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Rob Phillips, Professor of Biophysics

Richard Zhu
Contributing Writer

Like a cheerful lion prowling the lecture hall, Rob Phillips paces the floor of Baxter with a wide grin as he waits for the students to compute the estimated impact energy of a dinosaur-killing extinction asteroid. Phillips is a vivacious and larger-than-life lecturer. He opines to the students about the importance of having scale bars on pictures. Gesticulating wildly at a microscope picture of bacteria, he remarks, "how am I supposed to know that these bacteria are 10 microns across?"

In the fourth week, to demonstrate a point about the timescales of information transfer in the brain, he walks over the podium. Phillips snatches and puts on a rubber dog mask, staring at the students. Surprised, the lecture hall erupts in laughter. They understand — neuron signals travel fast, several tens of meters per second.

Previous editions of Bi 1 (Introductory Biology) have never been this interesting, the students all say. Having heard from upperclassmen how dull the mandatory lectures are, this past year's always-exciting lectures have shaped up to be more to handle than anyone expected.

Instead of emphasizing memorization and a standard biology curriculum, this term the class focuses on "street-fighting science". Inspired by astrophysicist Sterl Phinney's famed Ph 101 course (offered every other year), street-fighting science or "art of estimation" is now taught in Bi 1. For Phillips, having students estimate quantities like the number of sugars needed to synthesize a bacterium or the total water mass in someone's small intestines is a necessary step on the way to understanding the "scales" of something. To Phillips, if "you do not understand the scales of a problem, you do not understand it."

Phillips hasn't always been excited about science. Raised near a San Diego beach in a house full of books, Phillips recalls getting a D in his 9th grade algebra class. He believed science to be "boring and all about memorization." It was only after a talk about how Eratosthenes determined the radius of the Earth from the shadows cast from sticks that Phillips realized he wanted to pursue science.

On a campus where the main route to professorship and academia is through the undergraduate-graduate-postdoc-assistant professorship gauntlet, it is easy to forget how unconventional Phillips' background really is. While attending high school, he cracked a deal with his parents — if he got accepted into a UC school, he didn't have to go to college. In an 2013 joint interview with his mother, Phillips explained that "college seemed like something you were supposed to do. I didn't want to do things I was supposed to do, I wanted to do the things I should do."

He didn't go to college. Phillips traveled, self-studied, and worked for six years, before obtaining a physics degree from the University of Minnesota via correspondence. After this, he obtained a doctorate in condensed matter physics from Washington University in St. Louis. Phillips worked as a physics professor at Brown, before being recruited to Caltech in 2002 and switching research interests to biology and biophysics. For Phillips, the switch was driven largely out of a wealth of exciting unsolved problems in biology, and a lack of similar problems in condensed matter.

Biophysics is highly interdisciplinary, combining soft matter physics, statistical physics, and biological principles to make statements about living matter. For Phillips, the transition was made easier coming from condensed matter physics, which similarly focuses on materials and matter, but in inorganic forms.

In order to make the switch, Phillips had to be comfortable with "looking stupid", starting at the level of an incoming freshman undergraduate in biology. Dauntless, Phillips asked many questions. Absorbing all the information like a sponge, he quickly mastered the field - Phillips is one of the progenitors of biophysics, having written what some term the "Bible" of the field, the mammoth "Physical Biology of the Cell". For Phillips, the book-writing process is a means of learning. "I don't write about things I know about. Instead, I write about things I don't know anything about," he argues.

Humility is very important to Phillips. In a speech to the National University of Singapore, Phillips wrote how he often "acutely feels the shallowness of [the] interdisciplinary education" he has acquired on the road to where he is now, patterned with books, knowledge, and people. During Bi 1 this past year, he commented on a group of students who boasted about already knowing the material discussed in the previous night's recitation. "We are all epsilon away from being completely ignorant. You are not omni-talented! It proves nothing when you wear your impressive knowledge too loudly."

The consummate scientist, Phillips views science as a "relationship between one person and nature. It all comes down to you and your question." Having disliked authorities his whole life, Phillips is commonly seen brushing away questions about grades or passing, instead wanting his students to really learn the material. He asserts that "the life of the mind is sacred."

Phillips' deep study of classic texts may have influenced his faith (or lack thereof) in authorities. During his seven-year period away from academics, Phillips read through hundreds of classic books in world literature, drawn from Fadiman's Lifetime Reading Plan. He treasures his copy of the Reading Plan, which now has hundreds of margin annotations from friends and colleagues.

Phillips seems to have as great an understanding of people as he does of science. Justin Bois, a Caltech lecturer in bioengineering, pointed out that Phillips is "just so in tune with the fact that the people doing the science are real people. He is a person who really cares." Bois had previously chatted with Phillips about staying on as a researcher, because his then-girlfriend (now wife) lived in Southern California. Phillips, upon hearing that Bois needed to stay in the Los Angeles area for his personal life, arranged to offer Bois a position.

Eschewing the conventional way of doing things, Phillips often seeks out non-research chats. Soichi Hirokawa, a second-year graduate student, recalls his first encounter with Phillips: "It was a 2-hour discussion in his office about life, what it was like being born in Japan, coming from a liberal arts school to Caltech, etc." When asked how Phillips' mentoring has affected him as a researcher, Hirokawa responded: "More than anything, I think his confidence in asking so-called 'stupid' questions has inspired me to ask better questions as well."

Phillips often deflects praise. Despite his success as a scientist, Phillips, now in his fifties, reflects on it and feels unsatisfied. "I have everything I could want, but sometimes there's this feeling of not measuring up." The first time Phillips stepped foot on Caltech's campus, he was a paperboy delivering newspapers. One can imagine how it feels to return now as a tenured, endowed professor of biophysics. No, impostor syndrome is not just limited to undergraduates.

Phillips' hunger and dissatisfaction with the status quo propelled him through many hardships. At age 32 and in the final postdoc of his career, Phillips had been borrowing money from his parents to support his wife and two kids. In this nadir, he interviewed on Wall Street and for software engineering careers. He had received no callbacks for interviews. Finally, Brown University interviewed him and offered him a professorship. If it weren't for this "stroke of luck," he says, he may never have become a scientist.

Phillips remains energetic as ever, despite sleeping at most 6 hours a night. Phillips has completed twenty marathons, and also continues to swim and cycle avidly, nearly everyday. On most weekdays, many members of the Phillips group can be found swimming laps at the Caltech gym. Besides teaching Bi 1 this term, Phillips also teaches other courses in biophysics, runs the Ph 11 research seminar for freshmen, is engaged in several book writing projects, and runs several other campus roles on top of running his research group.

When asked what a successful term for Bi 1 would look like, Phillips smiles, thinking about the students who go up to him in adulation and utter variations on the common refrain of "I never knew biology was this interesting!" He views his role as lecturer to take students on a tour of the coolest parts of biology, and hopefully convince a few of them to admit that they were wrong about biology, that it is a beautiful subject.

During a group meeting, one of the TAs for the course relays a remark a student made on his way out of the course: "I feel like this class is making me a better person." Phillips cracks a smile, laughing it off. "I bet he won't be saying that after we cover statistical mechanics in a few weeks."

The next class, Phillips excitedly illustrates the story of myoglobin and hemoglobin, the role of the fossil record, and evolution from "limbs to fins." A student asks what a "peptide" is. Phillips responds "I don't remember my chemistry either, but I think of it like a waltz - CCN, CCN, CCN..." He sways to the rhythm.

This garners a few laughs, because Phillips just named the chemicals forming the long backbone of peptides. Later, he reads the last paragraph of Darwin's treatise on evolution, "The Origin of Species," asking the students to appreciate the prose:

"There is grandeur in this view of life, with its several powers, having been originally breathed into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved."

He finishes, and smiles at the class.

IN THIS ISSUE

ANNOUNCEMENTS

NOMINATE YOUR FAVORITE PROFESSOR FOR THE FEYNMAN TEACHING PRIZE!!!

Here's your chance to nominate your favorite professor for the 2017-18 Richard P. Feynman Prize for Excellence in Teaching! You have from now until December 15, 2017 to submit your nomination package to the Provost's Office to honor a professor who demonstrates, in the broadest sense, unusual ability, creativity, and innovation in undergraduate and graduate classroom or laboratory teaching.

The Feynman Prize is made possible through the generosity of Ione and Robert E. Paradise, with additional contributions from an anonymous local couple. Nominations for the Feynman Teaching Prize are welcome from faculty, students, postdoctoral scholars, staff, and alumni.

All professorial faculty of the Institute are eligible. The prize consists of a cash award of $3,500, matched by an equivalent raise in the annual salary of the awardee. A letter of nomination and detailed supporting material, including, but not limited to, a curriculum vitae, course syllabus or description, and supporting recommendation letters should be emailed to kkerbs@caltech.edu or directed to the Feynman Prize Selection Committee, Office of the Provost, Mail Code 206-31, at the California Institute of Technology, Pasadena, California, 91125. Nomination packages are due by December 15, 2017.

Additional information including guidelines for the prize and FAQ may be found at http://provost.caltech.edu/FeynmanTeachingPrize. Further information can also be obtained from Karen Kerbs (626-395-6039; kkerbs@caltech.edu) in the Provost's Office.

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VICE PROVOST OFFICE HOURS

Vice Provost, Chief Diversity Officer, and Professor of English Cindy Weinstein holds regular office hours as an opportunity for undergraduate students, graduate students, and postdocs to meet for discussions pertaining to the Council on Undergraduate Education; Caltech accreditation; the Staff and Faculty Consultation Center; Student-Faculty Programs; the Center for Teaching, Learning and Outreach; the Caltech Diversity Center; and the Caltech Libraries.

There are four 15-minute appointments available per office hour. Sign up in the Office of the Vice Provost, Parsons-Gates room 104, ext. 6339 or by sending an email to dlewis@caltech.edu. We look forward to hearing from you!

Student Office Hours for Fall Term 2017:

9/29/17 Friday 11:00 a.m.–12:00 p.m.
10/6/17 Friday 11:00 a.m.–12:00 p.m.
10/11/17 Wednesday 9:00–10:00 a.m.
10/19/17 Thursday 11:00 a.m.–12:00 p.m.
10/26/17 Thursday 10:00–11:00 a.m.
11/1/17 Wednesday 11:00 a.m.–12:00 p.m.
11/7/17 Tuesday 9:00–10:00 a.m.
11/16/17 Thursday 11:00 a.m.–12:00 p.m.
11/21/17 Tuesday 10:00–11:00 a.m.
11/27/17 Monday 10:00–11:00 a.m.

Joe Shepherd: The Vice President with a Nuclear Football

Tim Liu
Contributing Writer

"We blow stuff up," Joe Shepherd said, with a boyish grin, "But really that's kind of a simplistic way of thinking about it." He slides into a detailed monologue of his research: high speed combustion, and improving the safety of petrochemical industries and transportation systems. Shepherd speaks in long, extended sentences that flow from one thought to the next to the next, meandering from supersonic combustion waves to high speed data acquisition. He hunches slightly over the table as he gestures with both hands, occasionally running one through the receding hair on his head. Shepherd is a professor of aeronautics and mechanical engineering, and an unexpected expert on nuclear waste storage and the 2011 Fukushima nuclear accident. But among students, Shepherd is most well known by the position that, by his own estimate, consumes "80-90%" of his time and makes him one of the most influential individuals on campus: Vice President of Student Affairs.

The Student Affairs office covers a plethora of departments impacting students, ranging from housing to dining to the Deans and the Registrar's office. At the head of it all sits the Vice President of Student Affairs (VPSA), who oversees a web of directors that run the myriad offices under the Student Affairs umbrella. Before becoming VPSA, Shepherd previously held the title of Graduate Dean and served as the option representative for the aerospace department, acting as the chief administrator for the graduate and undergraduate programs. "We used to make fun of him for eating potato chips and coke for lunch," remarked Felicia Hunt, who had worked with Shepherd in the graduate office since 2009 and continues to do so as Assistant Vice President. "He wouldn't be in Student Affairs for 8 years and work with all these students if he didn't care," Hunt said, locking eye contact, "You can't fake investment for that long."

Over the last two years, Shepherd has become tightly associated with the ongoing discussion on how the under-construction Bechtel Residence will be occupied. Bechtel is scheduled to be opened in the fall of 2018. This timelines dictates that the debate over who Bechtel's occupants will be must be resolved before the class of 2022, the first cohort that will live under a residential system that includes Bechtel, matriculates. The discussion has at times been tempestuous and is an ongoing test of how well student government can work with administrators, including Shepherd. "He entrusts a lot to students in terms of getting certain things done," said Bobby Sanchez, former chair of the IHC, "I don't think he likes meeting for the sake of meeting, and Joe is the type of person that likes to have something concrete." Sanchez later recounted how after meeting with Shepherd to plan one of the town hall meetings on Bechtel, Shepherd tasked Sanchez and then ASCIT President Andrew Montequin with finding RAs to speak. Throughout the discussion on Bechtel, students have pondered why the decision has been so extended, with explanations ranging from innocuous to openly conspiratorial. "Joe has the point of view that Bechtel will set Caltech housing for the long term, and that's not a decision you make lightly," suggested Montequin, as an explanation for the seemingly lethargic timeline. Bechtel will be the first large residence to open at Caltech in 22 years and will have the capacity to house more than a fifth of the undergraduate population. Relative to the size of the school, it's the equivalent of UC Berkeley building housing for a quarter of South Pasadena. Its sheer size gives Bechtel the potential to transform a residential system that has been largely static for half a century. Given that the ultimate decision largely rests on Shepherd, the deliberate pace may simply be a reflection of his style of thinking. "Joe likes to think and learn and discuss," Hunt pointed out, "He doesn't make impulsive decisions."

Shepherd's calculated, meticulous nature is reflected in his previous experiences, where he worked in capacities that demanded attention to detail. Shepherd grew up tinkering with electronics, learning how to fix radios and TVs. "I was a vocational student...and I had a skill that was obsolete as soon as I graduated - fixing vacuum tubes," Shepherd said. After graduate school, Shepherd went to Sandia National Laboratories, where he worked on studying the nuclear accident at Three Mile Island. "They said 'you know about explosions,'" said Shepherd, recounting when he first joined Sandia, "I didn't actually know about explosions." Over the course of three decades, Shepherd has become something of an expert in nuclear energy, nuclear accidents, and waste handling. After the Fukushima Daiichi nuclear accident in 2011, he chaired part of a national committee that studied the accident, and in particular what to do with spent nuclear fuel. When asked what the best solution for nuclear waste is, Shepherd broke into a wide smile. The current U.S. strategy is to find a geologic repository where the waste can be stored, and uniquely, potentially recovered for later use. According to Shepherd, communities are effectively being asked, "would you like some nuclear waste in your backyard?"

The field of nuclear energy is one that obviously demands careful analysis, an empirical mindset, and steady deliberation. Some of these traits are also visible in how Shepherd approaches student affairs. "I think he's a scientist first and foremost," noted Sanchez, when asked how Shepherd approaches difficult problems, "He's not a fan of anecdotal evidence." Whether with regards to Bechtel or other discussions, Shepherd has repeatedly called for data and evidence from students when they defend their points. His penchant for data can also be seen in how he approaches rotation, the process that sorts freshmen into dorms, and why students don't graduate in four years. Numbers and clear arguments matter to him. The next step in the Bechtel process is to form small focus groups to study specific housing schemes. "I had the idea for focus groups, and I told Joe and he was in favor of it," noted Montequin, "He likes that there will be more thought put into each idea." Though he relishes facts and clear debate, Shepherd is not content with being a cloistered administrator secluded behind the doors of Parson's Gates. Shepherd likes to get out of his office and, quite literally, be on the ground and in the trenches. A white hard hat and a reflective vest sit at the corner of his otherwise clear desk. "This morning I went to Bechtel and put on my hat and vest and I wanted to look at the concrete." At a Bechtel town hall meeting in early May, Shepherd presented pictures of the construction site and educated students on the excavation process, rebar reinforcement, and concrete molds.

More so than almost any other faculty member, Shepherd has become the most visible personification of the otherwise faceless, hazy entity of administration. It's a distinction that can also come with a lightning rod that channels student discontent. "Not that I think either [students or administration] is necessarily wrong, just the two are coming from different views," said Sanchez, diplomatically. Shepherd is responsible for several looming decisions, but what matters to him most is how the decisions will affect students. "It's about the people to him," asserted Hunt, nodding steadily, " Not about Bechtel, it's about who's going to live there." Both as an administrator and as a faculty member, Shepherd cares deeply about Caltech as an institute, and how it shapes its students. In making big decisions about Caltech, Shepherd has to balance the desires of students with the pressure from other administrators and branches of Caltech. It's a process that depends on delicate compromise and faith in the groups involved. "He trusts students, he trusts student government," remarked Sanchez, " But [he] doesn't always agree with us."

The Surprising, Ancient Behavior of Jellyfish

Lori Dajose
Caltech Media Relations

This article is adapted from a story that was originally published online at caltech.edu.

At first glance, humans seem to have very little in common with Cassiopea, a primitive jellyfish. Cassiopea is brainless, spineless, and spends essentially its entire life sitting upside down on the ocean floor, pulsating every few seconds. However, Caltech scientists have now discovered that, as different as our daily schedules may seem, humans and jellyfish actually start and end their days with the same behavior: sleep. This finding that jellyfish sleep implies that sleep is an ancient behavior, largely untouched by millennia of evolution.

The work was a collaboration between three Caltech laboratories led by: Paul Sternberg, Thomas Hunt Morgan Professor of Biology and Howard Hughes Medical Institute Investigator; Viviana Gradinaru (BS '05), assistant professor of biology and biological engineering, Heritage Medical Research Institute Investigator, and Director of the Center for Molecular and Cellular Neuroscience of the Tianqiao and Chrissy Chen Institute for Neuroscience at Caltech; and Lea Goentoro, assistant professor of biology. The work appears online in the September 21 issue of Current Biology.

"It may not seem surprising that jellyfish sleep—after all, mammals sleep, and other invertebrates such as worms and fruit flies sleep," says Ravi Nath, the paper's co-first author and a graduate student in the Sternberg laboratory. "But jellyfish are the most evolutionarily ancient animals known to sleep. This finding opens up many more questions: Is sleep the property of neurons? And perhaps a more far-fetched question: Do plants sleep?"

In order to be considered "sleeping," an organism must meet three critical criteria. First, it must demonstrate a period of reduced activity, or quiescence. Second, the organism must exhibit a decreased response to otherwise-arousing stimuli while in the quiescent state. Finally, the organism must show an increased sleep drive when it is deprived of sleep.

"When humans sleep, we are inactive, we often can sleep through noises or other disturbances which we might otherwise react to if we were awake, and we're likely to fall asleep during the day if we don't get enough sleep," says Claire Bedbrook, co-first author and a graduate student in the Gradinaru laboratory. "We might seem extremely different from jellyfish, but we both exhibit a similar sleep state."

So, how do you prove that a jellyfish is asleep?

First, to demonstrate quiescence, the team set up a system of cameras to monitor the jellyfish around the clock. They discovered that the jellyfish go through periods of inactivity at night, only pulsing about 39 times per minute, compared to about 58 times per minute during the day.

Next, the team set out to prove that the animals had an increased arousal threshold during this period of decreased activity. The team set a jellyfish on a platform higher up in the tank and pulled the platform out from underneath the animal once the jellyfish showed signs of quiescence. Normally, an alert jellyfish would immediately swim to the bottom of the tank. But the jellyfish in a sleep state floated in the water for up to five seconds before "waking up" and reorienting itself.

Finally, the researchers needed to show that, when deprived of sleep, the jellies would exhibit an increased sleep drive—just as humans do after a sleepless night. To do this, the researchers pulsed water at the animals every 10 seconds for 20 minutes, effectively "poking" them to keep them

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DINNER

Last Name	First Name	Preferred Name	Dinner A	Dinner B	Dinner C	Linner D	Dinner E	Linner F	Dinner G	Dinner H
Abney	Nayla		Lloyd	Page	Blacker	Avery	Dabney	Ricketts	Fleming	Ruddock
Adams	Kasey		Lloyd	Page	Blacker	Dabney	Avery	Ricketts	Ruddock	Fleming
Agarwal	Ashima		Dabney	Fleming	Lloyd	Avery	Ruddock	Ricketts	Blacker	Page
Agarwala	Vandana		Page	Ruddock	Avery	Dabney	Ricketts	Lloyd	Fleming	Blacker
Alexander	Matthew		Fleming	Ricketts	Dabney	Page	Ruddock	Avery	Blacker	Lloyd
Amaolo	Alessio		Blacker	Fleming	Avery	Ruddock	Dabney	Ricketts	Page	Lloyd
Andrzejewski	Tomasz	Tomek	Avery	Page	Lloyd	Ruddock	Ricketts	Fleming	Dabney	Blacker
Apple	Logan		Dabney	Lloyd	Ricketts	Avery	Fleming	Page	Ruddock	Blacker
Ardavin	Nicholas		Ricketts	Page	Lloyd	Dabney	Ruddock	Blacker	Fleming	Avery
Arun	Rahul		Page	Avery	Dabney	Fleming	Blacker	Ricketts	Lloyd	Ruddock
Aw Young	Qingzhuo		Avery	Ruddock	Page	Fleming	Lloyd	Ricketts	Blacker	Dabney
Bao	Richard		Avery	Dabney	Lloyd	Blacker	Ricketts	Ruddock	Fleming	Page
Bao	Anthony		Blacker	Lloyd	Ruddock	Fleming	Dabney	Ricketts	Avery	Page
Bathwal	Rahil		Ruddock	Blacker	Page	Dabney	Avery	Fleming	Ricketts	Lloyd
Berrigan	Brendan		Lloyd	Ricketts	Fleming	Dabney	Avery	Blacker	Ruddock	Page
Blankenberg	Luke		Ruddock	Fleming	Dabney	Avery	Lloyd	Blacker	Page	Ricketts
Boubezari	Ali		Page	Avery	Blacker	Lloyd	Ricketts	Fleming	Ruddock	Dabney
Brabec	Cole		Fleming	Ruddock	Ricketts	Dabney	Avery	Blacker	Lloyd	Page
Brodsky	Krystal		Ruddock	Page	Dabney	Fleming	Ricketts	Avery	Lloyd	Blacker
Brown	Krystin		Lloyd	Avery	Ricketts	Ruddock	Blacker	Fleming	Page	Dabney
Brown	Michael		Ricketts	Dabney	Page	Blacker	Ruddock	Avery	Fleming	Lloyd
Camplisson	Isabella		Ricketts	Blacker	Dabney	Ruddock	Avery	Lloyd	Page	Fleming
Cao	Siting	Cindy	Avery	Ruddock	Lloyd	Fleming	Ricketts	Dabney	Page	Blacker
Catanzaro	Dominic		Lloyd	Ricketts	Fleming	Page	Blacker	Ruddock	Avery	Dabney
Chan	Andrew		Fleming	Avery	Ricketts	Blacker	Ruddock	Lloyd	Page	Dabney
Chelakkat	Kristine		Blacker	Fleming	Dabney	Ricketts	Lloyd	Avery	Page	Ruddock
Chen	Lucy		Avery	Fleming	Lloyd	Page	Dabney	Blacker	Ruddock	Ricketts
Chen	Eric		Lloyd	Dabney	Page	Avery	Fleming	Ricketts	Ruddock	Blacker
Chen	LC		Page	Blacker	Avery	Ruddock	Dabney	Ricketts	Fleming	Lloyd
Chitta	Pavan		Page	Ruddock	Ricketts	Dabney	Avery	Blacker	Lloyd	Fleming
Cho	Hyerin		Blacker	Dabney	Lloyd	Ricketts	Fleming	Page	Avery	Ruddock
Chow	Karena		Avery	Page	Fleming	Ricketts	Lloyd	Ruddock	Blacker	Dabney
Chung	Yoojin		Fleming	Blacker	Ricketts	Avery	Lloyd	Dabney	Page	Ruddock
Clausen	Nicholas	Nick	Fleming	Blacker	Lloyd	Ruddock	Avery	Ricketts	Page	Dabney
Como	Joseph	Joe	Ricketts	Page	Dabney	Avery	Blacker	Ruddock	Lloyd	Fleming
Costa	Reimond		Ricketts	Dabney	Page	Avery	Blacker	Ruddock	Fleming	Lloyd
Crotteau	Molly		Ruddock	Ricketts	Lloyd	Fleming	Dabney	Page	Blacker	Avery
Crowell	Irene		Avery	Dabney	Ruddock	Fleming	Lloyd	Page	Ricketts	Blacker
Csaposs	Steven		Page	Avery	Blacker	Fleming	Ruddock	Ricketts	Lloyd	Dabney
Curranlt	Douglas	Nicholas	Ruddock	Blacker	Ricketts	Lloyd	Avery	Dabney	Page	Fleming
Danielsen	Dorte		Blacker	Page	Avery	Ricketts	Dabney	Lloyd	Ruddock	Fleming
Dargan	Richard		Avery	Fleming	Ruddock	Dabney	Ricketts	Blacker	Lloyd	Page
de Castro	Gianfranco	Gian	Blacker	Dabney	Avery	Fleming	Page	Ricketts	Lloyd	Ruddock
Delgado	Daniel		Page	Avery	Lloyd	Ricketts	Blacker	Dabney	Ruddock	Fleming
Dev	Vidhya		Avery	Ruddock	Fleming	Ricketts	Page	Lloyd	Blacker	Dabney
Devasenapathy	Kiruthika	Kriti	Lloyd	Ricketts	Ruddock	Fleming	Page	Avery	Blacker	Dabney
Dibble	Jeremiah		Ruddock	Dabney	Avery	Lloyd	Ricketts	Fleming	Page	Blacker
Ding	Grace		Ruddock	Ricketts	Blacker	Page	Dabney	Lloyd	Avery	Fleming
Drango	Kaliden	Kali	Blacker	Dabney	Fleming	Ricketts	Ruddock	Page	Avery	Lloyd
Durrett	Olivia		Page	Ruddock	Blacker	Avery	Lloyd	Dabney	Fleming	Ricketts
Earney	Matthew		Ruddock	Dabney	Ricketts	Lloyd	Avery	Blacker	Page	Fleming
Escobar	Sergio		Dabney	Page	Fleming	Blacker	Ricketts	Lloyd	Avery	Ruddock
Fish	Sara		Blacker	Ruddock	Fleming	Avery	Ricketts	Lloyd	Dabney	Page
Fu	Rosita		Fleming	Blacker	Avery	Dabney	Ricketts	Lloyd	Page	Ruddock
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Griffith	Nora		Ricketts	Lloyd	Fleming	Avery	Ruddock	Page	Blacker	Dabney
Gudavalli	Sirisha		Blacker	Avery	Ricketts	Fleming	Lloyd	Ruddock	Dabney	Page
Guenov	Sarah		Fleming	Avery	Ricketts	Ruddock	Lloyd	Page	Dabney	Blacker
Guerra	Alex		Ruddock	Blacker	Ricketts	Avery	Lloyd	Page	Dabney	Fleming
Guo	Steve		Ricketts	Blacker	Page	Dabney	Avery	Fleming	Ruddock	Lloyd
Gupta	Arushi		Fleming	Dabney	Page	Ruddock	Ricketts	Blacker	Lloyd	Avery
Han	Ryan		Blacker	Ruddock	Ricketts	Page	Lloyd	Avery	Dabney	Fleming
Han	Eric		Page	Lloyd	Ricketts	Avery	Ruddock	Fleming	Dabney	Blacker
Hands Arocha	Andrea		Ruddock	Lloyd	Ricketts	Avery	Fleming	Page	Blacker	Dabney
Heath	John		Page	Avery	Blacker	Ricketts	Lloyd	Dabney	Fleming	Ruddock
Hess	Andrew		Fleming	Lloyd	Blacker	Ricketts	Avery	Page	Dabney	Ruddock
Ho	Andrew		Avery	Ricketts	Lloyd	Blacker	Fleming	Page	Ruddock	Dabney
Holder	Lofton	Dillon	Avery	Lloyd	Blacker	Ruddock	Page	Ricketts	Fleming	Dabney
Hommerich-Dut	Ankush		Ruddock	Avery	Ricketts	Fleming	Page	Blacker	Lloyd	Dabney
Hu	Xinyue	Claire	Blacker	Avery	Lloyd	Ruddock	Fleming	Dabney	Ricketts	Page
Hu	Laura		Ruddock	Avery	Dabney	Ricketts	Lloyd	Fleming	Blacker	Page
Huang	Christine	Christie	Ruddock	Dabney	Lloyd	Page	Fleming	Avery	Ricketts	Blacker
Huffman	Nerys		Blacker	Ruddock	Dabney	Fleming	Ricketts	Avery	Lloyd	Page
Iovine	Michael	Mike	Ruddock	Blacker	Page	Ricketts	Dabney	Fleming	Lloyd	Avery
Jain	Neymika		Fleming	Ricketts	Ruddock	Avery	Lloyd	Dabney	Blacker	Page
Janosi	Alex		Fleming	Dabney	Lloyd	Blacker	Ricketts	Page	Avery	Ruddock
Jaszewski	Ethan		Ruddock	Page	Fleming	Dabney	Ricketts	Avery	Blacker	Lloyd
Jerez Terceros	Maheck		Avery	Blacker	Ricketts	Lloyd	Page	Fleming	Dabney	Ruddock
Jin	Qixuan	Alice	Fleming	Lloyd	Dabney	Avery	Ricketts	Blacker	Ruddock	Page
Joseph	Alfred		Dabney	Fleming	Blacker	Page	Ruddock	Avery	Lloyd	Ricketts
Joseph	Roby		Ruddock	Avery	Blacker	Ricketts	Lloyd	Dabney	Page	Fleming
Jusuf	James		Dabney	Blacker	Ruddock	Fleming	Avery	Ricketts	Lloyd	Page
Kalisz	Aleksandra	Ola	Avery	Ricketts	Fleming	Dabney	Lloyd	Ruddock	Blacker	Page
Kang	Jaeyoung	Jae	Ricketts	Ruddock	Page	Dabney	Avery	Fleming	Lloyd	Blacker
Karim	Riana		Ruddock	Dabney	Page	Lloyd	Avery	Fleming	Ricketts	Blacker
Karmarkar	Ishani		Fleming	Blacker	Ruddock	Avery	Ricketts	Dabney	Lloyd	Page
Karras	Johanna		Page	Ricketts	Lloyd	Dabney	Ruddock	Avery	Blacker	Fleming
Khan	Alveera		Page	Blacker	Ricketts	Avery	Lloyd	Fleming	Dabney	Ruddock
Kim	Esther		Avery	Ruddock	Fleming	Lloyd	Page	Blacker	Dabney	Ricketts
Kim	Min Hyuk	Matthew	Dabney	Ricketts	Blacker	Avery	Ruddock	Lloyd	Fleming	Page
Kim	Joo Eun	June	Fleming	Ricketts	Blacker	Lloyd	Ruddock	Page	Dabney	Avery
Kim	Yu Jin		Page	Blacker	Avery	Ruddock	Lloyd	Fleming	Ricketts	Dabney
Kim	Daniel		Ruddock	Lloyd	Blacker	Fleming	Dabney	Ricketts	Page	Avery
Kitagawa	Lily		Page	Lloyd	Ruddock	Avery	Ricketts	Fleming	Blacker	Dabney
Koe	Nora		Avery	Page	Lloyd	Dabney	Ruddock	Blacker	Ricketts	Fleming
Kogan	Adam		Blacker	Avery	Fleming	Lloyd	Ruddock	Page	Ricketts	Dabney
Korovina	Ekaterina	Katrina	Blacker	Page	Lloyd	Ruddock	Dabney	Avery	Fleming	Ricketts
Kou	Frank		Fleming	Avery	Page	Dabney	Ruddock	Ricketts	Blacker	Lloyd
Kukavica	Anthony	Tony		Lloyd/Fleming	Blacker		Avery		Ruddock	Page
Kulkarni	Sanjana		Ricketts	Fleming	Blacker	Page	Dabney	Avery	Ruddock	Lloyd
Kumar	Vinayak		Ricketts	Avery	Blacker	Page	Fleming	Lloyd	Dabney	Ruddock
Kuzhagaliyev	Timur		Avery	Lloyd	Page	Blacker	Fleming	Dabney	Ruddock	Ricketts
Kwa	Thomas		Blacker	Page	Lloyd	Ricketts	Ruddock	Avery	Fleming	Dabney
Larson	Andrew		Dabney	Page	Blacker	Lloyd	Ricketts	Ruddock	Fleming	Avery
Lee	Regina		Fleming	Ruddock	Page	Dabney	Blacker	Lloyd	Avery	Ricketts
Lee	Su Min		Fleming	Ruddock	Blacker	Lloyd	Dabney	Ricketts	Page	Avery
Lee	Alycia		Lloyd	Dabney	Blacker	Page	Avery	Ruddock	Fleming	Ricketts
Lee	Yelim		Page	Dabney	Avery	Ricketts	Blacker	Lloyd	Fleming	Ruddock
LeMar	Lexy		Dabney	Blacker	Ruddock	Page	Ricketts	Fleming	Avery	Lloyd
Li	Amanda		Avery	Lloyd	Ruddock	Dabney	Ricketts	Blacker	Fleming	Page
Li	Chenyue		Fleming	Lloyd	Page	Dabney	Avery	Blacker	Ricketts	Ruddock
Liang	Xueer	Sherry	Avery	Blacker	Ruddock	Lloyd	Fleming	Dabney	Ricketts	Page
Liang	Erich		Dabney	Ruddock	Fleming	Lloyd	Avery	Ricketts	Page	Blacker
Lin	Rachel		Fleming	Page	Ricketts	Dabney	Ruddock	Avery	Lloyd	Blacker
Liu	Sarina		Blacker	Fleming	Lloyd	Ricketts	Dabney	Ruddock	Page	Avery
Liu	Lauren		Lloyd	Ricketts	Dabney	Blacker	Fleming	Avery	Page	Ruddock
Loveridge	Tegan		Avery	Blacker	Dabney	Lloyd	Page	Ricketts	Fleming	Ruddock
Lowinger	Elaine		Ruddock	Avery	Blacker	Fleming	Lloyd	Page	Dabney	Ricketts
Manohara	Mohith		Blacker	Fleming	Dabney	Page	Lloyd	Ricketts	Avery	Ruddock
Maruszko	Krystyna		Ricketts/Fleming	Avery				Dabney	Ruddock	
Maxfield	John	Jack	Fleming	Ruddock	Blacker	Dabney	Ricketts	Lloyd	Avery	Page
Merk	Liana		Lloyd	Blacker	Ricketts	Page	Fleming	Dabney	Avery	Ruddock
Mirchandani	Rohan		Blacker	Page	Lloyd	Dabney	Ricketts	Ruddock	Fleming	Avery
Mondello	Allessandra		Dabney	Ruddock				Avery	Lloyd	
Moreno	Eric		Avery	Dabney	Fleming	Ricketts	Page	Blacker	Lloyd	Ruddock
Morgenfeld	Spencer		Ruddock	Avery	Ricketts	Dabney	Lloyd	Fleming	Page	Blacker
Mudide	Shiva		Lloyd	Blacker	Dabney	Page	Avery	Fleming	Ruddock	Ricketts
Muise	Isabelle	Izzy	Blacker	Page	Ruddock	Ricketts	Dabney	Lloyd	Avery	Fleming
Mukherjea	Arundhati		Ricketts	Ruddock	Page	Avery	Lloyd	Fleming	Dabney	Blacker
Murphy	Catrin		Avery	Dabney	Ricketts	Blacker	Page	Lloyd	Fleming	Ruddock
Mutic	Maya		Ruddock	Fleming	Ricketts	Dabney	Page	Avery	Lloyd	Blacker
Nazeeri	Albert		Dabney	Fleming	Lloyd	Avery	Page	Ruddock	Blacker	Ricketts
Neamati	Daniel		Ruddock	Ricketts	Avery	Lloyd	Blacker	Fleming	Dabney	Page
Nguyen	Mai		Lloyd	Fleming	Page	Avery	Blacker	Dabney	Ricketts	Ruddock
Obernolte	Hale		Dabney	Ricketts	Lloyd	Ruddock	Fleming	Blacker	Page	Avery
Ordentlich	Ethan		Lloyd	Page	Ricketts	Avery	Dabney	Fleming	Ruddock	Blacker
Owen	Samuel	Sam	Page	Avery	Dabney	Fleming	Ruddock	Ricketts	Lloyd	Blacker
Pandey	Mayank		Page	Lloyd	Ricketts	Ruddock	Blacker	Dabney	Fleming	Avery
Park	James		Page	Fleming	Ricketts	Avery	Dabney	Ruddock	Blacker	Lloyd
Patil	Anjali		Fleming	Avery	Ruddock	Dabney	Blacker	Lloyd	Page	Ricketts
Patil	Amol		Lloyd	Blacker	Page	Fleming	Ruddock	Dabney	Avery	Ricketts
Patwardhan	Vivienne		Ricketts	Blacker	Fleming	Lloyd	Dabney	Ruddock	Page	Avery
Pham	Tynesha		Avery	Ruddock	Lloyd	Ricketts	Fleming	Blacker	Page	Dabney
Popov	Alexander		Ricketts	Page	Lloyd	Blacker	Ruddock	Dabney	Avery	Fleming
Porter	Tara		Ruddock	Page	Fleming	Dabney	Blacker	Lloyd	Ricketts	Avery
Prater	Kenyon		Fleming	Ruddock	Page	Blacker	Lloyd	Dabney	Avery	Ricketts
Pratuangtham	Sarida		Lloyd	Ruddock	Avery	Ricketts	Blacker	Page	Fleming	Dabney
Proskauer	Jose		Avery	Dabney	Lloyd	Ruddock	Page	Blacker	Ricketts	Fleming
Qi	Zihao	Hao	Avery	Ruddock	Page	Fleming	Lloyd	Dabney	Ricketts	Blacker
Qian	Hanmin	Emma	Fleming	Ruddock	Page	Lloyd	Avery	Blacker	Ricketts	Dabney
Qin	Hongsen		Page	Ruddock	Ricketts	Avery	Fleming	Lloyd	Dabney	Blacker
Quach	Brandon		Dabney	Ricketts	Lloyd	Fleming	Blacker	Avery	Page	Ruddock
Rangaswamy	Anirudh		Lloyd	Ruddock	Fleming	Blacker	Dabney	Avery	Ricketts	Page
Ravishankar	Netra		Fleming	Lloyd	Avery	Ruddock	Dabney	Blacker	Page	Ricketts
Rebollo	Malia		Ricketts	Page	Ruddock	Blacker	Fleming	Dabney	Lloyd	Avery
Ren	XinYi	Ren	Dabney	Blacker	Ricketts	Fleming	Ruddock	Page	Lloyd	Avery
Resca-Candini	Galileo Alessio		Avery	Dabney	Fleming	Lloyd	Blacker	Ricketts	Ruddock	Page
Ressler-Craig	Jacob		Ricketts	Ruddock	Fleming	Page	Blacker	Dabney	Avery	Lloyd
Ridland	Paulina		Dabney	Lloyd	Blacker	Ruddock	Avery	Page	Ricketts	Fleming
Riker	Matthew	Matt	Avery	Fleming	Blacker	Page	Dabney	Lloyd	Ricketts	Ruddock
Rosa	Kevin		Fleming	Ruddock	Dabney	Lloyd	Ricketts	Blacker	Avery	Page
Rosner	Ariel	Ari	Page	Blacker	Dabney	Lloyd	Ruddock	Fleming	Ricketts	Avery
Rostovtsev	Daniel	Dan	Ruddock	Ricketts	Fleming	Page	Dabney	Blacker	Avery	Lloyd
Rothstein	Andrew	Andy	Lloyd	Fleming	Dabney	Blacker	Ruddock	Page	Ricketts	Avery
Roychoudhury	Ankita		Ruddock	Ricketts	Page	Fleming	Dabney	Lloyd	Blacker	Avery
Sander	Caleb		Dabney	Lloyd	Page	Ricketts	Ruddock	Avery	Blacker	Fleming
Sanders	Julian		Avery	Dabney	Lloyd	Fleming	Page	Ricketts	Blacker	Ruddock
Sanderson	Neil		Page	Fleming	Dabney	Lloyd	Blacker	Avery	Ruddock	Ricketts
Santos	Louis	Louie	Fleming	Avery	Blacker	Ruddock	Lloyd	Dabney	Page	Ricketts
Schneider	Spencer		Dabney	Avery	Page	Fleming	Blacker	Lloyd	Ricketts	Ruddock
Shang	Zhengyuan	John	Lloyd	Dabney	Fleming	Avery	Page	Ricketts	Blacker	Ruddock
Shankar	Aditi		Avery	Ricketts	Blacker	Lloyd	Dabney	Ruddock	Page	Fleming
Shanker	Varun		Avery	Ruddock	Lloyd	Page	Ricketts	Fleming	Dabney	Blacker
Shi	Rachel		Blacker	Fleming	Avery	Dabney	Ruddock	Ricketts	Lloyd	Page
Singh	Tarini		Ricketts	Avery	Lloyd	Page	Fleming	Blacker	Ruddock	Dabney
Singh	Amritpal		Ricketts	Blacker	Page	Ruddock	Fleming	Dabney	Avery	Lloyd
Sloneker	Whitney		Dabney	Page	Ruddock	Ricketts	Lloyd	Avery	Blacker	Fleming
Smith	Nathaniel		Ricketts	Page	Fleming	Dabney	Avery	Lloyd	Blacker	Ruddock
Snyder	Jacob		Ricketts	Fleming	Page	Ruddock	Avery	Blacker	Dabney	Lloyd
Sock	Noah		Ricketts	Fleming	Blacker	Lloyd	Avery	Dabney	Ruddock	Page
Srikanth	Maya		Lloyd	Page	Dabney	Ruddock	Blacker	Ricketts	Fleming	Avery
Srinivasaragavar	Gokul		Page	Blacker	Fleming	Dabney	Lloyd	Ricketts	Avery	Ruddock
Su	Victoria		Ricketts	Avery	Blacker	Ruddock	Lloyd	Page	Fleming	Dabney
Suezaki	Lauren		Ruddock	Dabney	Page	Avery	Ricketts	Lloyd	Blacker	Fleming
Sun	Rachel		Lloyd	Fleming	Dabney	Ricketts	Avery	Blacker	Page	Ruddock
Sun	Jessica		Page	Ricketts	Fleming	Dabney	Ruddock	Lloyd	Avery	Blacker
Sun	Sharne		Ricketts	Dabney	Fleming	Blacker	Ruddock	Page	Lloyd	Avery
Sun	Haoyuan	Hao	Ruddock	Page	Blacker	Fleming	Dabney	Lloyd	Ricketts	Avery
Tang	Yuchen	Dawn	Lloyd	Dabney	Avery	Ricketts	Fleming	Ruddock	Blacker	Page
Tardif	Davis		Ruddock	Blacker	Avery	Lloyd	Dabney	Fleming	Page	Ricketts
Thierstein	Emily		Lloyd	Fleming	Ricketts	Ruddock	Avery	Page	Dabney	Blacker
Thut	Charles	Chad	Blacker	Page	Fleming	Ruddock	Dabney	Lloyd	Avery	Ricketts
Tiffany	Maquelle		Fleming	Dabney	Avery	Ruddock	Lloyd	Blacker	Page	Ricketts
Tirumala	Kushal		Avery	Fleming	Page	Ruddock	Blacker	Dabney	Ricketts	Lloyd
Trussell	Allyson		Ruddock	Lloyd	Page	Blacker	Avery	Fleming	Ricketts	Dabney
Tseng	Albert		Avery	Ricketts	Ruddock	Page	Fleming	Blacker	Dabney	Lloyd
Ung	Shu Fay		Dabney	Page	Fleming	Lloyd	Ruddock	Blacker	Ricketts	Avery
Varadarajan	Vignesh		Lloyd	Ricketts	Fleming	Ruddock	Dabney	Avery	Page	Blacker
Vinson	James	Jamie	Avery	Page	Ricketts	Ruddock	Dabney	Blacker	Fleming	Lloyd
von Ruden	Galilea		Avery	Page	Ruddock	Ricketts	Dabney	Blacker	Fleming	Lloyd
Vytheeswaran	Jagath		Blacker	Fleming	Page	Ricketts	Ruddock	Dabney	Lloyd	Avery
Walker	James	JD	Blacker	Dabney	Ruddock	Fleming	Avery	Ricketts	Page	Lloyd
Wang	Stella		Avery	Lloyd	Fleming	Ruddock	Blacker	Page	Ricketts	Dabney
Wang	Amy		Lloyd	Avery	Ricketts	Page	Fleming	Dabney	Blacker	Ruddock
Wang	John		Page	Fleming	Ruddock	Lloyd	Blacker	Ricketts	Dabney	Avery
Watson	Mitchell		Fleming	Dabney	Avery	Ruddock	Page	Ricketts	Blacker	Lloyd
Wei	James		Avery	Page	Dabney	Lloyd	Blacker	Fleming	Ruddock	Ricketts
White	Ryan		Lloyd	Avery	Ruddock	Blacker	Ricketts	Dabney	Page	Fleming
Winzey	Kevin		Lloyd	Avery	Ruddock	Ricketts	Page	Fleming	Blacker	Dabney
Wong	Katie		Page	Fleming	Avery	Lloyd	Ruddock	Blacker	Dabney	Ricketts
Woolls	Gabriel		Blacker	Fleming	Avery	Ricketts	Page	Ruddock	Dabney	Lloyd
Wu	David		Fleming	Page	Ruddock	Blacker	Ricketts	Lloyd	Avery	Dabney
Wylie	Brittany		Ruddock	Fleming	Page	Ricketts	Avery	Lloyd	Blacker	Dabney
Xie	Yuanzhe		Ruddock	Lloyd	Dabney	Fleming	Blacker	Page	Ricketts	Avery
Xu	Mark		Ricketts	Lloyd	Dabney	Blacker	Fleming	Avery	Ruddock	Page
Yang	Isabell		Dabney	Ruddock				Avery	Lloyd	
Yao	Leyu	Natalie	Lloyd	Ricketts	Dabney	Blacker	Avery	Ruddock	Fleming	Page
Yao	Michael		Lloyd	Ruddock	Dabney	Fleming	Page	Blacker	Avery	Ricketts
Ye	Donovan		Avery	Ricketts	Blacker	Ruddock	Page	Lloyd	Dabney	Fleming
Ye	Angelina		Dabney	Fleming	Ruddock	Blacker	Page	Ricketts	Lloyd	Avery
Ye	Jessica		Page	Avery	Ricketts	Fleming	Dabney	Ruddock	Blacker	Lloyd
Yeluri	Akshay		Lloyd	Fleming	Dabney	Ruddock	Ricketts	Page	Avery	Blacker
Yoon	Eunice		Page	Ruddock	Dabney	Fleming	Blacker	Ricketts	Avery	Lloyd
Yu	Shuyue	Erika	Blacker	Ricketts	Fleming	Dabney	Avery	Page	Lloyd	Ruddock
Yu	Kevin		Blacker	Fleming	Dabney	Ricketts	Lloyd	Ruddock	Page	Avery
Yu	Qiyao	Vivian	Dabney	Fleming	Ruddock	Blacker	Lloyd	Page	Ricketts	Avery
Yu	Christine		Ricketts/Fleming	Lloyd				Avery	Dabney	
Zeitlin	Matthew	Matt	Blacker	Lloyd	Dabney	Ruddock	Page	Ricketts	Fleming	Avery
Zhai	Albert		Page	Avery	Lloyd	Ricketts	Ruddock	Dabney	Fleming	Blacker
Zhang	Yan Tian	Tina	Avery	Lloyd	Fleming	Page	Blacker	Ricketts	Dabney	Ruddock
Zhang	Yuling	Aileen	Page	Ricketts	Dabney	Lloyd	Avery	Fleming	Ruddock	Blacker
Zhang	Isabella		Ruddock	Avery	Page	Blacker	Lloyd	Fleming	Ricketts	Dabney
Zheng	Ruoyun		Page	Ricketts	Dabney	Blacker	Avery	Lloyd	Ruddock	Fleming
Zheng	David		Ruddock	Blacker	Dabney	Page	Ricketts	Avery	Lloyd	Fleming
Zhou	Daniel		Avery	Lloyd	Ruddock	Dabney	Fleming	Page	Ricketts	Blacker
Zhou	Andrew		Dabney	Page	Ruddock	Lloyd	Fleming	Avery	Ricketts	Blacker
Zhu	Zimo		Lloyd	Dabney	Ricketts	Page	Ruddock	Avery	Blacker	Fleming
Zhu	Shiyun	Shirley	Lloyd	Ricketts	Dabney	Page	Ruddock	Avery	Fleming	Blacker
Zlokapa	Alexander		Dabney	Ricketts	Avery	Blacker	Page	Lloyd	Ruddock	Fleming

DESSERT

Last Name	First Name	Preferred Name	Dessert 1	Dessert 2	Dessert 3	Dessert 4	Dessert 5	Dessert 6	Dessert 7
Abney	Nayla		Page	Fleming	Blacker	Ruddock	Dabney	Ricketts	Avery
Adams	Kasey		Dabney	Fleming	Page	Ruddock	Blacker	Ricketts	Avery
Agarwal	Ashima		Lloyd	Ricketts	Fleming	Page	Avery	Ruddock	Blacker
Agarwala	Vandana		Dabney	Ricketts	Lloyd	Avery	Blacker	Fleming	Ruddock
Alexander	Matthew		Page	Lloyd	Blacker	Ruddock	Ricketts	Avery	Dabney
Amaolo	Alessio		Page	Ruddock	Fleming	Avery	Lloyd	Ricketts	Dabney
Andrzejewski	Tomasz	Tomek	Ricketts	Fleming	Dabney	Lloyd	Blacker	Ruddock	Page
Apple	Logan		Ruddock	Fleming	Blacker	Avery	Ricketts	Page	Lloyd
Ardavin	Nicholas		Dabney	Fleming	Lloyd	Page	Avery	Ruddock	Blacker
Arun	Rahul		Ruddock	Blacker	Ricketts	Fleming	Dabney	Avery	Lloyd
Aw Young	Qingzhuo		Page	Fleming	Dabney	Blacker	Ruddock	Ricketts	Lloyd
Bao	Richard		Lloyd	Fleming	Ruddock	Dabney	Blacker	Ricketts	Page
Bao	Anthony		Fleming	Page	Avery	Ruddock	Dabney	Ricketts	Lloyd
Bathwal	Rahil		Avery	Page	Ricketts	Lloyd	Fleming	Dabney	Blacker
Berrigan	Brendan		Ricketts	Avery	Page	Dabney	Blacker	Fleming	Ruddock
Blankenberg	Luke		Dabney	Ricketts	Blacker	Page	Lloyd	Fleming	Avery
Boubezari	Ali		Lloyd	Ruddock	Dabney	Avery	Blacker	Ricketts	Fleming
Brabec	Cole		Ricketts	Avery	Ruddock	Lloyd	Blacker	Dabney	Page
Brodsky	Krystal		Avery	Fleming	Lloyd	Dabney	Ricketts	Page	Blacker
Brown	Krystin		Ruddock	Dabney	Ricketts	Blacker	Fleming	Avery	Page
Brown	Michael		Blacker	Lloyd	Avery	Dabney	Ruddock	Page	Fleming
Camplisson	Isabella		Fleming	Lloyd	Dabney	Page	Avery	Blacker	Ruddock
Cao	Siting	Cindy	Dabney	Page	Lloyd	Ruddock	Blacker	Ricketts	Fleming
Catanzaro	Dominic		Fleming	Dabney	Ruddock	Blacker	Page	Avery	Ricketts
Chan	Andrew		Avery	Dabney	Ricketts	Page	Lloyd	Blacker	Ruddock
Chelakkat	Kristine		Ricketts	Ruddock	Fleming	Page	Avery	Dabney	Lloyd
Chen	Lucy		Page	Lloyd	Blacker	Ricketts	Fleming	Ruddock	Dabney
Chen	Eric		Ricketts	Page	Ruddock	Fleming	Dabney	Avery	Blacker
Chen	LC		Fleming	Ricketts	Avery	Ruddock	Dabney	Blacker	Lloyd
Chitta	Pavan		Fleming	Dabney	Blacker	Lloyd	Avery	Ricketts	Ruddock
Cho	Hyerin		Page	Lloyd	Dabney	Fleming	Ruddock	Ricketts	Avery
Chow	Karena		Dabney	Ricketts	Page	Blacker	Ruddock	Fleming	Lloyd
Chung	Yoojin		Ruddock	Lloyd	Blacker	Page	Ricketts	Dabney	Avery
Clausen	Nicholas	Nick	Ricketts	Dabney	Lloyd	Blacker	Avery	Ruddock	Page
Como	Joseph	Joe	Blacker	Dabney	Ruddock	Fleming	Page	Lloyd	Avery
Costa	Reimond		Lloyd	Avery	Page	Blacker	Dabney	Ruddock	Fleming
Crotteau	Molly		Avery	Lloyd	Ricketts	Blacker	Fleming	Dabney	Page
Crowell	Irene		Ruddock	Fleming	Blacker	Lloyd	Page	Ricketts	Dabney
Csaposs	Steven		Dabney	Ricketts	Lloyd	Ruddock	Avery	Blacker	Fleming
Currault	Douglas	Nicholas	Ricketts	Fleming	Page	Blacker	Avery	Dabney	Lloyd
Danielsen	Dorte		Lloyd	Ricketts	Ruddock	Dabney	Fleming	Page	Avery
Dargan	Richard		Page	Ricketts	Lloyd	Fleming	Dabney	Blacker	Ruddock
de Castro	Gianfranco	Gian	Ruddock	Lloyd	Dabney	Avery	Page	Fleming	Ricketts
Delgado	Daniel		Lloyd	Fleming	Avery	Ricketts	Dabney	Ruddock	Blacker
Dev	Vidhya		Page	Fleming	Dabney	Ricketts	Ruddock	Lloyd	Blacker
Devasenapathy	Kiruthika	Kriti	Ricketts	Avery	Blacker	Dabney	Page	Ruddock	Fleming
Dibble	Jeremiah		Avery	Lloyd	Fleming	Page	Dabney	Ricketts	Blacker
Ding	Grace		Page	Dabney	Blacker	Ricketts	Fleming	Avery	Lloyd
Drango	Kaliden	Kali	Dabney	Avery	Lloyd	Fleming	Ricketts	Ruddock	Page
Durrett	Olivia		Fleming	Lloyd	Dabney	Ricketts	Avery	Ruddock	Blacker
Earney	Matthew		Blacker	Fleming	Dabney	Avery	Lloyd	Ricketts	Page
Escobar	Sergio		Page	Ricketts	Fleming	Ruddock	Blacker	Lloyd	Avery
Fish	Sara		Dabney	Avery	Ruddock	Fleming	Page	Ricketts	Lloyd
Fu	Rosita		Blacker	Avery	Lloyd	Page	Ruddock	Dabney	Ricketts
Garcia	Alexei		Lloyd	Dabney	Ricketts	Page	Fleming	Blacker	Ruddock
Gee	Marcus		Dabney	Avery	Blacker	Lloyd	Ruddock	Fleming	Ricketts
Gokuli	Mahi		Blacker	Page	Avery	Ricketts	Fleming	Dabney	Lloyd
Gonzalez Hermc	Ruy		Avery	Ruddock	Ricketts	Lloyd	Dabney	Blacker	Fleming
Gowda	Jethin		Ruddock	Fleming	Page	Lloyd	Blacker	Dabney	Ricketts
Granovskiy	Reggy		Fleming	Blacker	Lloyd	Avery	Ricketts	Ruddock	Page
Griffith	Nora		Dabney	Fleming	Lloyd	Ruddock	Avery	Page	Blacker
Gudavalli	Sirisha		Page	Dabney	Avery	Fleming	Lloyd	Ricketts	Ruddock
Guenov	Sarah		Blacker	Ruddock	Page	Avery	Lloyd	Dabney	Ricketts
Guerra	Alex		Page	Ricketts	Dabney	Blacker	Fleming	Lloyd	Avery
Guo	Steve		Lloyd	Fleming	Page	Ruddock	Blacker	Avery	Dabney
Gupta	Arushi		Blacker	Avery	Dabney	Ruddock	Page	Ricketts	Lloyd
Han	Ryan		Ricketts	Fleming	Dabney	Ruddock	Avery	Lloyd	Page
Han	Eric		Avery	Ricketts	Lloyd	Dabney	Blacker	Ruddock	Fleming
Hands Arocha	Andrea		Blacker	Fleming	Page	Ricketts	Dabney	Avery	Lloyd
Heath	John		Ricketts	Fleming	Dabney	Avery	Ruddock	Lloyd	Blacker
Hess	Andrew		Ricketts	Ruddock	Blacker	Avery	Lloyd	Dabney	Page
Ho	Andrew		Blacker	Ruddock	Page	Fleming	Dabney	Lloyd	Ricketts
Holder	Lofton	Dillon	Fleming	Page	Ricketts	Blacker	Ruddock	Lloyd	Dabney
Hommerich-Dut	Ankush		Fleming	Ricketts	Dabney	Page	Avery	Blacker	Lloyd
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Hu	Laura		Dabney	Ricketts	Page	Lloyd	Fleming	Blacker	Avery
Huang	Christine	Christie	Fleming	Ricketts	Avery	Lloyd	Dabney	Page	Blacker
Huffman	Nerys		Fleming	Lloyd	Dabney	Page	Ruddock	Avery	Ricketts
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Jain	Neymika		Avery	Page	Ruddock	Blacker	Ricketts	Lloyd	Dabney
Janosi	Alex		Page	Lloyd	Ruddock	Ricketts	Blacker	Avery	Dabney
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Kim	Min Hyuk	Matthew	Avery	Page	Fleming	Ruddock	Lloyd	Blacker	Ricketts
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Kim	Yu Jin		Ruddock	Lloyd	Blacker	Ricketts	Dabney	Fleming	Avery
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Muise	Isabelle	Izzy	Page	Ruddock	Lloyd	Ricketts	Dabney	Avery	Fleming
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Patwardhan	Vivienne		Fleming	Ruddock	Avery	Lloyd	Dabney	Blacker	Page
Pham	Tynesha		Ricketts	Dabney	Blacker	Fleming	Ruddock	Page	Lloyd
Popov	Alexander		Lloyd	Blacker	Dabney	Avery	Fleming	Page	Ruddock
Porter	Tara		Avery	Dabney	Fleming	Page	Lloyd	Blacker	Ricketts
Prater	Kenyon		Ruddock	Page	Dabney	Lloyd	Blacker	Avery	Ricketts
Pratuangtham	Sarida		Dabney	Ricketts	Page	Avery	Blacker	Fleming	Ruddock
Proskauer	Jose		Ruddock	Fleming	Ricketts	Lloyd	Dabney	Page	Blacker
Qi	Zihao	Hao	Fleming	Ricketts	Page	Blacker	Lloyd	Ruddock	Dabney
Qian	Hanmin	Emma	Ruddock	Blacker	Page	Avery	Lloyd	Ricketts	Dabney
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Resca-Candini	Galileo Alessio		Blacker	Lloyd	Page	Fleming	Ricketts	Ruddock	Dabney
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Ridland	Paulina		Avery	Fleming	Blacker	Lloyd	Ruddock	Ricketts	Page
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Rosa	Kevin		Ruddock	Lloyd	Page	Dabney	Ricketts	Blacker	Avery
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Sander	Caleb		Ricketts	Avery	Blacker	Lloyd	Fleming	Ruddock	Page
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Ye	Donovan		Dabney	Lloyd	Fleming	Blacker	Ruddock	Page	Ricketts
Ye	Angelina		Ruddock	Avery	Fleming	Page	Ricketts	Lloyd	Blacker
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Yeluri	Akshay		Blacker	Avery	Dabney	Ricketts	Page	Ruddock	Fleming
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Yu	Shuyue	Erika	Ricketts	Fleming	Lloyd	Dabney	Ruddock	Page	Avery
Yu	Kevin		Avery	Dabney	Fleming	Ricketts	Ruddock	Page	Lloyd
Yu	Qiyao	Vivian	Avery	Blacker	Ruddock	Lloyd	Page	Fleming	Ricketts
Yu	Christine		Avery	Page	Dabney	Lloyd	Ruddock	Blacker	Ricketts
Zeitlin	Matthew	Matt	Ruddock	Fleming	Avery	Dabney	Ricketts	Lloyd	Page
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Zhang	Yan Tian	Tina	Dabney	Ruddock	Lloyd	Blacker	Page	Fleming	Ricketts
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Zhang	Isabella		Blacker	Page	Avery	Ricketts	Lloyd	Fleming	Dabney
Zheng	Ruoyun		Dabney	Lloyd	Fleming	Blacker	Ricketts	Ruddock	Avery
Zheng	David		Dabney	Fleming	Blacker	Ricketts	Page	Lloyd	Avery
Zhou	Daniel		Ruddock	Blacker	Ricketts	Fleming	Lloyd	Dabney	Page
Zhou	Andrew		Blacker	Ruddock	Page	Lloyd	Fleming	Ricketts	Avery
Zhu	Zimo		Ruddock	Blacker	Fleming	Page	Avery	Ricketts	Dabney
Zhu	Shiyun	Shirley	Page	Blacker	Avery	Ricketts	Ruddock	Fleming	Dabney
Zlokapa	Alexander		Page	Ruddock	Fleming	Ricketts	Blacker	Lloyd	Avery

Sorting Molecules with DNA Robots

Lori Dajose
Caltech Media Relations

This article is adapted from a story that was originally published online at caltech.edu.

Imagine a robot that could help you tidy your home: roving about, sorting stray socks into the laundry and dirty dishes into the dishwasher. While such a practical helper may still be the stuff of science fiction, Caltech scientists have developed an autonomous molecular machine that can perform similar tasks—at the nanoscale. This "robot," made of a single strand of DNA, can autonomously "walk" around a surface, pick up certain molecules and drop them off in designated locations.

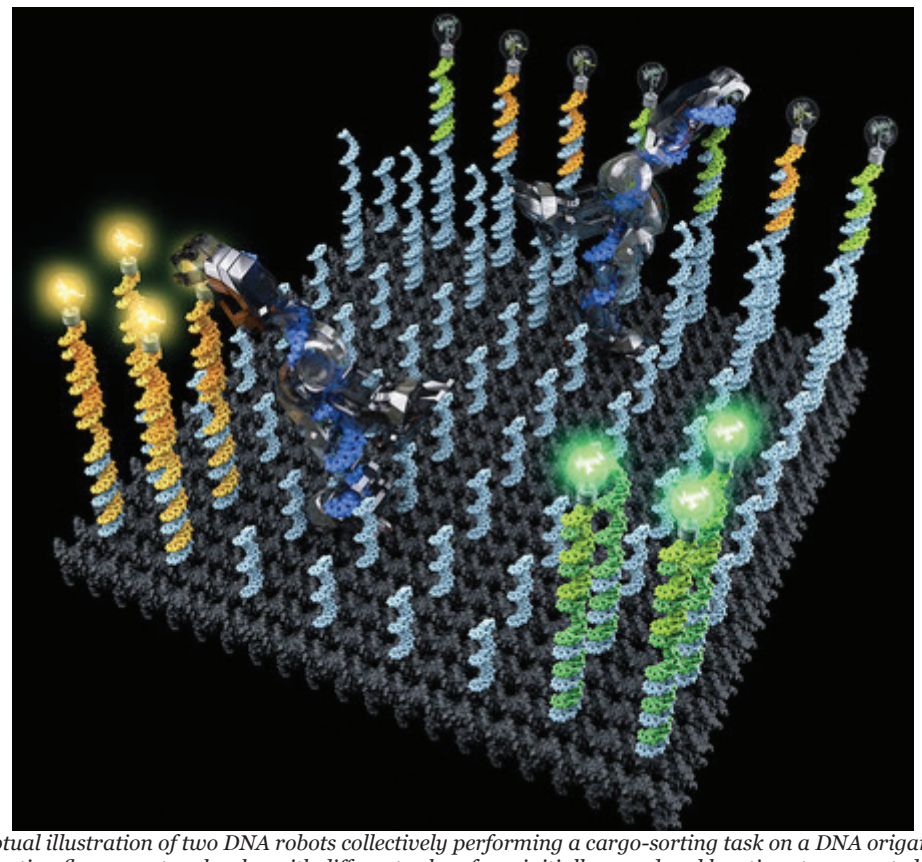
The work was done in the laboratory of Lulu Qian, assistant professor of bioengineering. It appears in a paper in the September 15 issue of Science.

Why Nanobots?

"Just like electromechanical robots are sent off to faraway places, like Mars, we would like to send molecular robots to minuscule places where humans can't go, such as the bloodstream," says Qian. "Our goal was to design and build a molecular robot that could perform a sophisticated nanomechanical task: cargo sorting."

How to Build a Molecular Robot

Led by former graduate student Anupama Thubagere (PhD '17), the researchers constructed three basic building blocks that could be used to assemble a DNA robot: a "leg" with two "feet" for walking, an "arm" and "hand" for picking up cargo, and a segment that can recognize a specific drop-off point and signal to the hand to release its cargo. Each of these components is made of just a few nucleotides within a single strand of DNA.



Conceptual illustration of two DNA robots collectively performing a cargo-sorting task on a DNA origami surface, transporting fluorescent molecules with different colors from initially unordered locations to separated destinations. Considerable artistic license has been taken.

Photo Courtesy of Demin Liu

In principle, these modular building blocks could be assembled in many different ways to complete different tasks—a DNA robot with several hands and arms, for example, could be used to carry multiple molecules simultaneously.

In the work described in the Science paper, the Qian group built a robot that could explore a molecular surface, pick up two different molecules—a fluorescent yellow dye and a fluorescent pink dye—and then distribute them to two distinct regions on the surface. Using fluorescent molecules enabled the researchers to see if the molecules ended up in their intended locations. The robot successfully sorted six scattered molecules, three pink and three yellow, into their correct places in 24 hours. Adding more robots to the surface shortened the time it took to complete the task.

"Though we demonstrated a robot for this specific task, the same system design can be generalized to work with dozens of types of cargos at any arbitrary initial location on the surface," says Thubagere. "One could also have multiple robots performing diverse sorting tasks in parallel."

Continued on page 7

Jellyfish and Humans May Seem Wildly Different, but Both Still Need to Sleep

Continued from page 3

awake. They then observed that the jellyfish were more likely to fall into the quiescent state during the day, when they would normally be active.

Though this work demonstrates that jellyfish exhibit sleep behavior, the genetic mechanisms that underlie sleep remain unknown.

"Many animals have the same genes that govern sleep," says Michael Abrams, co-first author and a graduate student in the Goentoro laboratory. "Though it was beyond the scope of our project to measure gene expression in jellyfish, we tested the effects of compounds that in other animals are known to promote sleep, such as melatonin. We found that these compounds did affect jellyfish sleep in the predicted ways, suggesting that their underlying sleep mechanism is similar to those of other organisms—including humans."

The project was a collaborative effort across several laboratories with different areas of expertise. In addition to the three first authors and their advisers, the team had help from Ty Basinger, a lab technician in the Goentoro lab, in working with the jellyfish; from Justin Bois, lecturer in biology and biological engineering, with computational analysis; and from Professor of Biology David Prober, an expert on how genes and neurons regulate sleep.

The paper is titled "The Jellyfish Cassiopea Exhibits a Sleep-like State." Funding was provided by the National Institutes of Health, the James S. McDonnell Foundation for Complex Systems Science, the National Institute of Mental Health, the National Institute of Neurological Disorders and Stroke, the National Science Foundation, the Heritage Medical Research Institute, and the Howard Hughes Medical Institute.

A DNA Nanorobot is Programmed to Pick Up and Sort Molecules into Predefined Regions

Continued from page 6

Design through DNA

The key to designing DNA machines is the fact that DNA has unique chemical and physical properties that are known and programmable. A single strand of DNA is made up of four different molecules called nucleotides—abbreviated A, G, C, and T—and arranged in a string called a sequence. These nucleotides bond in specific pairs: A with T, and G with C. When a single strand encounters a so-called reverse complementary strand—for example, CGATT and AATCG—the two strands zip together in the classic double helix shape.

A single strand containing the right nucleotides can force two partially zipped strands to unzip from each other. How quickly each zipping and unzipping event happens and how much energy it consumes can be estimated for any given DNA sequence, allowing researchers to control how fast the robot moves and how much energy it uses to perform a task. Additionally, the length of a single strand or two zipped strands can be calculated. Thus, the leg and foot of a DNA robot can be designed for a desired step size—in this case, 6 nanometers, which is about a hundred millionth of a human's step size.

Using these chemical and physical principles, researchers can design not only robots but also "playgrounds," such as molecular pegboards, to test them on. In the current work, the DNA robot moves around on a 58-nanometer-by-58-nanometer pegboard on which the pegs are made of single strands of DNA complementary to the robot's leg and foot. The robot binds to a peg with its leg and one of its feet—the other foot floats freely. When random molecular fluctuations cause this free foot to encounter a nearby peg, it pulls the robot to the new peg and its other foot is freed. This process continues with the robot moving in a random direction at each step.

It may take a day for a robot to explore the entire board. Along the way, as the robot encounters cargo molecules tethered to pegs, it grabs them with its "hand" components and carries them around until it detects the signal of the drop-off point. The process is slow, but it allows for a very simple robot design that utilizes very little chemical energy.

Futuristic Applications

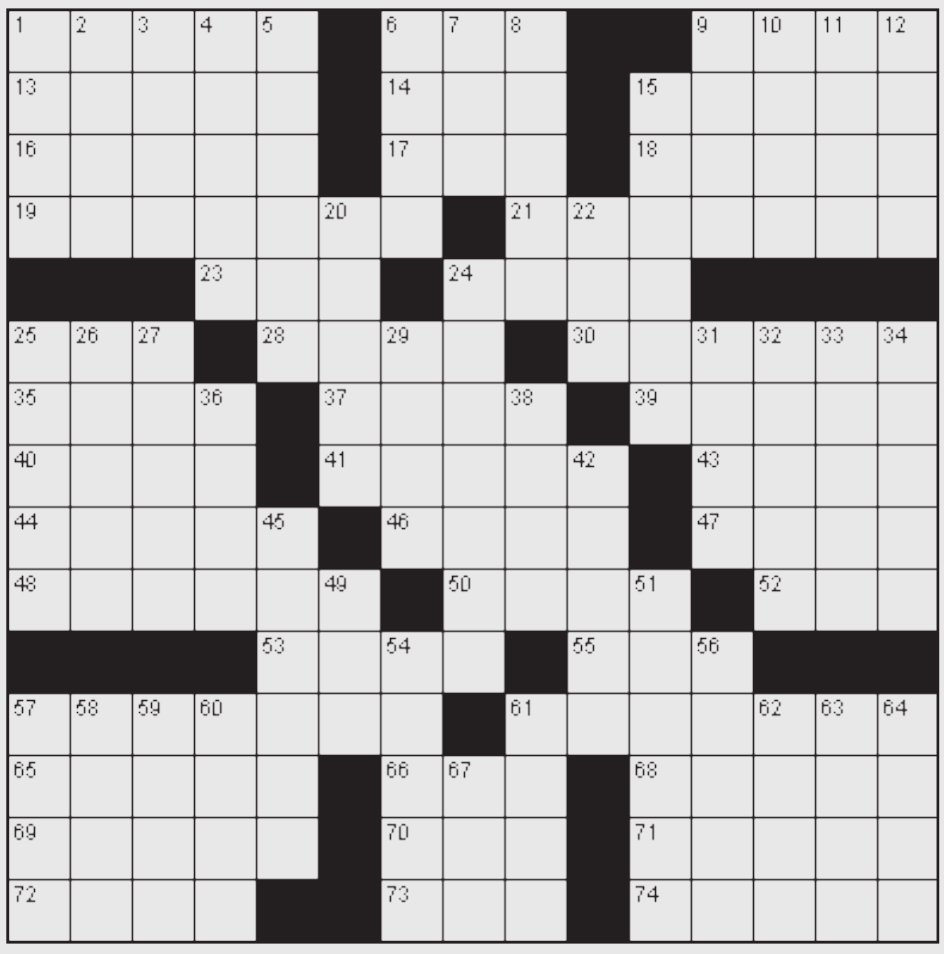
"We don't develop DNA robots for any specific applications. Our lab focuses on discovering the engineering principles that enable the development of general-purpose DNA robots," says Qian. "However, it is my hope that other researchers could use these principles for exciting applications, such as using a DNA robot for synthesizing a therapeutic chemical from its constituent parts in an artificial molecular factory, delivering a drug only when a specific signal is given in bloodstreams or cells, or sorting molecular components in trash for recycling."

The paper is titled "A cargo-sorting DNA robot." In addition to Thubagere and Qian, other co-authors are postdoctoral scholar Wei Li, graduate student Robert Johnson (BS '15), former visiting student Zibo Chen, former undergraduates Shayan Doroudi (BS '13), Yae Lim Lee (BS '12), Gregory Izatt (BS '14), and Sarah Wittman (BS '13); former graduate student Niranjan Srinivas (PhD '15), former senior research fellow Damien Woods; and Erik Winfree (PhD '98), professor of computer science, computation and neural systems, and bioengineering. Funding was provided by Caltech Summer Undergraduate Research Fellowships, the National Science Foundation, and the Burroughs Wellcome Fund.

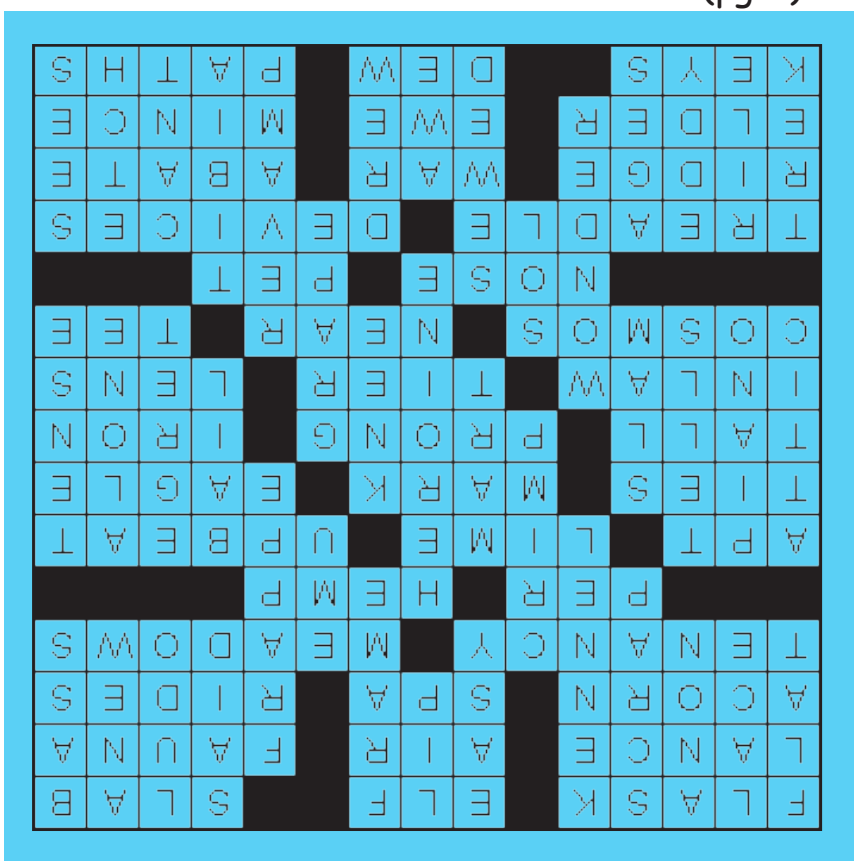
Crossword

Across
1. Ampulla
6. Kind of fairy
9. Block
13. Spear
14. Atmosphere
15. Animal life in a particular region
16. Fruit of the oak
17. Resort area
18. Travels by horse
19. Occupancy
21. Grasslands
23. For each
24. Plant fiber
25. Pertinent
28. Acidic fruit
30. Cheerful
35. Affiliations
37. Grade or score
39. Bird of prey
40. High in stature
41. Tine
43. Golf club
44. Relative by marriage
46. Level
47. Optical device
48. Everything that exists everywhere
50. Close
52. Golf peg
53. Proboscis
55. Animal companion
57. Foot pedal
61. Instruments invented for particular purposes
65. Long narrow range of hills
66. Armed conflict
68. Lessen
69. Church officer
70. Female sheep
71. Cut into small pieces
72. Tonal frameworks
73. Condensation
74. Trails

Down
1. Horizontally level
2. Delicate decorative fabric
3. Sweet pulpy tropical fruit
4. Dispose of
5. Dog house
6. Requiring little effort
7. Part of the mouth
8. Chassis
9. Expressed in words
10. Board game
11. Afresh
12. Lowest singing voice
15. Frozen dessert
20. Curl tightly
22. Australian flightless bird
24. A female theatrical role
25. Garret
26. Musical instrument
27. Narrates
29. Marketplace
31. Release after a security has been paid
32. Heron
33. Solitary
34. Taut
36. Close violently
38. Leg joint
42. Juicy fruit
45. Marvel
49. Ancient Roman god
51. Patch up or renovate
54. Stitched
56. Shin
57. Long and difficult trip
58. Annoy
59. Miniature whirlpool
60. Historic periods
61. Traced
62. Jargon
63. Engrave
64. Visualizes
67. Veneration



Answers to current crossword (pg 7)



-http://puzzlechoice.com

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