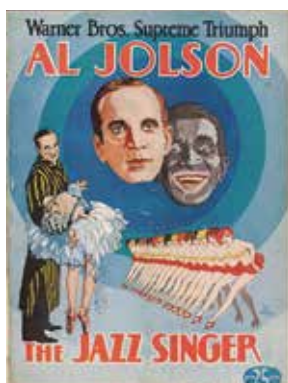
By selecting a small subset of photos showing protestors confronted by police batons, firehoses, and attack dogs, editors emphasized white power and black passivity. Photos depicting black agency or courage—such as Emmett Till's great uncle pointing out

the teenager's torturers while testifying in a Mississippi courtroom—rarely made the mainstream media. Berger contends that such selective documentation built white support for social change but had the unintended effect of limiting the extent of reform.

For his current book project, *Inventing Stereotype*, Berger focuses on the 1920s. Besides spawning *The Jazz Singer*, the decade saw vigorous debate about the nature of race as a biological or cultural category. Into this debate came the modern concept of stereotype, recast by prominent journalist Walter Lippmann as a social shortcut for perceiving something outside one's experience. Lippmann's idea of stereotype quickly took hold throughout American society—and never let go.

With a fellowship from the National Humanities Center, Berger is now examining stereotype through the works of artists such as Archibald Motley Jr., and Eugene O'Neill, who were both acclaimed and derided for their depictions of black culture. Berger suspects that past arguments about whether specific artworks are stereotyped will inform the deeper debate about race. "The controversial works [of art] are much more interesting and revealing of the boundary zone where racial identity is being resolved," he said.

In the end, Berger hopes to explain why our interest in racial stereotype endures: "I want people to understand that stereotype isn't a self-evident thing. Stereotype is a social construction produced in a particular moment."



Above left: Program from *The Jazz Singer* with Al Jolson in blackface; above right: *Freedom Now!* book cover. Below: *Getting Religion*, painting by Archibald Motley, 1891–1981.

Thinking in tongues

Uncommon language hints at linguistic logic

► On the streets of Saipan, the conversations of passersby are a blur of Korean, Japanese, Russian, and—much less often—the island’s native language of Chamorro. Once widely spoken across the Northern Mariana Islands and Guam, native speakers now number only in the tens of thousands, and they form isolated groups within the tiny archipelago in the western Pacific Ocean. Chamorro is on the cusp of endangerment. Before it becomes another lost language, a team of UC Santa Cruz linguists are using it to decipher how we understand sentence structure.

The chance to analyze Chamorro outside of a laboratory setting drew UC Santa Cruz professors **Matthew Wagers** and **Sandy Chung** to the tropical spot. There, they work with Manuel Borja, a Chamorro author and educator, to understand how native speakers comprehend and process the language’s distinctive grammar. Their work is not simply an exercise in examining the exotic.

Observing a language in action, part of the field of psycholinguistics, offers a window into the workings of memory and the logic we use to communicate.

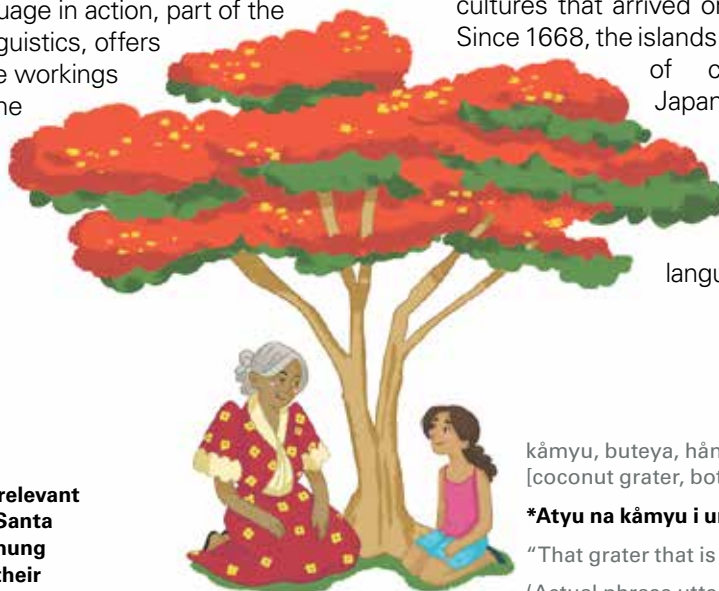
So far, such studies have led to a theory that the human brain relies on common mechanisms for language processing, regardless of what’s being spoken. But nearly 85 percent of psycholinguistics research is based on studying one-tenth of the world’s languages. That’s akin to studying cats and horses and assuming we know how all animals function.

“When we see certain patterns across French, German, and English, we might say, ‘Aha, this is how the mind is wired to process language.’ Well it could be that, or it could be how the mind is adapted to those specific languages,” said Wagers. “Only by looking at distinct languages with different kinds of grammar, like Chamorro, can we see if the same mental patterns hold true.”

Drowning in diversity

Like much of life on the archipelago, the Chamorro language has been shaped by the foreign cultures that arrived on these shores, war after war. Since 1668, the islands have been held by a succession of countries: Spain, Germany, Japan, and finally, the United States.

With every political wave, Chamorro people were encouraged—sometimes forcibly—to learn a new language. But economic prosperity,



Creating culturally relevant images helped UC Santa Cruz researchers Chung and Wagers adapt their studies to work with native Chamorro speakers. There are two sets of translations. The word cues are in gray print. The others are sentences, some provided by Chamorro speakers, to describe the image.

biha, palão’an [old lady, woman]

I biha yan i patgun palão’an gaigi gi papa’ trongku.

“The old lady and the little girl are under the tree.”

kâmyu, buteya, hânnum, apu’
[coconut grater, bottle, water, lean against]

***Atyu na kâmyu i uma’apu’ guatu gi galon hânnum.**

“That grater that is leaning on the water bottle.”

(Actual phrase uttered by a Chamorro speaker in a production experiment. A kâmyu is the wooden object depicted with the lei. You sit on it, like a bench, and use the serrated edge at the tip to grate coconut.)



not colonization, pushed the Chamorro language to the brink of extinction. As money and jobs flowed into the islands under U.S. governance, most homes had two working parents and children were often cared for by workers whose only common language with their charges was English.

“When I first went to Saipan, I remember lots of little kids under the age of five who spoke Chamorro,” said Chung, who’s been going to the island since 1976. “Then they went to English-language schools and spoke English after school with their caregivers. So this generation, from the early eighties to the early nineties, grew up not speaking Chamorro. That was an amazingly rapid language loss.”

The endangered language has a grammar and structure uniquely suited to draw in a linguist. Rather than a classic subject-verb structure, such as “Lisa ate her dinner,” Chamorro sentences often begin with a verb that’s conjugated in myriad ways depending on its subject, type of action, and other features. A single verb at the start of a sentence can speak volumes.

In English, the past tense of a verb such as “kissed” is the same, independent of the person performing the action: “He kissed” and “you kissed” use the same verb. In Chamorro, however, “he kissed” turns into “achiku” while the latter is “unchiku,” so the sentence makes sense even without a subject. For questions, Chamorro verbs are inflected in a special manner called Wh-agreement, in which the form of the verb reflects the grammatical relation between “what” or “who” and the missing material at the end of the question.

These complex words and phrases fascinated Chung. But adapting lab-developed psycholinguistics experiments, which often rely on standardized methods and designs, to field studies of a lesser-studied language like Chamorro had rarely been attempted.

A rich—yet fragmented—past has left the older Chamorro speakers more proficient in the language than younger adults. Yet, speakers have varying levels of literacy in Chamorro; many rarely see the language in print, and the language has at least two different writing and spelling systems.

Furthermore, the tightly knit island community doesn’t readily welcome outsiders. In the early years of her studies, Chung worked closely with Borja, a retired teacher. “We couldn’t post a notice at the library and expect people to show up for experiments,” she said. “We would go out and meet the people who knew the people we knew—that’s the kind of culture it is.”

So, the first question the research group faced was simple: Were psycholinguistic studies of Chamorro even possible?

Field tests

At research institutes around the world, psycholinguists rely heavily on student participants who volunteer to take tests in exchange for cash or class credit. Participating in a research study is often a requirement for basic undergraduate courses, according to Wagers. “At universities, we tend to think of the student population as a very renewable resource for experiments,” he said. “That’s really not possible if you’re in someone’s community or their home—it changes your perspective on how you treat a participant in a study.”



amigu, palão’an, florisí [friend, woman, apply a flower]

Ha florisí ní floris máyu si Bernadita anai munháyan kinadena.

“She put a plumeria flower on Bernadita when she was done with her necklace.”

dengkut, sihik, gâyu
[peck, kingfisher, rooster]

Atyu na sihik i dumedengkut i gayu.

“That kingfisher’s the one that’s pecking the rooster.”



maipi, lâhi, pãtgun, tuâya
[hot, man, child, towel]

Maipi na ha’âni. Ha tâmpi gui’ ni tuâya i tata, kosa ki ti u atagga’ ni semnak.

“It’s a hot day. The dad covered himself with a towel, because he was burned by the sun.”

Thinking in tongues

Working in the field also required Chung and Wagers to modify their experiments significantly. Lab experiments typically last at least 40 minutes, some can extend over hours. So the team adapted all their study tasks to be no more than 15 minutes long from start to finish. Many of their experiments measure reaction times or finger movements when a participant swipes and taps on an iPad.

In one experiment, participants were asked to link a spoken phrase to one of two pictures that represented its meaning. The researchers worked with an illustrator to create culturally relevant images that included coconut crabs, kingfishers, and flame trees rather than less familiar Western species.

Although their work wasn't specifically designed to revive the Chamorro language, it's raised interest in indirect ways. In addition to the psycholinguistics studies, Chung and Borja are part of a project to create a comprehensive Chamorro dictionary. One of Wagers' students is working on a browser extension to translate Chamorro on websites.

Ripple effects

In a 2015 study published in the journal *Language*, the team observed how Chamorro speakers reacted to question statements to see if the mental processes involved are similar to those in English.

When a sentence such as "John chopped the steak with the cleaver" is turned into the question "What did John chop the steak with?" speakers move the words around so that the subject of the question moves to the front of the sentence. The way people connect the first word in that question, in relation to the position in which it originally appeared, hints at how we use memory to understand language.

Previous studies of English have suggested that the instant listeners hear a question word, they begin to guess what the question is about. Asking "What did John chop?" elicits guesses such as, "Is this about the object he chopped? Or the instrument he used?" And so forth. These quick predictions partly explain why we're able to use language without pauses. If we waited, the added processing time, perhaps hundreds of milliseconds, would make conversations sound stilted or cause listeners to forget what they heard.

In Chamorro, questions often begin with a verb that's uniquely inflected to tell a listener precisely what the question is about, so they don't need to make those quick guesses. Rather than predictively parsing what a question might mean, Chamorro listeners appear to simply wait a little longer for the disambiguating word.

"As a listener, you wouldn't make too many aggressive predictive guesses because all of the information is going to come in a relatively tight packet and you can say—okay, that's what they mean, I'm not going to waste my time making wrong guesses," said Wagers.

Predictive parsing works in a top-down way. Even as our brain receives external information, it begins to fill gaps or make guesses based on previously stored knowledge. An alternative mechanism, called bottom-up processing, could work by pausing to listen to incoming cues before ascribing meaning to words. While top-down mechanisms might help English speakers think fast, bottom-up processing might be more efficient when processing Chamorro questions.

"Without sampling different languages, it's impossible to know whether we're biased in estimating how these two mechanisms interact," said Wagers. "When we come up with a theory on language processing based on English, is that a universal wiring diagram for how things work in your mind?"

Chung and Wagers' studies of Chamorro suggest that the way top-down and bottom-up processing work together is adapted to the structure of individual languages. Moreover, the pattern of top-down parsing that seemed so widespread among languages was not present in Chamorro.

There's an emerging view that the design characteristics of working memory are shared between language and other processes, noted Wagers. "We might have a dedicated neural circuit for language and another for remembering where the car is parked, but the construction of both circuits is likely the same," he said. Assuming a processing mechanism is the default based on studies of just a few languages might make us miss other ways our brains work—or fail, he added.

As Chung and Wagers investigate Chamorro's linguistic idiosyncrasies, their research is revealing the brain's blueprints for building these circuits.

pānglao, peskadot, kostat, ayuyu, ākka' [crab, fisherman, bag, coconut crab, bite]

***Atyu na bihu i bumebendi ya manteteni nu kostat, ya inakka' addeng-ña ni panglao.**

"That old man who is bending and holding a bag, his leg is bit by a crab."

(Actual sentence produced by a Chamorro speaker in a production experiment.)



Unwinding the clock

Carrie Partch breaks circadian rhythms

► When the circadian clock stops, most healthy cells wither and cancer cells thrive. The clock is our body's 24-hour timekeeping system that helps regulate everything from insulin levels to cell division. For years, scientists wondered how cancer cells dodged the circadian cycle. Then, **Carrie Partch**, UC Santa Cruz assistant professor of biochemistry, discovered a protein with the unwieldy name of PER-ARNT-SIM domain containing 1 (or PASD1) and began to understand what made that clock tick.

Partch was the first to show that PASD1 can stop circadian rhythms. Her study findings, published in *Molecular Cell*, strengthen the link between disrupted clock function and cancer. Her research also points toward a new target for cancer therapies.

The relationship between cancer and the clock is just one of the questions driving Partch's research. Her lab creates high-resolution "snapshots" to see how globs of proteins interact with each other and the cell's DNA to keep the clock running. The health implications are big; many chronic illnesses, including diabetes and heart disease, arise from irregular circadian rhythms. Uncovering the underpinnings of the clock could improve medications that target disrupted circadian-controlled genes.

"There are so many important questions to answer that haven't been dealt with yet," Partch said of the potential discoveries in the circadian field. "It's not low-hanging fruit; the fruit is so ripe it's falling off!"

For billions of years, life on Earth has abided by a strict solar schedule. In animals, plants, and even single-celled bacteria, the circadian clock ticks tirelessly over 24 hours, driving daily cellular rhythms to match the planet's light and dark cycles.

In people, a "master clock" contained in the hypothalamus of the brain takes light cues from the Sun to send a ripple of chemical and temperature signals that tell the body's tissues when to turn on, or off, the right genes. These circadian-controlled genes regulate metabolism, blood pressure, hormone levels, and most other aspects of our physiology.

"The clock has evolved, I think, as a mechanism to help us prepare for the profound transitions from being upright and active to horizontal and sleeping," said John Hogenesch, professor of systems pharmacology and translational therapeutics at the University of Pennsylvania, in Philadelphia. Hogenesch discovered two of the four core proteins that regulate the circadian cycle in cells.

The 24-hour feedback loop starts when the proteins CLOCK and BMAL1 bind together to activate the production of two more proteins: period (PER) and cryptochrome (CRY). After accumulating in the cell, at just the right time PER and CRY bind together. This new PER:CRY complex migrates into the cell's nucleus to block the CLOCK:BMAL1 complex; this binding stalls further transcription until the proteins degrade and the cycle starts anew.

Studies have shown that a dysfunctional circadian clock leads to health problems, including diabetes, neuro-degenerative diseases, and cancer. Disruption usually occurs when something disturbs the complex interactions of proteins driving the clock.

The only human cells without circadian rhythm are embryonic stem cells and some cancer cells. They share one thing in common: the PASD1 protein. For years, scientists assumed there was no built-in way to shut down these vital circadian rhythms, but Partch had a hunch that this protein was the key.

Unwinding the clock

Little Legos

Proteins are made up of multiple units called domains that fit together like Legos, said Partch. The shape of the domain determines which molecules the protein can interact with. PASD1 is structurally similar to the CLOCK protein except it's missing the domain that binds to DNA. This made Partch think that it could block the CLOCK protein's ability to activate genes. When she started her lab at UC Santa Cruz, Partch began a series of experiments to test her hypothesis.

In a healthy cell, scientists can see the clock "ticking" by fusing a bioluminescent tag to one of the core clock proteins and then tracking it through the course of one day. "We can watch the light being emitted in these beautiful waves of the clock," said Partch. She traced an imaginary sine wave. Each peak represented a burst of gene expression every 24 hours, she explained.

In a tumor cell, the waves are irregular and weak, a clear sign that circadian rhythms are not functioning at full steam.

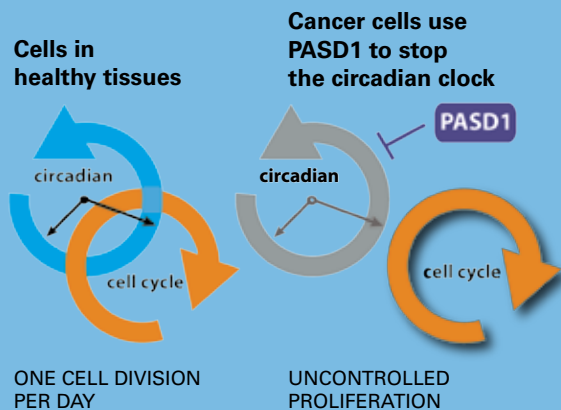
The success of this project drew **Alicia Michael**, one of Partch's first graduate students, to the lab. "It got me really excited that we could basically change the Wikipedia page if we figured out what it does," said Michael, lead author of the paper in *Molecular Cell*.

Partch and Michael altered the PASD1 gene on tumor cells to either overproduce the PASD1 protein or prevent its expression. The cancer cells without the PASD1 protein began to emit more regular, glowing waves, demonstrating the protein's disrupting effect on the circadian cycle. They think that PASD1 binds to the CLOCK and BMAL1 proteins, blocking circadian gene expression.

Cancerous cells have an advantage by shutting off the clock, said Hogenesch, who was not involved in the study. "If the cell wants to keep dividing and dividing and dividing, maybe it doesn't want to be told it has to divide at one time of the day."

Germline stem cells are the only healthy cells that produce PASD1, so when the protein shows up outside those cells, the immune system takes notice. That reaction means that targeting PASD1 could lead to cancer treatments, said Hogenesch.

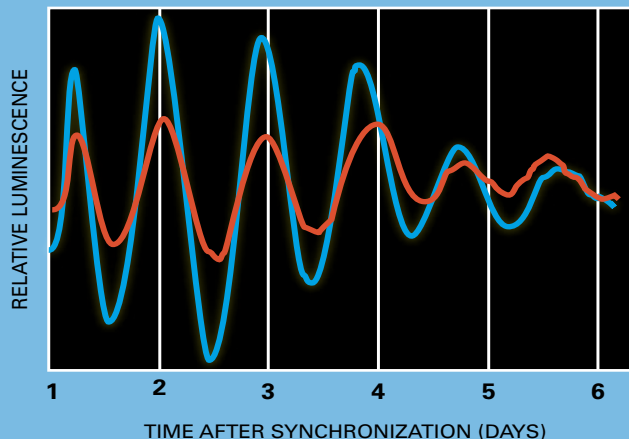
Cancer cells use PASD1 to evade the circadian clock



Above: An illustration to convey how circadian rhythms and the cell cycle are linked, and how PASD1 might disrupt that rhythm in cancer.

Below: Colon cancer cells express PASD1, the protein that can block the clock. By using a bioluminescent tag, researchers could illuminate the weak, glowing circadian waves (RED) of the cancer-afflicted cells. When they restricted PASD1 expression, the clock dramatically improved (BLUE), resuming its more regular sine wave form.

Cancer cells with PASD1 (red) Suppressed PASD1 cancer cells (blue)



Protein power

Partch first learned the power of protein structures as a graduate student in the lab of biochemist Aziz Sancar at the University of North Carolina School of Medicine, in Chapel Hill.

Sancar may be best known for his Nobel Prize-winning work on a bacterial protein that uses blue light to repair UV-damaged DNA. But, years ago, he was interested in cryptochrome because of its similarity to the DNA repair enzyme. He discovered cryptochrome didn't repair DNA; instead, it was one of the core clock proteins. Moreover, unlike most proteins, which stacked neatly together, cryptochrome had a strange, wiggly tail. Sancar wanted to know what the heck it did, Partch recalled.

With Sancar's encouragement, she collaborated with a structural biology lab that made high-resolution images of the oddly built protein. They showed that in plants, exposure to light made the cryptochrome release an intrinsically disordered tail; a dynamic, flexible domain that tells the plant it's time to rise and shine.

"That has been really key to understanding how cryptochrome works, so she gets full credit for it," said Sancar. This insight into biochemical problems keeps Sancar sending his research papers to Partch for her opinion before he submits them to journals for publication.

Dynamic domains

Structural biologists approach the clock by taking high-resolution pictures to try to tease out the details of protein interaction at an atomic level, said Ning Zheng, professor of pharmacology at the University of Washington, in Seattle.

Zheng was the first to solve the overall structure of cryptochrome in mammals, but was missing key information about the mobile element. It was difficult to find an imaging technique that could capture precisely how the flexible tail region engaged in protein interactions.

"Why do we want to know the details? The clock is super important to all living systems. In humans, it's highly related to health," said Zheng.

Partch nailed down cryptochrome's movement—solving how the protein works as the "pause button" of the clock—using nuclear magnetic resonance (NMR) spectroscopy. The technique picks up radio signals emitted in a magnetic field from every amino acid, the molecular building blocks that make up

a protein. The signals build a "fingerprint" of the protein; throw another protein into the mix and the fingerprint will change. The method tells you where important interactions are happening on the protein, an essential tool to guide experiments, said Partch.

To spotlight these key places, Partch made mutations at the site where BMAL1 and cryptochrome interacted. When they strengthened the connection of the two proteins, the circadian clock extended another hour. When they weakened the interaction, the circadian clock got as short as 19 hours, or fell apart altogether. This revealed that the binding site was crucial to holding off transcription until just the right time. The study was published last year in *Nature Structural and Molecular Biology*.

Thinking big

Our understanding of the circadian clock is transforming the way we treat disease, said Hogenesch. For instance, cholesterol is on a circadian schedule and its production peaks while we sleep. Since many cholesterol-lowering medications are only active for a few hours at a time, taking the drugs at bedtime works best to prevent heart disease. In a 2014 study, Hogenesch found that hundreds of FDA-approved drugs targeted circadian genes, suggesting that many other medications could improve with dosing timed to the body's clock instead of the wall clock.

Partch's lab is now developing direct drug-screening approaches to find new therapies aimed at the molecular underpinnings of the clock. For example, scientists know that high-fat diets can weaken the circadian rhythms' controlling metabolism. By pinpointing how two proteins come together to regulate that circadian-controlled gene, perhaps a molecule could be found to strengthen those clock rhythms and override the effects of the high-fat diet.

"It's not just lip service," said Partch. "Direct screening would save us years of asking what this amazing molecule does in the black box of the cell."

Beyond understanding how pieces of clock proteins interact, Partch and her graduate students are asking a more fundamental question: "How do these different protein complexes change over time to give rise to the timekeeping itself?"

The future



Present-day ruins at Karnak

Karnak in the time of Thutmose I

Archaeologists use digital tools to dig into an ancient site.

► The image of the Egyptian temple is beautiful: sun-warmed stone bricks glow; the shadows cast on the ground and buildings make a dramatic geometry. A row of statues and fluted columns flank a dark doorway. But this image is more than a lovely photograph. It can also reveal, beyond the portal, walls covered with bas-relief carvings of ancient religious rites and granite obelisks piercing the sky.

This likeness is a 3D virtual model of the ancient Karnak temple, a center of Egypt's spiritual life for millennia. The immense compound has been fully and accurately re-created via computer and is available online as part of the Digital Karnak Project created at UCLA with **Elaine Sullivan**, assistant professor of history at UC Santa Cruz, as a main collaborator.

Moving through such a richly detailed 3D space provides a compelling learning experience. But even more important, virtual models are scientific visualization tools that, in the same way as early telescopes, allow researchers to see in new ways and understand things that were not possible to study before. With digital tools, archaeologists can scan buildings and artifacts, map site dimensions, and peer below the ground without digging.

"There's a revolution going on in archaeology now, with imaging and digitization out in the field. We need a matching one in how we analyze and display the results of our work," said Sullivan.



Professor Sullivan used the Karnak model to see how priests might have carried a sacred statue through the temple. Digital models, with their accurate dimensions and other characteristics, allow researchers to visualize events and test their theories about the spaces.

of the past



Karnak site after Thutmose III added a roof and new papyrus-style columns

The virtual model draws on more than a hundred years of archaeological work at the site. The Digital Karnak website lets users explore 2,000 years of history, watching the temple grow and change under Egypt's different rulers, from Senusret I through Ptolemy VIII and into the Roman era—adding a fourth dimension of time.

Alongside still shots and video fly-throughs of the model, the evolving website holds a trove of information on Karnak's buildings and other features. Users can read how ancient priests honored the gods with daily offerings, trace the routes of ritual processions through the 69-acre site, learn about quarrying stone, and discover the difference between fluted, papyrus, and Hathor-headed columns. There are photographs of the site as it looks today, artifact

descriptions, downloadable materials for use in teaching, and a bibliography.

A simplified version of the model on Google Earth lets users move through Karnak's buildings on their own, like a video game. A fully detailed, interactive model intended for scholars is under development. "We want to create an annotated model with all the information embedded in the site, so you don't have to read-then-look—you learn from right there in the model," said Sullivan.

Eventually, Sullivan envisions archaeologists using virtual sites to publish their research, bypassing traditional journals and pouring their data and analyses into freely available models for others to access and examine. She's working hard to bring such a future to the past.

Saqqara, a cemetery site near the Great Pyramids of Giza, is Sullivan's next target for digital modeling. She's adding landscape information to her architectural model that will allow her to study the buildings in a geographic context, clarifying things like their relationship to the Nile River and sight lines to other monuments.



Professor Sullivan onsite at Saqqara



Ahmet Yanik holds his nanopore device up to the light. The three squares become opaque when proteins are bound to them.

A lab in the hand

High-tech creates low-cost medical tests

► In the late summer of 2014, new Ebola virus cases in West Africa jumped from around 150 to more than 500 per week. With no vaccine and no cure, quarantining infected individuals was the only hope to halt the epidemic.

Suspected Ebola patients—those with high fevers and potential viral exposure—could wait up to a week in cramped, makeshift “holding centers” while their blood samples were tested at the few diagnostic labs. A Doctors Without Borders study conducted at the height of the epidemic found that more than a third of the patients initially diagnosed with the virus returned a negative blood test. These patients may have come to the clinic with malaria or Lassa fever but left having been exposed to Ebola virus, which spreads readily through saliva, blood, and other bodily fluids.

There’s no way to estimate how many patients might have been infected in the holding centers, the study concluded. But the situation demonstrated the critical need for point-of-care diagnostic tests that were accurate, fast, affordable, easy to administer and read, and didn’t need an external power source.

While other researchers have focused on miniaturizing current laboratory techniques to create “lab-on-a-chip” devices that rely on chemical reactions to detect the virus, two researchers at UC Santa Cruz took a different approach—exploiting the behavior of light on the micro- and nanoscales to reveal Ebola molecules directly. Initial results indicate these lab-on-a-chip prototypes could be as sensitive as the current gold standard tests, at a fraction of the cost.

Finding Ebola’s code

The gold standard Ebola test uses a reverse transcription polymerase chain reaction (or RT-PCR) to amplify the viral genetic material and tag it with fluorescent molecules. Hit these tags with a specific color of light and they re-emit it as a different color. For example, violet light converts to green, and the green light’s intensity is measured by a sensor.

This process takes more than two hours and requires specialized lab equipment, exotic chemicals, and trained technicians. Even a few contaminating Ebola molecules from another patient’s sample can return

a false positive result. All these factors add up to around \$100 per test, about a third of the average yearly salary in West Africa.

For emergency use during the most recent epidemic, the U.S. Food and Drug Administration approved a far simpler commercially available device called the ReEBOV Antigen Rapid Test, made by Corgenix Medical Corporation. Reminiscent of a color-change pregnancy test, it uses an antibody-laden strip which changes color when it binds Ebola proteins in the blood. The test takes about 15 minutes and costs around \$10.

While the ReEBOV is slightly less accurate when compared in a lab to RT-PCR, in field tests the device matched the RT-PCR results 100 percent of the time. Robert Garry, a virologist at Tulane University in Louisiana, who helped design and test ReEBOV, noted that sensitivity mattered less because “people with such low levels of the virus aren’t showing up at the clinics.”

However, Ebola’s aggressive nature makes early viral detection a priority.

“One would like to test, isolate, and treat lots of people before they show symptoms and are already approaching death,” said UC Santa Cruz electrical engineer **Holger Schmidt**. In an article published in *Nature Scientific Reports*, his lab demonstrated a lab-on-chip that could sift through extracts of human

When he joined the faculty at the Baskin School of Engineering, he developed an approach to coax light through gas vapors on a chip, and then applied them to liquids, specifically liquids containing biological molecules.

The idea to analyze single biomolecules on a chip came from conversations with David Deamer, a UC Santa Cruz biomolecular engineer who developed techniques to glide strings of DNA through sub-microscopic holes, called nanopores, to study the DNA’s molecular bonds. With collaborators that include a chip-manufacturing group, Schmidt’s group produced a two-chip hybrid device. The clear silicon-based microfluidics chip isolates individual molecules from the sample and chemically preps them for detection on the second optofluidics chip. The two are joined by flexible tubing and the whole system is about the size of a microscope slide.

The thumbnail-sized optofluidics chip resembles a piece of modern jewelry, with tiny copper cylinders rising above iridescent patches that shimmer pink to green in changing light. The cylinders hold the solution containing Ebola RNA with fluorescent tags, and then release the molecules, one by one, into liquid-filled channels that look like golden hairs etched into the chip. Other golden lines are the solid channels that carry light. Where the channels intersect, the light flows through the liquid and any passing molecule. As in RT-PCR, light is absorbed and released as a different color. But because the tagged RNA passes through single file, the optofluidic’s sensor can count each flash, or, as Schmidt likes to call it, “blip.”

Schmidt’s device is generic. Proteins, viruses, and even small bacteria can be tagged and counted. “We use exactly the same chips. One day we test Ebola, the other day cancer markers,” said Schmidt. This non-specificity will help keep costs down to one or two dollars per device.

While Schmidt’s device is disposable, it needs an external case to supply electric power and light. The device doesn’t quite snap in; the fiber optic cables’ alignment needs to be manually adjusted by microscrews—a process Schmidt said will be automated in the final prototype. His lab is also optimizing the microfluidic system to be faster and capable of running larger volumes of starting sample.

By the end of the year, they plan to deliver a portable external case to be installed, permanently, at the Texas Biomedical Research Institute’s biosafety level-4 lab in San Antonio. There, technicians trained in virology, not optics, will test the devices on live viruses.



Several of Holger Schmidt’s optofluidic chips to be used in counting molecules tagged with fluorescence.

cells infected with Ebola and detect as few as two infectious particles in ten milliliters—about two teaspoons—of sample.

Rather than trying to amplify DNA on a microscale, Schmidt built a device that simply counts virus RNA genomes. “Let’s say we run one milliliter [of sample] through our chip,” he said, “however many blips we get, that’s the viral load.”

Schmidt’s background is in physics, studying the quantum effects of light in semiconductor devices.

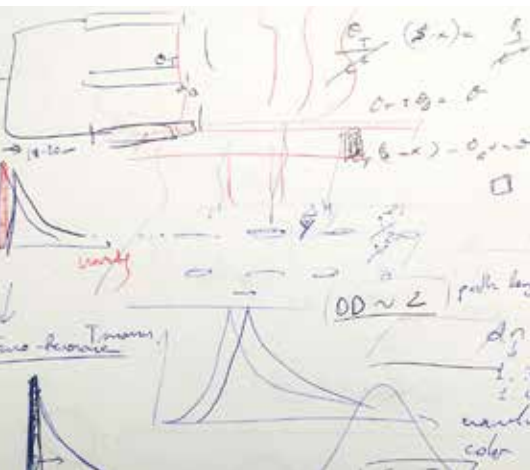
PHOTOS: BY MACIEK SMUGA-OTTO

A lab in the hand

"They've come up with a very good solution that is state-of-the-art," said Ajeet Kaushik, a bioengineer at Florida International University, in Miami. An immunologist by training, he's reviewed various point-of-care Ebola diagnostic technologies, including an Ebola protein detection device under development by **Ahmet Yanik**, UC Santa Cruz electrical engineer.

Naked eye detection

Unlike viral diagnostic tests that rely on chemical reactions to make the proteins visible, Yanik's idea is to simply use light "in a label-free manner, no enzymatics, no fluorescence, to see proteins directly."



Ahmet Yanik's notes

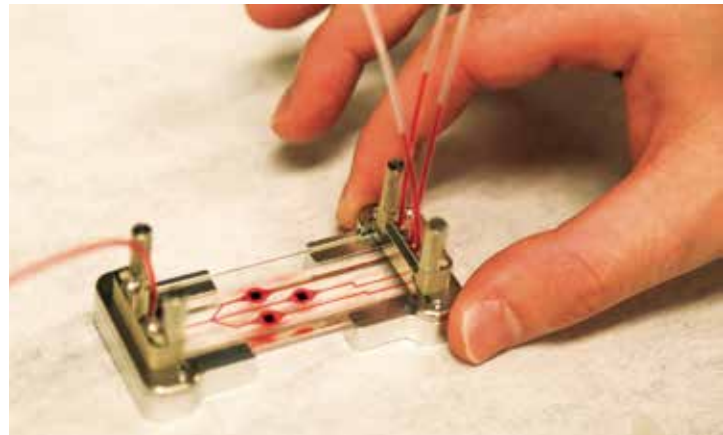
The device he designed works because of a curious optical phenomenon called the extraordinary light-transmission effect. Shining light through an arrangement of holes that are narrower than the light's own wavelength produces much more light than beaming it through one big hole.

As he talked, Yanik scribbled down graphs, diagrams, and formulas on printer paper. He hastily filled in the page with four to six images

before flipping it over to explain the next concept.

"The nanoholes are so small," said Yanik, "light shouldn't be able to pass through them." But it does, through its interaction with the nanohole surfaces. By coating the nanoholes with different antibodies, Yanik can use the device to bind any protein—cancer markers, drugs, or even a whole virus. When he captured killed Ebola biomarkers on the nanoholes, the transmitted wavelength (or color), shifted about 15–20 nanometers. That's too subtle for our eyes to see, but easy to measure electronically.

As a postdoctoral fellow at Harvard, Yanik developed a device that worked great in a state-of-the-art hospital lab. He jokingly called it the "chip-on-a-lab"

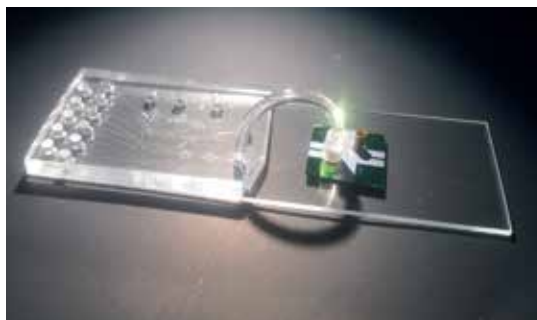


Ahmet Yanik's lab-on-a-chip with liquid covering the three nanopore plates.

system. To take the chip out of the lab, he figured out how to constrict the wavelength range that could pass through the nanoholes.

On paper, Yanik drew two sharp peaks with almost no overlap to show the light transmitted with, and without, the attached virus. Place a filter over the device to cut out the longer wavelengths and the material with the nanoholes turns from translucent to opaque. When the virus binds, said Yanik, "you have complete darkness."

He flipped another page. Light detection is not the only hurdle, said Yanik. Blood is thick with proteins that can bind randomly in the nanoholes, shifting the light and causing a false positive reading. Equally critical is making sure the test works quickly—it isn't practical to wait six hours to decide if someone should be quarantined.



Schmidt's hybrid device integrates a microfluidic chip for sample preparation and an optofluidic chip for optical detection of individual molecules of viral RNA.

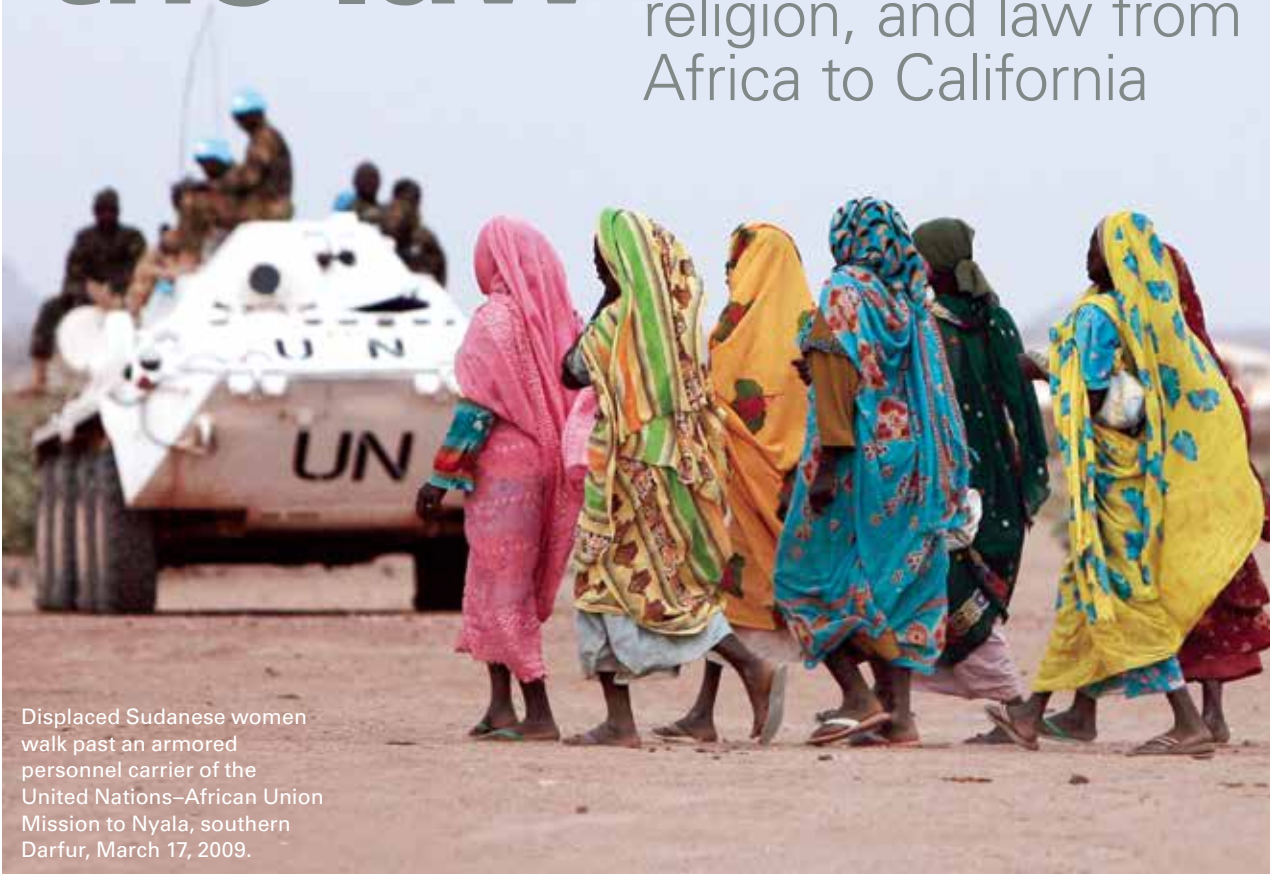
Since starting his UC Santa Cruz lab in February 2014, Yanik and his graduate students have tackled these problems. Now they hope to have a device in production within a year or two. Over time, the pitch for his device has changed. It used to be all about responding to biological threats from terrorists. Now his presentations include a slide listing the leading causes of death in the

developing world; almost all are infectious diseases.

"In this lab," said Yanik, "I can detect anything. But can I do that in the far corners of the world? It seems that is where you can make a huge impact."

Following the law

Chronicling politics,
religion, and law from
Africa to California



Displaced Sudanese women walk past an armored personnel carrier of the United Nations–African Union Mission to Nyala, southern Darfur, March 17, 2009.

► When peace returned to Sudan after more than two decades of civil war, **Mark Fathi Massoud** followed. After a long absence from his native country, the UC Santa Cruz professor of politics and legal studies spent a hot and dusty summer interviewing people about their encounters with law during those tumultuous years. He returned repeatedly during the next six years to question hundreds more. His goal was to uncover the way successive rulers exploited the law throughout the country's troubled history. Ultimately, his investigations revealed how law survived in the thick of political chaos.

Massoud's research documents the interaction between law and society. Scholars in his field study

how citizens use courts and the legal system to further political agendas. Most of that work has focused on institutionalized settings in developing countries. In the United States, for example, *Brown v. Board of Education* pushed forward the goals of progressives who considered school segregation morally wrong. More recently, gay activists won the right to marry via a series of court decisions.

A few intrepid scholars have broadened this scope, studying women's rights in the Middle East, environmental rights in China, or gay rights in Asian countries. But they are the vanguard and—until Massoud—none had considered looking at laws and courts in the world's most fragile states.

Following the law

“I realized there’s a gap here,” said Massoud. “Do all these grand theories about law and society apply to a place like Sudan?”

Expanding on that research, he’s now documenting the complex interplay of religion, law, and politics in places as disparate as war-torn African nations and his adopted home, in California.

Back to the beginning

When Massoud told colleagues he planned to write about the rule of law in Sudan, they joked to him that his book would be a short one. The country has only known ten years of democracy, scattered between lengthy dictatorships, since its release from British colonial rule six decades ago. Between 1983 and 2005, the country was wracked by war between powerful politicians in the country’s capital of Khartoum and forces in what is now known as South Sudan.

Accounts of the country’s southern and eastern regions are peppered with words like “lawless” and “chaos.” With such strife, Sudan has ranked at, or near, the top of the Fund for Peace’s Fragile States Index (formerly known as the Failed States Index) for years. The Index tracks a dozen factors such as the number of refugees and internally displaced people, economic decline, and governmental legitimacy.

Massoud was drawn to understand the paradoxical role that law played in his war-torn homeland. His own family fled Sudan in the early 1980s, and he returned to study not just Sudan’s postcolonial history, but how the legal framework constructed during colonial times set the stage for post-independence laws. His collected observations became an award-winning book, *Law’s Fragile State*.

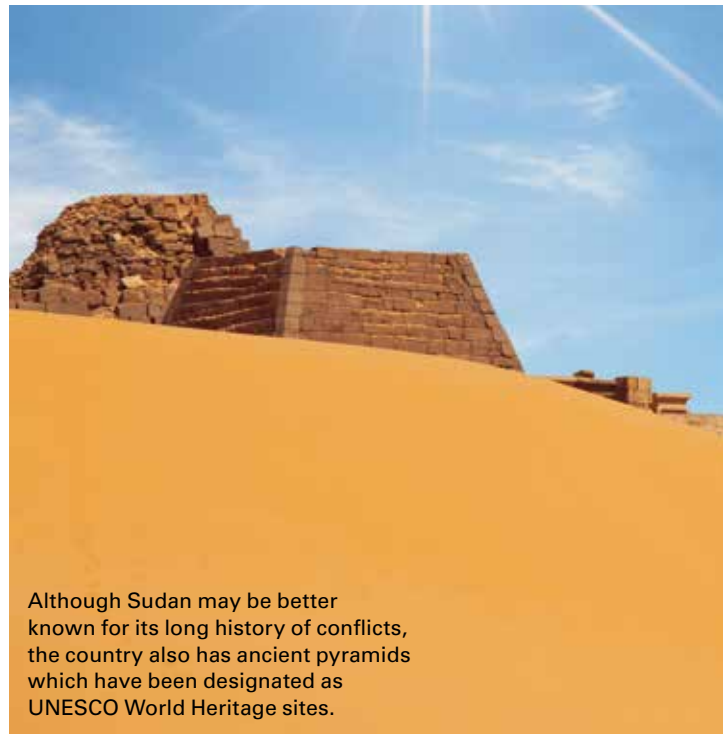
“Trained in the study of the law, his work reaches deep into other disciplines like political science, sociology, and anthropology in ways that are novel and thought provoking,” said Kent Eaton, UC Santa Cruz professor of politics.

Massoud examined Sudan’s rule of law during three political eras: colonial times, during the country’s post-colonial independent years from 1956 to 2005, and the transitional period between 2005 and 2011. Finally, in a move facilitated by peace treaties signed six years earlier, South Sudan seceded from Sudan in 2011.

Despite those upheavals, he found that law wasn’t absent from Sudan. In fact, it permeated the country even as a series of autocratic rulers sought to bolster their legitimacy and strengthen their power by manipulating the legal system.

In Sudan

For more than 50 years, from around the turn of the 20th century to Sudanese independence in 1956, colonial rule in Sudan was a joint operation between Egypt and Britain. In reality, power was retained mostly by the British, but they made room within the colonial legal system for Islamic laws and local customary laws for matters such as marriages and family disputes vis-à-vis a parallel court system run by local arbiters. They also provided courts where Sudanese could petition for exceptions or minor changes to the law involving issues such as adjustments to a family’s grain allocations or allowing a murder victim’s family to request a death sentence.



Although Sudan may be better known for its long history of conflicts, the country also has ancient pyramids which have been designated as UNESCO World Heritage sites.

After independence, Sudan suffered through a series of shaky governments. Democratically elected governments were routinely toppled in a series of coups d’état. But Massoud noted that both the democratic governments and the dictatorial rulers used the law to push forward their political goals. When they could, democratic governments attempted to build new laws on the British colonial common law system. In turn, authoritarian governments sought to consolidate their hold on the country through legal maneuvering of Sudan’s system. For example, when dictator Jaafar Nimeiri neared the end of his regime in the early 1980s, he suddenly decreed that all

Sudanese law would be based on shari'a (roughly translated as Islamic religious law).

As a counterbalance to government machinations, since 2005 an influx of aid groups—including United Nations agencies, the World Bank, and other human rights organizations—have sought to teach Sudanese people about their country's laws and international laws. Massoud noted that international aid workers also often see the law as a way to promote equality among the citizens of developing countries.

However, human rights NGOs are not an unalloyed good in this conflict-ridden country. Despite noble goals, their abstract ideas about human rights may not take into account the particular ways that Sudanese



authorities can stymie the rights of their citizens. Trainings for local people may help them understand human rights conceptually, but it may not help them apply those ideas to their own predicaments.

Massoud also noted that one unintended consequence of these trainings is that authoritarian regimes may allow NGOs to operate in their country to create a false legitimacy among the Sudanese and international powers. This further cements dictatorial control, despite ongoing oppression of citizens' rights. For example, President Omar al-Bashir, indicted by the International Criminal Court for his

part in atrocities in Darfur, allows NGOs to operate in Sudan, but only within limits set by his government.

"When those boundaries are transgressed, these organizations face persecution from local or national authorities," Massoud said. Sudanese government authorities routinely thwart court petitions they see as problematic, and human rights advocates are regularly jailed or, in the case of foreign aid workers, ejected from the country.

Massoud argues that none of these—neither the colonial rulers, the authoritarian regimes, nor the NGOs—are monoliths. Therefore, their impact cannot be simplified as either good or bad. Even within the worst of dictatorships that exert great power and abrogate citizens' rights, there are individuals—usually at lower- to mid-levels of government—that attempt to make decisions that promote human rights and democratic representation, said Massoud, thereby muddying the divide between authoritarian and democratic governments.

This work in Sudan formed the basis for both Massoud's doctoral dissertation at UC Berkeley and his first book. Massoud's thesis adviser, Malcolm Feeley, made the book required reading for his courses at UC Berkeley and said he expects it to become a critical text about law in unstable countries. Among other awards, Massoud earned a Guggenheim fellowship for his contribution to the study of law, and most recently has been named an Andrew Carnegie Fellow.

Exploring uncharted territory

"An important, new, understudied issue arose and Mark helped define the nature and scope of it," said Feeley of the relatively new study of the rule of law in middle- and low-income countries. "Of all the people who have worked in [this area], his work is not only among the very best, he has the most extreme case—in the instance of Sudan—to explore law and courts. And what he reports is a tragedy."

Between 2005 and 2011, Massoud conducted more than 200 interviews in Sudan for his studies. He spoke to clerks and judges, government employees, humanitarian aid workers, and civil society activists. The interviews with locals were often fluid, consisting of a series of open-ended questions about the law, human rights, and what role they played in Sudanese life. He asked lawyers and judges about the details of the Sudanese legal system and he asked civil activists what motivated them to undertake the risks they did for their work.

Following the law

But arranging those conversations wasn't easy.

"Professor Massoud has faced and overcome tremendous logistical and cultural challenges in his research," said Eaton, "which combined formal interviews with high-level political and judicial elites in Khartoum and Juba on the one hand, with ethnographic insights derived from extensive conversations with individuals in camps for the internally displaced on the other."

Relying on his early exposure to Arabic as a child and language studies while he was a law student, Massoud spoke and read Arabic well enough to navigate the country and parse written legal documents. Weaving through the cultural issues took more effort, since most of his formative years were spent abroad.

One inescapable challenge of working in Sudan was what outsiders have called the country's "IBM" mentality. It's not a reference to the tech giant; the phrase dates back to colonial times and refers instead to "Inshallah, Bukra, Ma'elesh." When Massoud requested meetings with potential sources, he often heard, "Inshallah (if God wills)," or "Bukra (tomorrow, in a loose sense), 11 a.m." But the interview often didn't happen. The interviewee would tell him, after the missed appointment, "Ma'elesh!" (never mind, forgive me).

Over the years Massoud spent researching in Sudan, he came to appreciate the mindset. "You're an academic, and you're trying to get your work done, so Inshallah Bukra Ma'elesh doesn't work because you need answers now, now, now," said Massoud. "But also, it's a little liberating because you can slow down a little bit."

More unnerving were the risks for locals participating in Massoud's research. Speaking frankly about the government in Sudan can be a perilous prospect. Al-Bashir's authoritarian regime routinely apprehends activists and others it sees as dangers to the country's stability. So Massoud had to work to get his sources to trust him. At least one of his interviewees accused him of working for the Central Intelligence Agency. But Massoud persevered, doggedly reaching out, again and again, to make the contacts necessary for his research.

As a result, Massoud is fiercely protective of his sources' confidentiality, revealing scant personal information about them. As an added precaution, he translated all the interviews from Arabic himself, and then transcribed them, too.

Along with gathering information about the technical aspects of Sudanese law, Massoud also documented

the painful realities of life in Sudan, especially among the poor who attended the legal training workshops held by NGOs. He learned of people who had been imprisoned but didn't know what their crime was. Massoud described how internally displaced people fleeing civil war told him about government soldiers' disregard for the rights of civilians in conflict regions and countless instances of outright violence against them. Lawyers he spoke with described the lengths to which the government would go, infiltrating Sudanese human rights groups or disbanding them entirely, if they became big enough threats.

"There's a story there and I've been trusted with it," he said, of the information gathered from his interviewees. "When someone opens up, I'm tasked with holding this precious thing, of what is in someone's heart, what is in someone's mind."

Among his projects in Sudan—and his recent research on Islamic law in Somalia and California—Massoud conducted more than 400 interviews. "It's a lot of stories, and sometimes a lot of stories of suffering," he said.

Inspecting history

In addition to the in-depth interviews and ethnographic studies, Massoud reviewed upwards of 4,000 pages of archived documents and records in three different countries. He reviewed documents in half-a-dozen libraries in Sudan and hunted down files in the historical archives of Sudan's former colonial masters, Egypt and Britain.

Next Massoud looked for recurring words that pointed to themes in the interviews and legal documents. His methodological approach involved categorizing parts of the transcribed interviews using hundreds of codes and subcodes, such as "the impact of colonialism on religion" or "courtroom procedures." He then compared these codes across his interviews and field notes.

To understand the information he gathered, Massoud borrowed an approach from the field of comparative politics, which seeks to understand politics by comparing, for example, the forms of legislature or foreign policy in different countries. Instead of looking at different countries, though, Massoud compared political regimes during different eras of Sudan's history.

"History is very important to me," said Massoud. "Not just the history that shapes the present, but the history that shapes history. In my work, I've thought comparatively across historical contexts within the same national context."



A young girl raises a flag for South Sudan, which seceded from Sudan in 2011 as part of a peace agreement made six years earlier to end Africa's longest-running civil war. Not all countries recognize this independence and conflicts continue in the country, which holds the top spot in the Fragile States Index.

Sudan's neighbors

One of the themes that emerged from Massoud's work on the Sudanese rule of law was how authoritarian leaders used shari'a to give their governments a veneer of religious legitimacy.

Many Westerners are unfamiliar with shari'a, which goes beyond codified law and provides a moral framework for the everyday decisions of Muslims, noted Massoud. It forms the foundation of behaviors such as how to treat others, how to settle disputes between neighbors, and how to make difficult ethical choices such as whether or not to vote for controversial propositions that extend marriage rights to gay couples.

Like Sudan, the governments of Somalia and the self-declared, independent Somaliland also rely on shari'a. These countries share many of the same political troubles, too. Somalia frequently tops the Fragile States Index and has been subjected to civil strife for many years. Border disputes between breakaway states are flash points for violence, and civilians live with the threat of displacement in each country.

For Massoud, these similarities made studying the legal systems of Somalia—and how shari'a is interpreted in a setting like Somaliland—a natural

extension of his work in Sudan. Since 2013, he's done fieldwork in Somaliland, located in the northern reaches of Somalia.

In many parts of the world, including Somalia, he noted, some people justify the brutal treatment of women or minorities using shari'a. But Massoud stressed that the functions of Islamic law depend on context. "It depends on where you are, what time period you're talking about, and which political leader is looking to justify policies, and how," he said.

Rulings made by courts about the obligations and rights of women differ by country. For example, some Muslim-majority countries, including Sudan, allow women to be judges. Yet, in Saudi Arabia, women are barred from driving cars and cannot leave the country without written permission from their wali (male guardian).

However, Morocco, another country where shari'a dictates national law, has made strides toward gender equality. In the last decade, the country revised its family law code to provide more protections for women. These included more equitable rules for inheritance (previously, female heirs received half of what male heirs received), less strict rules for divorces initiated by women, and an older minimum marriage age for women. And four years ago, a slate of amendments

Following the law

to Morocco’s constitution included some that required greater gender equality. Such examples highlight how interpretations of shari’a change over time.

Like the law, Massoud noted, religion can also be used for good or bad, so it’s an oversimplification to label shari’a as simply in opposition to human rights. Debates among Muslims about the meaning of shari’a are much more complicated, because some activists also use shari’a to justify women’s rights. This research will fill his next book, which he has begun as a visiting fellow at Princeton University in 2015–16.

Returning to California

While Massoud studied religious law in Sudan and Somalia, the word “shari’a” started appearing in the newspapers and television reports in the United States. The specter of radical fundamentalists cast a frightening shadow for many Americans whose primary exposure to Muslims and Islam was through the lens of the war on terror. “Since 9/11, things have changed,” Massoud said. “Some people fear Islam or Muslims.”

Even as he gathered data in Somalia, Massoud said he realized he knew little about the role shari’a plays in the lives of American Muslims. In a secular legal system, he wondered:

“How are Muslims interpreting shari’a? How do people engage with practices of Islamic law and human rights? These are questions that not only Muslims in Somalia are asking themselves. Muslims in California are asking and answering these questions, too.”

With a project dubbed “Shari’a Revoiced,” Massoud partnered with Kathleen Moore, chair of the Department of Religious Studies at UC Santa Barbara, who studies Islamic law. They secured long-term funding to set up an interdisciplinary studio that brought together scholars, journalists, filmmakers, and visual artists to talk about Islamic law. The goal of the collaboration was to bring the discussion about the Muslim experience in America to a wider

public audience than most political or religious scholarly work usually garners. It’s a facet of the project, Massoud and Moore noted, that is critical in an era of Islamophobia.

The two led a team that invited input from Muslim community leaders in California on the interview protocol they developed. After more than 100 interviews with Muslims in California, they distilled key words such as “pathway,” “Sunnah” (sayings and teachings of the prophet Muhammad), and “divine,” much the way Massoud extracted themes from his interviews in Sudan. This word list reflected ideas, such as “religious obligation,” “jurisprudence,” and “Islamophobia” that interviewees associated with shari’a.

One surprising result, said Moore, was how much people within a single household can differ in how they interpret shari’a. Those differences demonstrate how flexible the interpretation of shari’a can be, despite the common perception among non-Muslims of shari’a as a rigid set of laws.

“For instance, a husband might rely on the written law, created by judges living in the thirteenth century. He might think that has a lot of authority,” said Moore. “Whereas the wife might say, ‘all of that stuff is history and it’s not relevant to me living in America. God granted me intellect so that I could reason about these things and I can know what pleases God.’”

Despite the groundbreaking nature of Massoud’s work and the international acclaim he’s received, Massoud doesn’t see its role as prescriptive. He’s been asked what should be done in Sudan, but said a clear answer cannot come without an appreciation of legal history. Before we can know how to use the law in a place like Sudan or Somalia, Massoud argued, we must understand how it’s already been used.

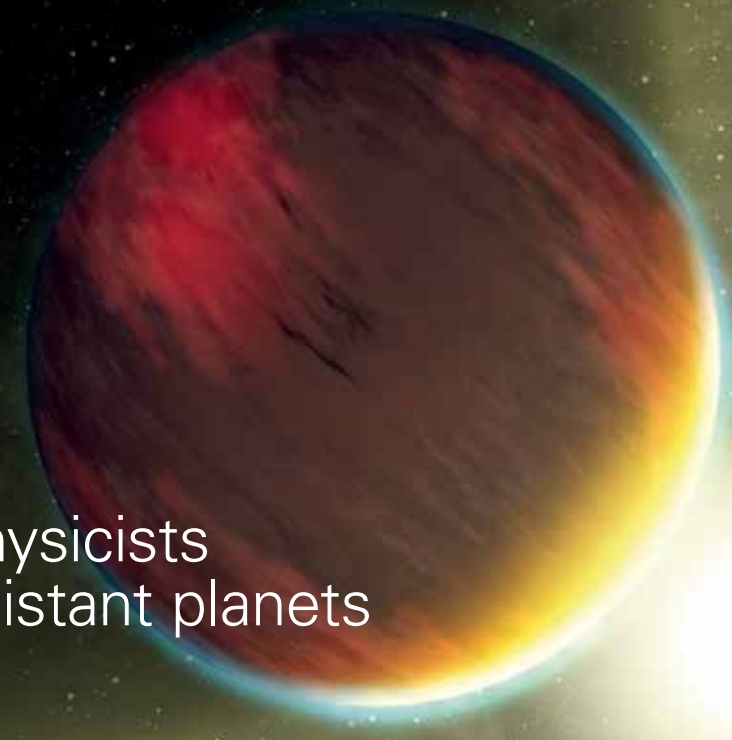
“It’s only when we realize how law has been used—as a force for bad or a force for good—that we can understand our own goals and hopes for the law in the future,” said Massoud.



The academic team asked a digital artist to create a “word cloud” image based on the thematic words pulled from the interviews. They also commissioned a video installation of excerpts of the transcribed interviews read aloud by a spoken word poet. The video produced by Massoud and Moore was shown at a team-sponsored exhibit featuring work by Muslim artists at the Downtown Independent theater in Los Angeles. Preliminary results from the project were published in *Boom*, a journal about California life.

Cloudy with a chance of life

Astrophysicists
probe distant planets



Hot gas planet, HD 209485b, depicted in this artist's concept. Two of NASA's Great Observatories—the Hubble Space Telescope and the Spitzer Space Telescope—yielded spectral observations that revealed molecules of carbon dioxide, methane, and water vapor in the planet's atmosphere.

HD 209458b, bigger than Jupiter, occupies a tight, 3.5-day orbit around a sun-like star about 150 light-years away in the constellation Pegasus. Planets like this one, which circle stars beyond our Sun, are called exoplanets.

▶ HD 209485b would make a lousy place to live. Anything that could call this exoplanet “home” would have to withstand air temperatures hotter than the inside of a volcano and storm winds gusting faster than the speed of sound. Clouds of vaporized rock would make for sunsets of brilliant green—if only they weren't so deadly.

More astounding, perhaps, than the bizarre environment of HD 209485b, is the fact that we know anything about it at all. The gas giant orbits a star 150 light-years away; a distance so vast that even our most powerful telescopes can't yet glimpse the planet.

These vast distances are a daily commute for **Jonathan Fortney**, an astrophysicist at UC Santa Cruz and director of the university's nascent Other Worlds Laboratory. He's helped detect water, salt clouds, and vaporized metals in the atmospheres of planets even farther away than HD 209485b. And most appear to be similarly hellish. “There's a crazy range of inhospitable and more inhospitable atmospheres,” he said. “Planets have a tremendous amount of character.”

While Fortney investigates the atmospheres of distant planets, his colleague **Pascale Garaud**, professor of

applied mathematics, studies the motions of fluids in their interiors to better understand convection and its role in heat transfer. Together, Fortney and Garaud are refining not only the models governing planet formation and evolution, but also some of the basic principles of astrophysics.

Stars aligned

When researchers first detected an extrasolar transit—a planet outside our solar system passing in front of its star—Fortney was studying planetary interiors and atmospheres as a doctoral student at the University of Arizona. Soon after that observation, Fortney and his adviser, William Hubbard, penned one of three landmark papers that demonstrated atmospheric information could be derived from the starlight transmitted during transits.

“That was a big deal at the time when the first transits were being observed,” said Hubbard. “There was a lot of skepticism about whether or not you could really do this.”

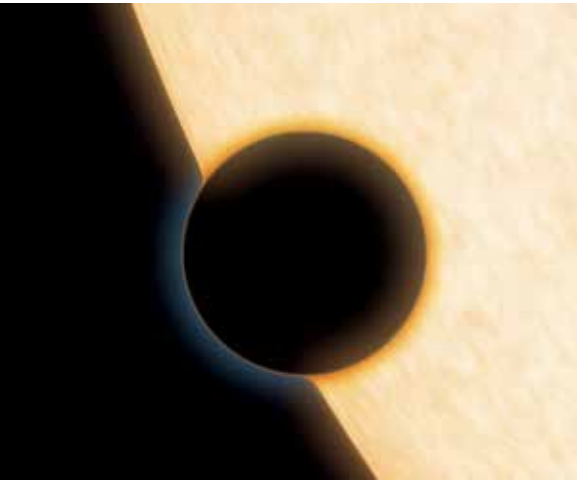
Later, Fortney collaborated with the Kepler Mission, a NASA space telescope designed to find Earth-like

Cloudy with a chance of life

planets elsewhere in the Milky Way. In 2011, Fortney and the Kepler team gained considerable media attention for their research on Kepler-11, a planetary system that contains at least six planets tightly packed around their star. Fortney and his students showed how Kepler-11's "super Earths"—planets intermediate in size between Earth and Neptune—are gradually losing their atmospheres due to intense heating from their parent star.

Enigmatic exoplanets

At its most basic level, a transiting planet is a black dot, blocking light as it passes directly between its star and the Earth. But at a higher resolution, even the thinnest veneer of atmosphere will absorb or scatter



An artist's rendering of how an exoplanet's atmosphere distorts the starlight passing through it.

a small amount of light instead of blocking it. And every element, molecule, cloud, and speck of dust in that atmosphere will influence light differently. So, if the Hubble or the Spitzer space telescopes record a dip in starlight during a transit, they also record any signature left behind by a planet's atmosphere.

From a transit, researchers isolate the light that penetrates

the atmosphere and produce a transmission spectrum—a graph of the light's intensity across a range of wavelengths. The challenge, then, is decoding the spectrum. And that's where Fortney comes in. By combining that data with information about the planet's orbit, size, and temperature, Fortney's research group creates thousands of atmospheric simulations and searches for the best fit. They determine the chemical makeup of the atmosphere and infer which materials are in the spectrum.

Some of those inferences are remarkably detailed. "If you have a really hot planet in a one-day orbit, you can actually have your day side be hot enough that you have vaporized rock," Fortney said—similar to HD 209485b, which orbits its star in three-and-a-half days. "Then it flows onto the night side where it's cold; it just collapses and freezes onto the surface."

The easiest atmospheres to study, Fortney said, are the thick ones around huge planets in tight orbits

around their star—like the hydrogen- and helium-rich "hot Jupiters" similar to the gas giant in our own solar system, except they're blisteringly hot. While hot Jupiters make up the majority of the 60 or so exoplanets whose atmospheres have been described in any detail, recent discoveries of "super-Earths" have pushed this exo-atmospheric science to smaller planets.

Sometimes, Fortney solves planetary mysteries—such as the case of the missing water. For nearly eight years, atmospheric observations of many hot Jupiters detected far less water than planetary models predicted. Astrophysicists wondered if their models could be wrong. "It would be surprising to find a giant planet that did not have water," Fortney said. "So the question is, where do you hide all that water?"

But it turned out water wasn't the only thing missing; other chemical signatures appeared muted, too. So what could dampen multiple sections of the transmission spectrum? This past December, Fortney coauthored a paper that put forth an answer: clouds. Masses of dust and vaporized metals obscure transmitted light—just as water clouds do at home. "Earth's clouds are white, and what white means is that they don't really have any absorption features," he said. "They're just scattering all wavelengths of light the same amount."

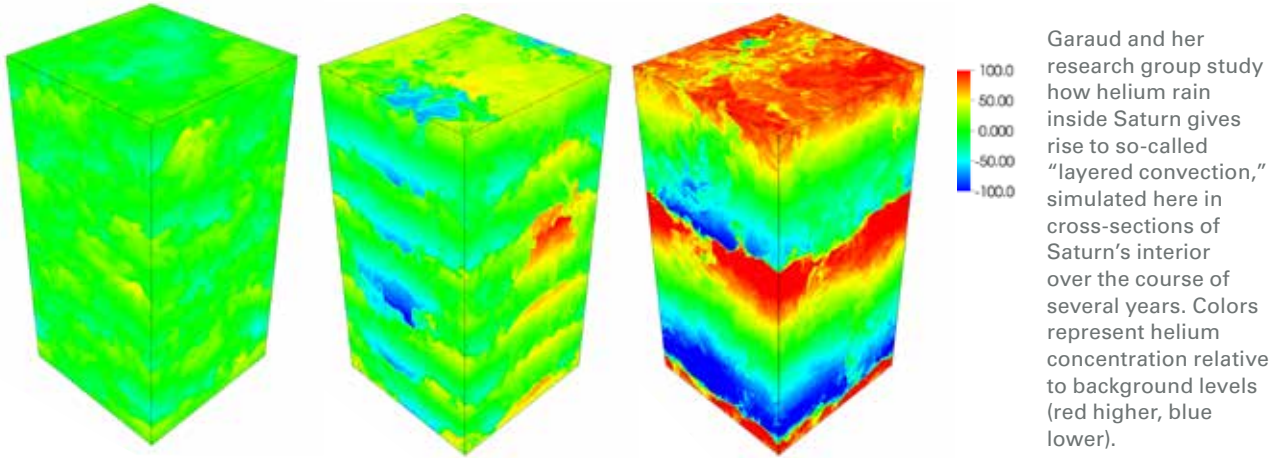
Finding the missing water wasn't just a chance to confirm planetary models or even to find signs of life. The exploration itself is important, said Fortney. He wants to know how planets can vary so much—from salt clouds on some, metallic atmospheres on others, to something completely different on Earth.

Reducing error bars

Fortney will discuss these questions when dozens of like-minded explorers visit UC Santa Cruz for the Kavli Summer Program in Astrophysics. Focused this year on exoplanet atmospheres, with Fortney as science director, it's the fourth in a series of summer research institutes founded by Pascale Garaud.

Like Fortney, Garaud is something of a consultant, lending her skills as a theorist to teams of observers working in natural systems. Currently funded by four National Science Foundation grants, and one from NASA, her fluid dynamics research ranges from convection in the tropical ocean to the interiors of stars. "That's the beauty of fluid dynamics," she said. "The same equations describe all sorts of different fluids."

But Garaud's passion, and Ph.D., is in astrophysics—particularly in refining models that don't seem to jive with observations. For instance, calculations of Saturn's age based on its observed temperature and models of



thermal convection miss the mark by billions of years—which either means the planet formed much later than the rest of the solar system or planetary thermal models are missing some important variables. She’s trying to figure out if the combined weight of all the droplets in Saturn’s helium rain could play a significant role in slowing down the planet’s thermal evolution.

“The models that are being used to study heat transfer are ancient, and they’re very, very basic,” she said. “The better we refine the stellar and planetary models, the better we’ll refine everything that we know about astrophysics.”

To make the field more robust, Garaud founded a six-week summer astrophysics program. It teams 15 graduate students with faculty members and postdoctoral students to pursue hyper-focused research projects. She modeled it after the Geophysical Fluid Dynamics Program at the Woods Hole Oceanographic Institution in southeastern Massachusetts, of which she is a permanent faculty member.

“Nobody really believes it’s possible to do decent research in such a short of amount of time,” Garaud said. But, in just three summers, program participants have published more than 30 papers on topics ranging from gravitational dynamics and magnetism to star and planet formation.

“This idea that you’ve got six weeks of relative isolation locked up with other people who are equally excited about science is really a privilege and a luxury in the academic year,” said Subhanjoy Mohanty, an astrophysicist at Imperial College London who joins the program’s faculty every year. In his fourth paper resulting from Garaud’s program, Mohanty recently published a study on the habitability of planets

around a class of relatively small and cool stars known as red dwarfs.

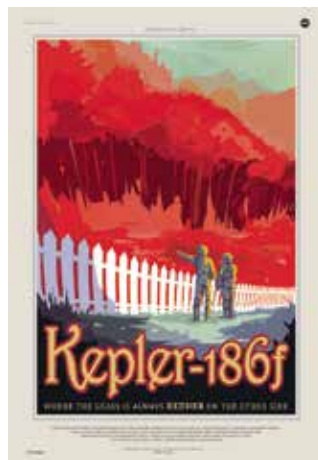
A new era

Two decades ago, the only observable planets beyond Earth were the others in our own solar system. Today, researchers have confirmed close to 2,000 new planets and another 4,600 likely candidates—not to mention the possibility of a mysterious “Planet X” beyond Pluto. At the inaugural all-exoplanet conference in 2002, Fortney recalled about 100 attendees. Now, that number of researchers focus on atmospheres alone.

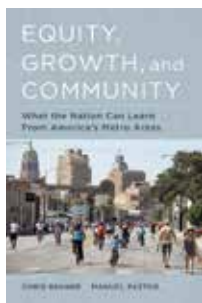
In the next 10 years, he said, two soon-to-be-launched instruments could jump-start the field all over again: the Transiting Exoplanet Survey Satellite, designed to find transiting planets around stars relatively close to our solar system, and the James Webb Space Telescope, which will collect more precise transmission spectra in a broader range of wavelengths. Together, these instruments will gather more information about planets that are smaller and more difficult to detect than hot Jupiters, including planets as small as Earth.

“Things that we’re getting hints of today will become real ironclad discoveries,” Fortney said. “We’ll find planets like Dune [Frank Herbert’s science-fictional planet] that are probably mostly dry, and we’ll find icy planets. All those things exist.”

And if there’s life out there, they may well find that, too.



Kepler-186 f—Where the Grass is Always Redder. This was the first Earth-sized planet found by Kepler, NASA’s planet-hunting telescope. Although it orbits in a potentially “habitable zone” around another star, where liquid water could exist on the planet’s surface, its star is much cooler and redder than our Sun, according to JPL’s “travel bureau.”



City Smarts

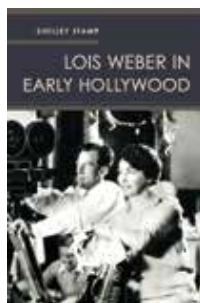
Creating economically sustainable cities may take more ideas than money.

"In mainstream economic thinking, intervening in the marketplace to promote social goals will lower growth and efficiency," said **Chris Benner**, UC Santa Cruz professor of environmental and social studies.

"But there's growing evidence that more equitable regions actually grow faster. One key factor in both faster growth and greater social equity seems to be diverse and dynamic regional knowledge communities."

For his book, **Equity, Growth, and Community: What the Nation Can Learn From America's Metro Areas**, Benner and coauthor **Manuel Pastor** (a UC Santa Cruz alum) analyzed data from 200 metropolitan regions. They found that regions least likely to sustain growth had more inequality in social opportunities, voting patterns, and income.

Case studies of successful cities, such as Seattle, showed how engaging all sectors of diverse communities—by making more knowledge connections—boosted metropolitan growth.



Hollywood Hustle

A century ago, the top-grossing film released by Universal Pictures was written and directed by Lois Weber, a leading lady of that Hollywood era. Although she ran her own studio, formed a production company, and earned a star on the Walk of Fame, few recognize her name today.

Shelley Stamp, professor of film and digital media at UC Santa Cruz, hopes to change that with her book, **Lois Weber in Early Hollywood**.

Despite tackling controversial subjects, such as abortion and birth control, Weber's films were often box-office hits. Stamp rediscovered Weber through old documents, films preserved in Europe, and scripts archived at the Academy of Motion Picture Arts and Sciences.

"I assumed she was forgotten after her death in 1939, but found instead that she, and other prominent women in early movie-making days, were actively written out of Hollywood history during their careers," said Stamp, also the founding editor of *Feminist Media Histories: An International Journal*.



A New View

The way we see the world requires a reasoning-like process, according to one popular theory of vision. In this constructivist view, we can't translate the light that hits the back of our eyes into a detailed three-dimensional world without some implicit knowledge of what's in the environment.

"That model of visualization seemed over-intellectualized to me," said **Nico Orlandi**, UC Santa Cruz assistant professor of philosophy.

Instead, Orlandi suggests an "embedded view" in her book, **The Innocent Eye: Why Vision Is Not a Cognitive Process**. Visual receivers, she argues, can take the environment as is, without needing knowledge or creating perceptual representations before the world can be seen.

Perceptual creatures can coordinate with what is present in an environment in a way that doesn't demand cognition: a cat with an empty food bowl doesn't need reason to perceive the bowl as it is.

While reason isn't required for visual perception, Orlandi next wants to explore what it takes to be rational and to create constructs of our environment.



Religious Politics

When governments try to separate religion and politics, they often end up with the opposite result, noted **Mayanthi Fernando**, UC Santa Cruz associate professor of anthropology.

For example, in 2004, the French ban on Islamic headscarves was justified as essential to the constitutional requirement of laïcité—the separation of state and religious activities. The law defined the headscarf as a conspicuous religious sign rather than understanding this garb as a practice, as many Muslim French do.

Ironically, the state made a theological decision about the headscarf in the name of preserving secularism. Under these conditions, the very actions intended to remove the state from religious affairs became a link between the two.

Fernando draws from a decade of ethnographic research on Islam in France to examine these conflicts in her book, **The Republic Unsettled: Muslim French and the Contradictions of Secularism**.



Trade Routes

In a book that begins where most studies of the slave trade end—with the sale of a slave at a colonial port—**Gregory O'Malley**, UC Santa Cruz associate professor of history, tracked the trade of enslaved people throughout the Americas.

His multi-award winning book, **Final Passages: The Intercolonial Slave Trade of British America, 1619–1807**, solved a riddle from O'Malley's doctoral studies. Although ships from Africa delivered thousands of slaves to a few main American ports, no one knew how slaves ended up in so many other places—from the northern British colonies to silver mines in Peru.

After 11 years of poring over port records and correspondence from merchants and imperial officers, O'Malley created a database that logged more than 7,600 individual slave shipments. "It became clear that the key distributors weren't slave specialists, but regular merchants looking to fill ships loaded with other commerce," he said.

His studies also showed that slave trading enabled Great Britain to trade other profitable goods with rival Spanish and French empires.

INQUIRINGMINDS



Eileen Campbell ('83)



Elizabeth Devitt ('13)



Blake Edgar ('89)



Kerry Klein ('15)



Greta Lorge ('03)



Jyoti Madhusoodanan ('14)



Lisa Marie Potter ('15)



Heather Rock Woods ('94)



Rina Shaikh-Lesko ('13)



Kim Smuga-Otto ('15)

Ten graduates from the UC Santa Cruz Science Communication Program contributed their expertise to the second edition of [inquiry@UC Santa Cruz](mailto:inquiry@ucsc.edu).

These “SciCommies,” as program alums are known, represent every decade of the writing program established in 1981 by **John Wilkes** (B.A., M.A., and Ph.D. in English literature at UC Santa Cruz). In contrast to his credentials, Wilkes recruited scientists—not English scholars—to become the next generations of storytellers.

Now under the leadership of **Robert Irion** (SciCom '88), who studied planetary sciences before he became one of Wilkes' students, the internationally recognized writing program counts close to 300 graduates. These scientists-turned-journalists work for newspapers, online news services, magazines, museums, university news offices, federal agencies, and as freelance writers. They also share stories through podcasts, photographs, video, and radio shows.

“Our graduates have all been in the realms of research—they know it from the inside—and that changes the questions they ask, it changes the nature of the

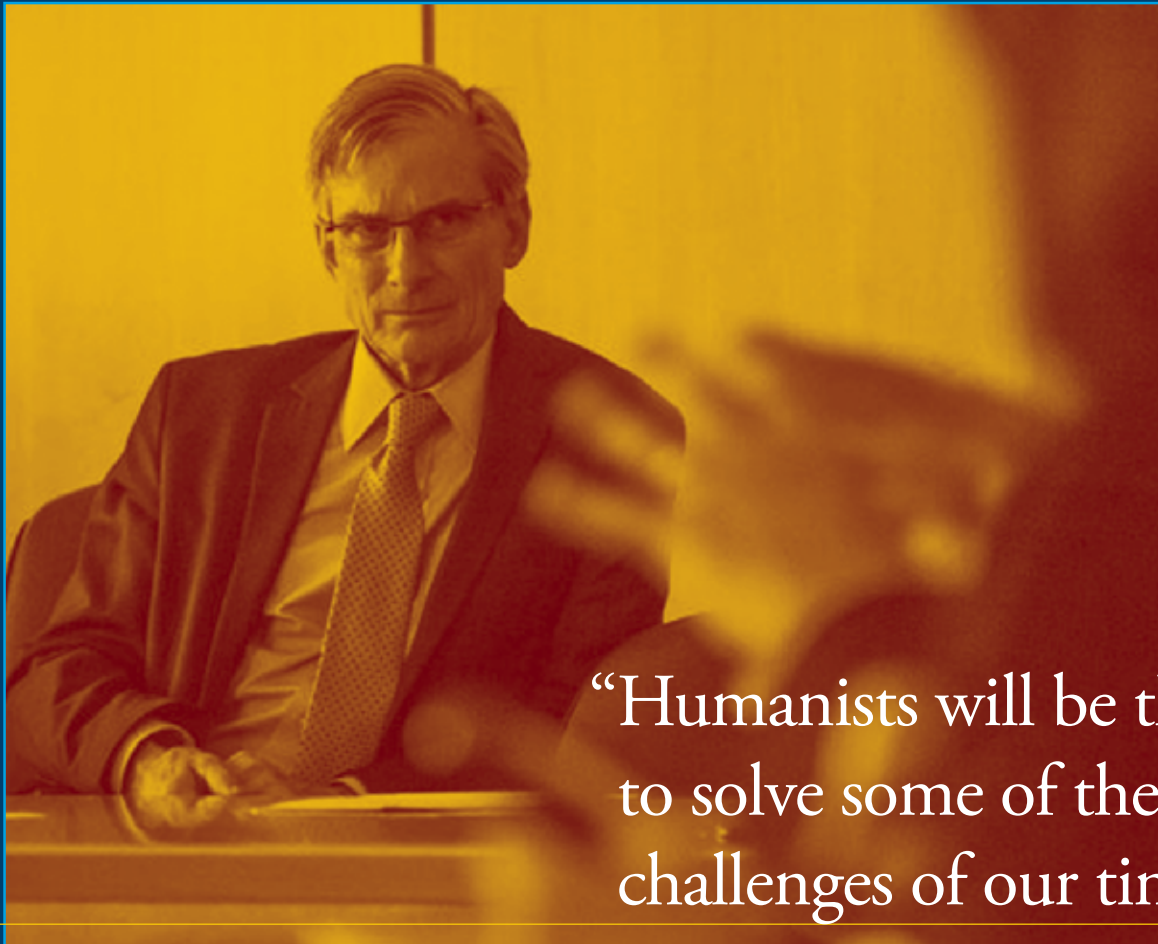
conversations they have, and it makes their stories richer, more robust, and more reliable,” said Irion.

SciCom also stands out as the only graduate-level program at a public university that is dedicated to science writing. In that respect, Irion noted, the program fits in well with the University of California's mission of research, teaching, and public service. “The students are fascinated by the scientific enterprise as a whole and they can't wait to share those passions with society,” said Irion.

So, wherever science is happening, there's probably a SciCommie on that reporting beat. We hope you enjoy the stories we found among the world-class researchers at UC Santa Cruz.

Learn more
news.ucsc.edu

Photo: Mike Cohea/Brown University



“Humanists will be the ones to solve some of the greatest challenges of our time.”

—William “Bro” Adams
(Ph.D. '82, history of consciousness), Chairman
of the National Endowment for the Humanities,
UC Santa Cruz alumnus

INSTITUTE FOR HUMANITIES RESEARCH

Cultural literacy. Ethics. Religion. Technology. Language. Identity.

Now more than ever, the sensibilities cultivated by the humanities are critical to our society. The Institute for Humanities Research at UC Santa Cruz is dedicated to furthering new approaches to interdisciplinary research and teaching in order to foster the next generation of critical thinkers and problem solvers. Learn more at ihr.ucsc.edu.



UNIVERSITY OF CALIFORNIA
SANTA CRUZ