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JOHNS HOPKINS
CENTER FOR TALENTED YOUTH

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Big Ideas for Bright Minds

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Biology

The International Biology Olympiad

Teens Take on iGEM

Lessons from Chess

Students Review Cornell University

contents

departments

editor's note

Life studies


CHARLES BECKMAN

Last summer, scientists Tullis Onstott and Gaetan Borgonie discovered a new species of worm. That might not seem too surprising—until you learn that this nematode was found two miles underground, in water thousands of years old within tiny fractures in solid rock, where there was barely any oxygen. Before this discovery of *Halicephalobus mephisto* (named after Faust's devil Mephistopheles), no one thought multicellular organisms could thrive in such an environment. Only bacteria had been found at such depths.

The existence of *H. mephisto* raises many questions: How is this nematode able to survive such extreme heat and pressure? Might there be other organisms living even deeper underground—or underground on other planets, such as Mars? What defines a habitable environment? What other forms of complex life have we not yet discovered? The scientists trying to answer these questions include ecologists, nematologists, geobiologists, environmental microbiologists, evolutionary biologists, astrobiologists, and more. As this roster suggests, understanding living things—whether bacteria, worms, plants, or humans—is a multidisciplinary endeavor.

Biology is an incredibly diverse field, offering opportunities to study life at scales ranging from biomes to molecules. You can study the big picture in environmental science, epidemiology, or public health. You can focus on plants or animals, or on a certain species. You can zoom in to study nanobiology, genetics, or epigenetics. You can also apply other interests you might have—whether in math, physics, chemistry, engineering, or computer science—to topics in biology.

In this issue of *Imagine,* our writers introduce you to a range of exciting topics in biology. You'll hear from high school students whose research focused on DNA barcoding, assembling genetic parts to create a new biological system, and studying a mouse model of a developmental disorder. You'll learn about cutting-edge epigenetics research from a student who worked for three summers in labs at Johns Hopkins, and you'll go behind the scenes of the International Biology Olympiad with the top competitor from last year's contest. You'll see how both students and experts, including Nobel laureate Carol Greider, made some important discoveries by following their curiosity about living things.

If you're inspired by what you learn, you'll find an extensive listing of resources to get you started on your own biological explorations. Who knows? If you follow your curiosity as this issue's writers have done, your own big discoveries might be just around the corner.—**mh**

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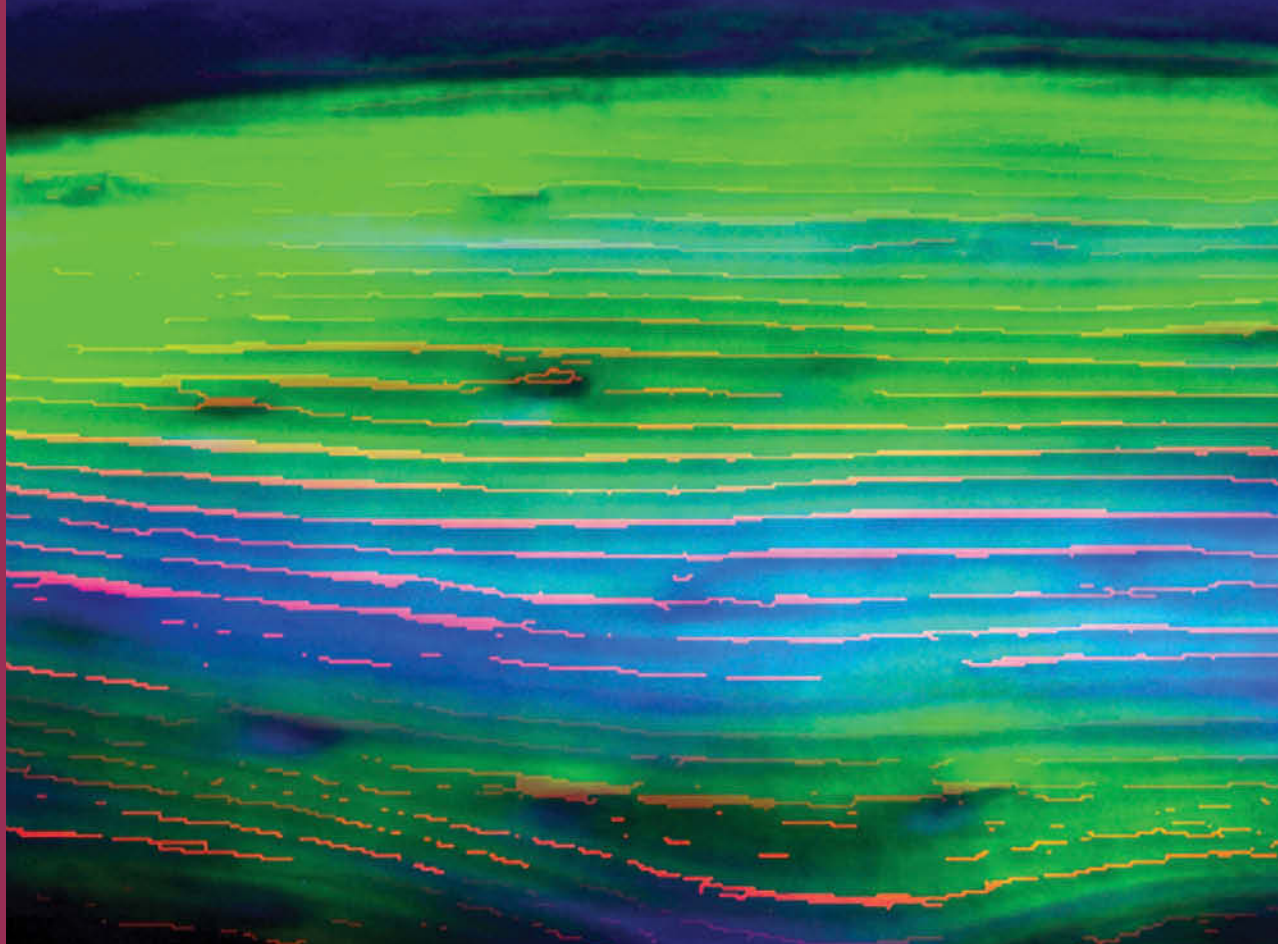


Biology, Space, and Time

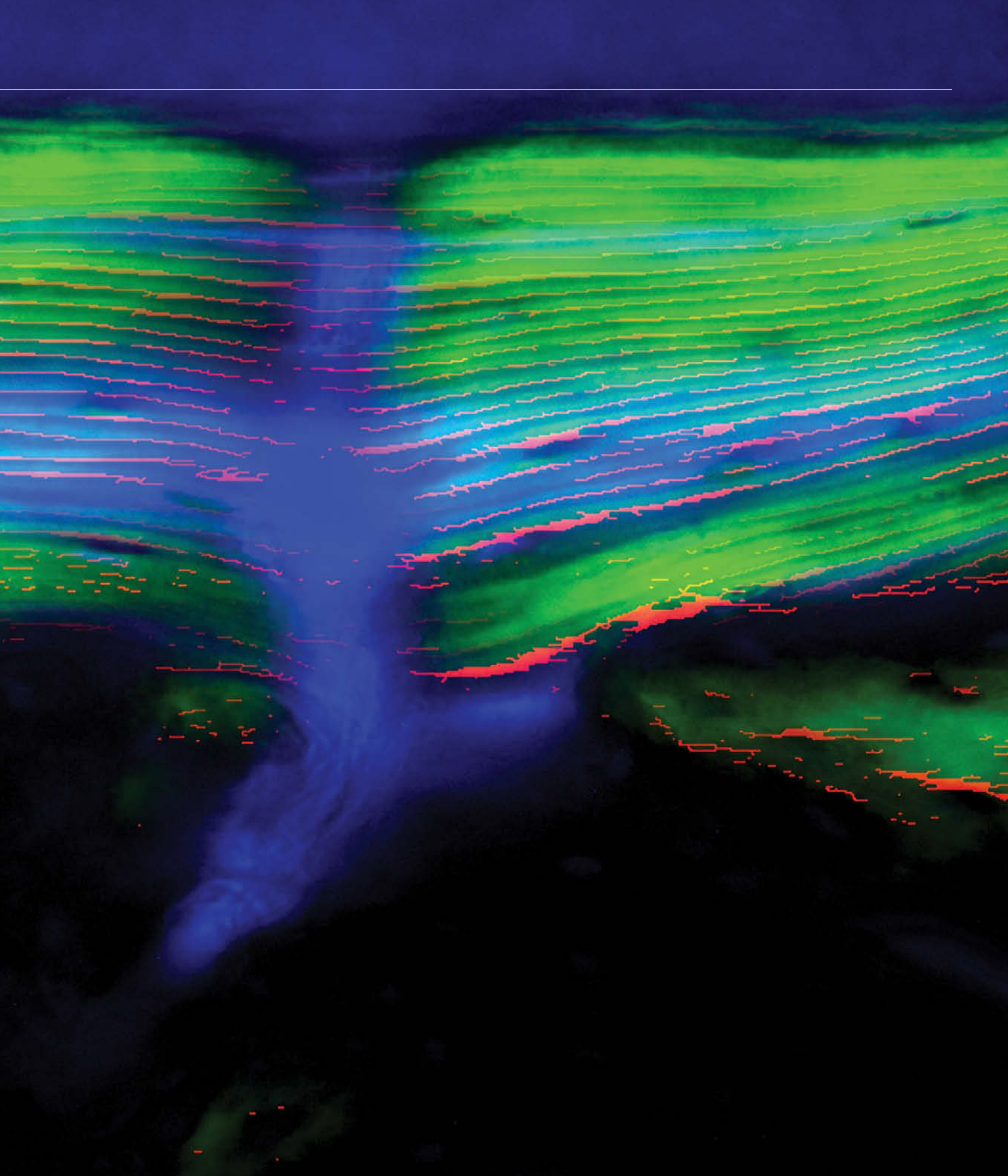
Like growth rings in a tree, growth layers in bone record the passage of time. In this image of bone tissue from a rat that flew aboard the Space Shuttle, horizontal layers of new growth are clearly visible. But while all trees add one ring per year, all animals do not add bone at the same rate—a fact that was discovered only a few years ago. And this photograph played a part in that discovery.

New York University professor Timothy Bromage was studying the effects of microgravity on bone growth when he discovered a previously unknown "biological clock" that controls bone growth. Unlike the circadian (daily) rhythms found throughout the animal kingdom, this biorhythm is shorter for smaller, shorter-lived animals and longer for larger, longer-lived animals. "This biological rhythm also regulates body size and likely many metabolic processes, including heart and respiration rates. In fact, the rhythm relates to an organism's overall pace of life and its life span. So, a rat that grows teeth and bone in one-eighth the time of a human also lives faster and dies younger."

This discovery has opened up new avenues of research in developmental biology, and will also help paleobiologists reconstruct the life histories of extinct species.

In 2010, Professor Bromage received the Max Planck Research Award for this discovery. The prize, considered the "Nobel Prize for Life Science," is the highest international honor bestowed in the natural sciences. i

IMAGE COURTESY DR. TIMOTHY BROMAGE, NYU

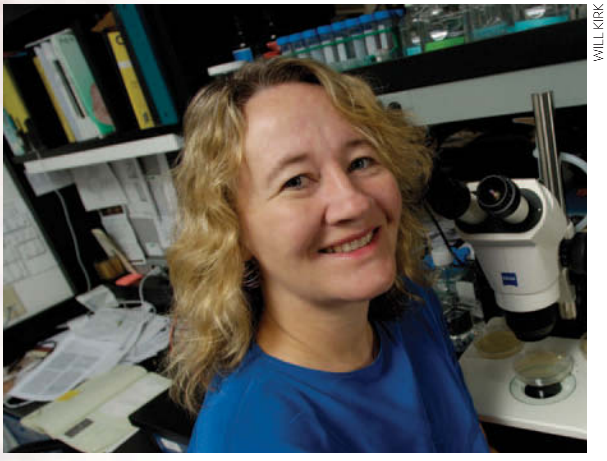


Captivated by Chromosomes

CAROL GREIDER, PhD
Chair, Department of Molecular Biology and Genetics
Johns Hopkins University School of Medicine

Scientists have a reputation for being driven, and Johns Hopkins University's Carol Greider is indeed driven—by curiosity. She pursues and champions what she calls "curiosity-driven science." It led her to the 2009 Nobel Prize in Medicine for critical work characterizing the ends of chromosomes and discovering telomerase, the enzyme that attaches a repetitive sequence of the bases thymine and guanine on the ends of chromosomes, essentially buffering the gene-containing areas from damage. Curiosity has also driven her to a long list of discoveries in basic cell biology that shed light on cancer, degenerative diseases, and aging.

SHUTTERSTOCK



WILL KIRK

How I got hooked

As an undergraduate at the University of California in Santa Barbara, I started as a marine ecology major. But there's nothing like the experience of being in a lab and doing experiments to let you know whether you're actually interested in that field. It was through working in a number of different labs in my first two years that I found that I didn't like to think as a marine ecologist—I preferred more mechanistic, biochemical ways of thinking, such as treating proteins in different ways to see how they behaved.

So when I studied in Germany for my junior year in college and wanted some lab experience, I found a place in a lab at the Max Planck Institute for Biophysical Chemistry. There, I studied giant chromosomes from the larvae of a type of fly related to the fruit fly *Drosophila*, which is often used as a model system in biology. Giant chromosomes are 10,000 times bigger than most chromosomes, so we could actually dissect them out under a simple light microscope and stain them with various things to see what proteins were there. It was a lot of fun to have this hands-on experience, and I was captivated by the beauty of chromosomes.

Finding my niche

I was having so much fun doing molecular biology and biochemistry in the lab as an undergraduate that I decided I would also pursue it in graduate school. It was while I was interviewing for various graduate positions that I met with Dr. Elizabeth Blackburn, a faculty member at the University of California at Berkeley. She was studying how chromosome ends—which scientists predicted should get shorter and shorter and lose genetic material as a cell replicates, because the copying machinery of the cell can't work all the way to the end of the chromosome—somehow stay elongated. Dr. Blackburn and her collaborator Dr. Jack Szostak (both also joint winners of the 2009 Nobel) had found that in both *Tetrahymena* (related to paramecium) and baker's yeast, the ends were very simple repeats of the bases thymine and guanine—specfically, TTGGGG. These repeating, protective ends are called telomeres.

Drs. Blackburn and Szostak had made a very bold proposal—with only indirect evidence supporting it—that perhaps telomeres are maintained when this simple sequence is actively added onto the chromosome end, rather than being copied from another chromosome location. So that's what I set out to do for my PhD research in Dr. Blackburn's lab: see if we could find an enzyme that would add these simple telomere sequences onto chromosome ends.

We did. Our discovery of the enzyme telomerase, which ended up winning us the Nobel Prize, really started off as what we call curiosity-driven science. We wanted to understand the puzzle of how chromosomes stay long and keep their genes intact even though they "should" get shorter with each replication. Telomerase was the missing piece to the puzzle.

Following my curiosity

I've continued to follow my curiosity in my research, first by asking basic questions like "What if cells can't maintain chromosome ends?" We did experiments in both yeast and mice to get rid of the telomerase so we could see what would happen. It turns out that telomerase is essential for all cells that have to divide many times: when telomeres are too short, cells die. We developed a mouse that lacks telomerase and began to study the diseases that the mouse was then susceptible to. This led us to understand that there are age-related degenerative diseases that appear in part because cells that divide many times over a lifetime need telomerase to maintain chromosome ends.

By starting off trying to understand the fundamental problems at the level of cells, we ended up finding mechanisms of major human degenerative diseases. For instance, we were very interested in the structure of the RNA component in telomerase. Shape is important because telomerase RNA has to interact with proteins to do its job. Over a period of five or six years, we did extensive biochemical experiments to clearly define its structure. Then we analyzed a whole lot of regions in the RNA by making a number of small changes in the RNA and observing the consequences.

Separately, the genetic research community discovered that dyskeratosis congenita—a disease in which affected people can develop bone marrow failure, cancer, or scar tissue build-up in the lungs—is caused by defects in telomerase RNA. By the time it became apparent to the human genetics community studying the disease that telomerase RNA was critical, we had a whole series of functional studies characterizing all the different components of telomerase. We had just been following our interest in trying to figure out how telomerase worked. But suddenly there was a large body of studies that were directly relevant to human disease.

Life after a Nobel

Winning the Nobel has not really changed my research. My job is to train the next generation of scientists and hopefully discover things along the way. So I run a research group that includes six to eight graduate students or postdoc researchers at any given time, as well as two technicians who help me run the lab. Everyone has a particular project they're working on, and the weekly data meetings I have with each of my lab members are the most fun part of my week. Then, of course, I have to spend a fair amount of time designing and writing grants. I am also chair of the Department of Molecular Biology and Genetics at the Johns Hopkins School of Medicine, so I represent the 14 faculty members in my department to the university as a whole and to the medical school.

The Nobel has had a bigger influence in terms of my life. It certainly has given me an opportunity to meet people I wouldn't normally have and allowed me to have a soapbox to point out why it's important to fund the curiosity-driven research that will fuel innovation in the future.

Future of biology research

The biggest technology jump in molecular biology and genetics in the recent past has been the huge boom in sequencing. Although we don't do a lot of heavy-duty sequence analysis in my lab, we and all our colleagues in molecular biology are beneficiaries of that technology. What used to be a four-year project to identify and clone a single gene is now reduced to about two weeks.

Because of advances in sequencing technology, I often encourage developing scientists to go into genomics and bioinformatics. There has been a lag in graduate training of computationally minded people, and we don't have that many students entering our biology labs with training in computational areas. So I encourage people to keep up their math skills and think about areas where biology intersects with computer science and mathematics. That's what I would do if I were going to go back and do it again.

Your future

Getting hands-on experience early in my education was critical to my finding a field I loved. I was fortunate to have mentors before "mentoring" was a common idea, and they encouraged me to jump in to the lab. You may think you don't know how to get started, but all you need is one person to get some advice from, to ask who might be interested in having a student in the lab, and who can point you in the right direction. **i**

To see a short documentary about the work for which Drs. Greider, Blackburn, and Szostak won the Nobel Prize, visit www.nobelprize.org/nobel_prizes/medicine/laureates/2009/greider-docu.html.

READ Tea

by Grace Young

THINKSTOCK

After water, tea is the world's most popular beverage. People all over the world drink billions of cups of it every day—more than all the coffee, soda, and other drinks combined. Do you know what's in your tea?

In my freshman year of high school, I saw a poster in the biology hallway inviting students to conduct a research project with Dr. Mark Stoeckle of the Rockefeller University. Dr. Stoeckle had helped create the Consortium for the Barcode of Life, an organization devoted to developing and promoting DNA barcoding as the global standard of species identification. The goal of DNA barcoding is to identify short DNA sequences that can be used to characterize species. A database of confirmed reference sequences allows scientists to match test samples. DNA barcoding is both faster and cheaper than full genome analysis because it looks not at an organism's entire genome, but at only one tiny snippet of it—one gene among millions.

Dr. Stoeckle's work with high school students began in 2008, when his daughter and her friend—then seniors at my school—conducted an experiment that found that one-fourth of sushi samples they bought from local restaurants and supermarkets were mislabeled, a discovery that won widespread media attention. The following year, Dr. Stoeckle mentored students in a project identifying animal species commonly found in the urban domestic environment.

I had enjoyed a genetics course at CTY the previous summer, and was excited by the prospect of gaining hands-on research experience. I contacted Dr. Stoeckle, who invited me to participate in the project. Two more students from my school, seniors Rohan Kirpekar and Catherine Gamble, completed the team.

DING

Leaves

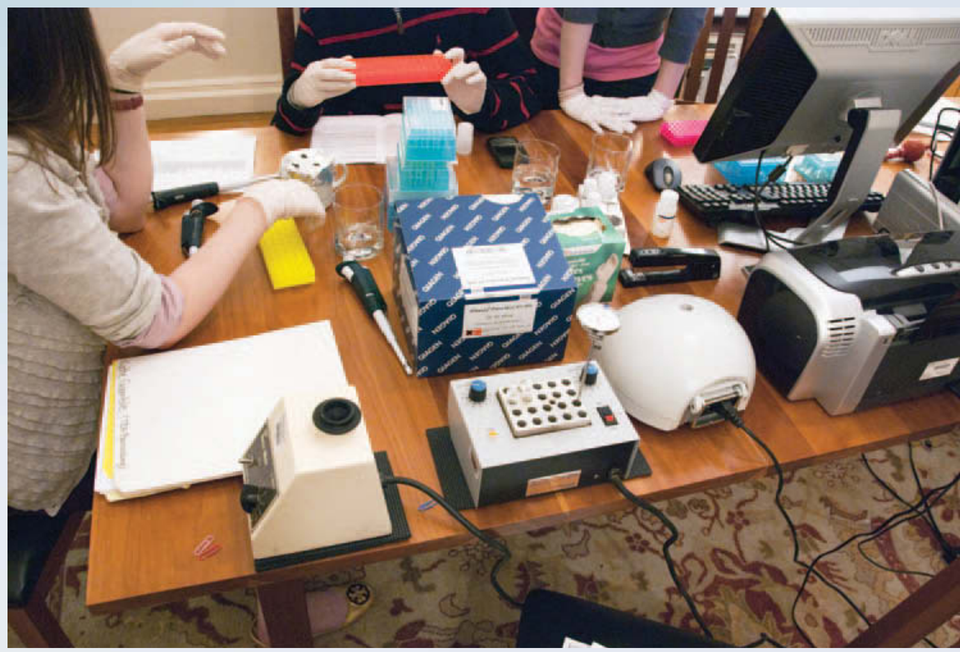
This time, Dr. Stoeckle wanted to work with plant DNA, which had been studied less extensively than animal DNA. My teammates and I were struggling to narrow our research focus when Dr. Stoeckle asked if we drank tea. Of course I did! Almost every afternoon after school, I made a cup of tea. And on weekends, when my family and I had lunch in Chinatown, the default drink that the waiters poured wasn't water; it was tea. And so tea it would be.

Samples and Spreadsheets

We began by collecting 146 regular and herbal tea products originating in 17 different countries and produced by over 30 different companies. They came from our pantries, local supermarkets, tea shops, an herbal pharmacy, and our school cafeteria. Seventy-three of the samples were regular teas made from leaves of the tea plant *Camellia sinensis*; 73 were herbal products made from flowers, leaves, and roots of other kinds of plants. We found over 50 different plant ingredients listed on the herbal tea labels.

Working after school and over breaks, we labeled and photographed each sample and recorded each product's information on a spreadsheet: ingredients, type of tea (such as green, oolong, or black), origin, brand, retailer, and price. The next step would be to obtain DNA sequences for our samples so we could search for possible matches in GenBank, a search engine of the NIH's library of genetic sequences.

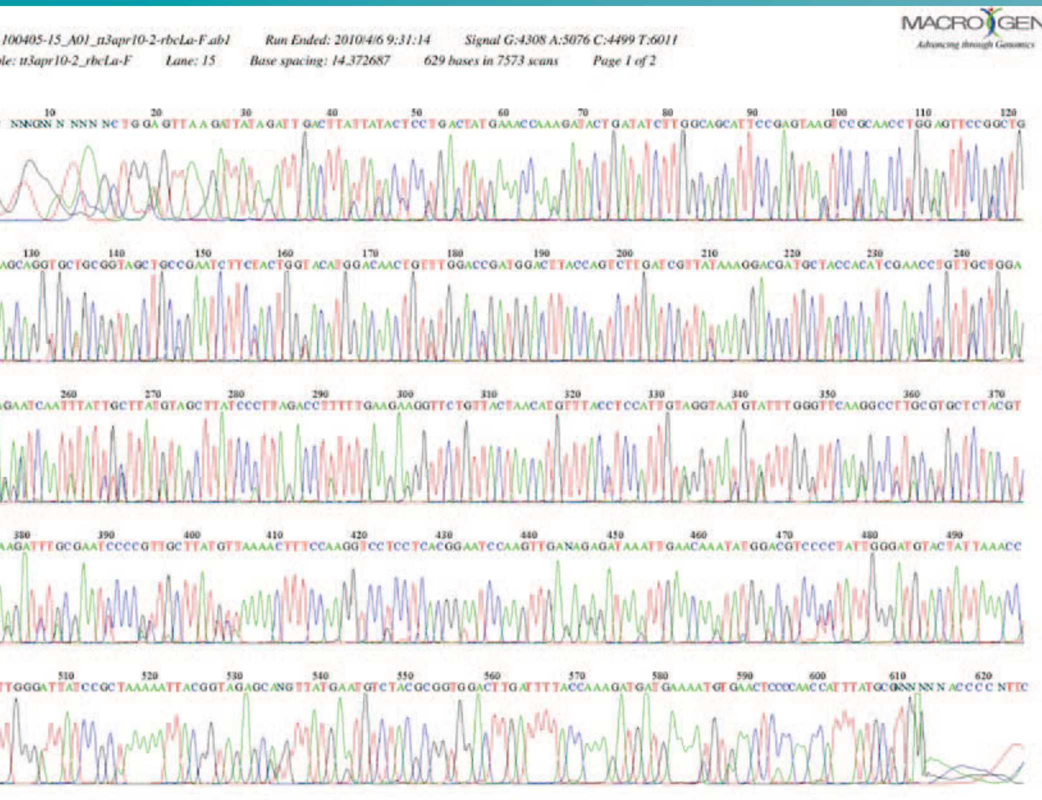
When we shipped our first samples to researchers at the New York Botanical Garden (NYBG) for DNA analysis, we wondered if they would be able to extract any readable DNA at all from such processed plant products. After all, we were working with tea leaves that had been wilted, oxidized, and baked. But when we received the DNA barcode sequences for our samples, we were surprised to find that nearly all of them had yielded high-quality results. There were very few ambiguous bases: almost every base in the sequences was assigned a definitive A, T, G, or C.



Grace Young and colleagues in Dr. Stoeckle's dining room. Most of the laboratory equipment they used was purchased secondhand on eBay.

Our Turn

Now that we knew we could get DNA from our samples, we wanted to see if we could do it ourselves. We chose to examine rbcL and matK, two genes scientists use for plant DNA barcoding because, while they are universal to almost all land plant species, the variation in these genes among species allows for identification.



This Klee diagram demonstrates relationships between species. It includes all the plant families Grace and her colleagues found in their samples, grouped by their relationship to one another.

For each of 10 samples, we ground the material into a fine powder using a mortar and pestle. Then, using tabletop equipment, we extracted the DNA from the rest of the cell matter. In order to make sure that we had done the DNA extraction process successfully, we separated the molecules by size by running them down an electrically charged agarose gel, staining them with a special dye, and using an ultraviolet light to make them glow. Now we could actually see the DNA molecules! After the processing was complete, we sent our samples to a biotechnology company for DNA sequencing—the process that would determine the nucleotide sequence of the gene segment.

As with the samples we'd sent to NYBG, almost all of the teas we processed returned definitive sequences. We copied and pasted the results into GenBank to search for candidate species matches. With Dr. Stoeckle's help, we learned how to compare sequences, account for misalignments, and find meaning in the similarities and differences we found.

Some of our samples did not have close matches in the database. Possible reasons include incorrectly sequenced data, too many ambiguous nucleotide bases in the DNA sequence, or a species that had not yet been entered into the genetic database. The GenBank database is by no means complete; scientists estimate that while there are about 500,000 plant species in the world, the DNA of only 20,000 of them has been sequenced.

Surprise Ingredients

In matching our DNA sequences with those in GenBank, we found that almost half of the herbal tea product samples we tested contained ingredients not on the label. These undisclosed "filler" ingredients included *Camellia sinensis*, the "default" plant used in regular teas; chamomile; and Apiaceae family plants, which include herbs such as dill and fennel. Other plants missing from product labels included grass, common weeds, alfalfa, and plants from the mint family. We found it disturbing that consumers may be paying for an expensive herbal infusion, only to get grass they could find in their backyard. In addition, incompletely labeled teas mean that consumers may not know what they're drinking, which could be dangerous for those with allergies or dietary restrictions.

We also found a genetic difference among *Camellia sinensis* teas that represents a new finding: Most of the Chinese teas were of one genetic type, while those from India were of another. This difference may suggest an adaptation to photosynthesis in different environments.

We submitted two sequences without close matches to GenBank, and they are now on public release in the database. Our paper detailing our research was published by *Nature Scientific Reports,* and our research was featured by media sources including Reuters, *The New York Times,* and *Scientific American.*

It's a little mind-boggling to think that at 15, I had the opportunity to make discoveries, co-author a peer-reviewed academic paper, and make a real contribution to science. I'm a junior now, and making time for anything is tough, but when I do, I plan to take an afterschool course on modern drug development at the American Museum of Natural History, or perhaps work with a cancer biology researcher at a nearby research institute such as New York University. Working in a more traditional laboratory would provide me with valuable experience, as well as insight into what I would like to do for a career.

Grace Young is a junior at Trinity School in New York. She is founder and president of Under the Same Sky, a community service club that supports education for underprivileged children in rural China. In her spare time, Grace enjoys playing piano, figure skating, and travel.

CREATIVE COMMONS

Synthetic Biology, Brick by Brick

by Chris Thompson

When my AP biology teacher, Mr. Rihm, first mentioned iGEM, I actually thought he was talking about a new Apple product. Then he explained that iGEM stands for International Genetically Engineered Machines, a competition that combines engineering principles with biology. Those are my two favorite subjects, so that was all I needed to hear. Three of my friends, Austin Frazier, Brent Poling, and Lucas Ruff, and I decided to start a team.

As interested as we were in iGEM, we had no idea of what it actually involved. We started by going to an information session at our school, where our teachers tried to explain what we would have to do. Because our teachers had never participated in iGEM, either—largely because the contest has been geared to college students—their attempts at explanation just increased our confusion. Finally, they sent us out to do some research and to brainstorm possible projects. For inspiration, we looked at projects that other iGEM teams had done in the past.

High school volunteers and iGEM participants gather at the 2011 Americas Regional Jamboree, where teams competed for a spot at the world championships.

Wanted: High School Synthetic Biologists

iGEM began in 2003 as a month-long course at MIT. In 2004, it became a summer competition, and five college teams participated. The contest has grown steadily over the years, with 165 teams from around the world participating in the 2011 competition.

High school students can and do participate in the main iGEM competition. Gaston Day School in North Carolina, for example, competes with a team of all high school students; other teams, such as the one at UC San Francisco, have allowed high school students to participate.

In 2011, the iGEM High School Division started with five teams from Indiana. More than 20 teams—including teams from Turkey and Canada—will participate in this year's contest. If you'd like to start an iGEM team, visit http://igem.org/High_School_Division and http://igem.org/Start_A_Team. If you'd like to join a team, contact existing teams near you to see if there's an opportunity for you to participate: http://igem.org/Team_List?year=2011.

Learn more about iGEM at http://igem.org.

THINKSTOCK

Because of scheduling problems and a steep learning curve, it took us a few weeks to understand how iGEM works. At iGEM.org, there is a database of genetic "parts," DNA sequences that make cells do different things, such as give off light or even a scent. The goal of iGEM is to use this registry of parts to create a biological system. It's like using a tub of Lego bricks to build a car or building, but the parts have to be arranged in a certain order, much like a circuit. The sequence starts with a promoter, which controls whether genes are switched on or off. After the promoter comes the translational region, which codes for a specific protein. The terminator ends the sequence. All of these parts are inserted into a plasmid, a circular piece of DNA that can in turn be inserted into the DNA of another organism, such as *E. coli,* the most commonly used organism for iGEM.

Our Project

When we discussed what we wanted our bacterium to do, we considered creating an odor-producing bacterium, a bacterium that can test water for malaria, or one that tests water for toxic heavy metals. We did a lot of research—reading scientific papers, searching the iGEM registry, and doing old-fashioned Google searches—and learned about a promoter called CUP-1 that can detect the presence of copper and various other heavy metals. This promoter already exists naturally in yeast, so we decided to use yeast as our organism instead of *E. coli*.

Now we needed an indicator: something the yeast would produce to indicate the presence of heavy metals. Looking at projects from the previous year, we noticed that many teams used a fluorescent protein as an indicator. We found a red fluorescent protein in the iGEM registry that worked great with yeast, so we decided to use that. When we started looking for terminators, our teachers told us that we could use the terminator on the plasmid for our system, so we didn't need an extra one. We had all the parts; now we had to actually build our system.

In May, we started assembling our parts. This was the part we had signed up for—the lab work! Donning safety glasses, lab coats, and rubber gloves, we got to work. First, we extracted yeast DNA using ethanol, dish soap, and a centrifuge. This was a procedure we had heard of before but had not actually done, so it was a great learning experience. From the DNA, we then extracted the CUP-1 promoter and ran a gel electrophoresis test, which shows the base pair length of the part, so we could make sure that our part had the length identified with the CUP-1 promoter.

Getting the fluorescent protein was easier because, unlike CUP-1, another team had already extracted it and added it to the iGEM registry. All we had to do was order it. The sequence came in a standardized plasmid,

Chris explains his team's project to a judge at the 2011 High School Division iGEM Jamboree.

called a BioBrick, which we easily cut open with restriction enzymes. Then, using a process known as the Gibson Method, in which you use primers to bind together multiple pieces of DNA, we fused the fluorescent protein and the CUP-1 promoter together. Then, using the Gibson Method again, we inserted the two parts into our plasmid.

To insert the plasmid into *E. coli* DNA, we used a method called cold shock: we set the *E. coli* into an ice bath for a period of time, then rapidly moved it into a warm water bath. The temperature shock causes *E. coli* to start a survival mechanism in which it takes up any DNA in its media—in this case, the DNA contained in our plasmid. Then, when the *E. coli* reproduced, it would create multiple copies of DNA containing our parts. Our plan was to then extract our parts from the *E. coli* and insert them into our final organism, yeast.

Now that might sound easy, but the whole process took us almost a month to complete—and we ran out of time to finish and test our biological system. Fortunately, not finishing or not creating a functional system doesn't mean you can't share your work at iGEM. So with no time to spare, we started working on our presentation and poster to compete in the iGEM competition.

The Finale

After three months of learning, researching, and working in the lab, we were ready to compete at the iGEM Jamboree, hosted at our school. The collegiate iGEM Jamboree is held at MIT, but the high school teams competed at our school because it cost less for all the teams. There are two parts to the Jamboree: a poster session and a presentation. For the former, we designed a scientific poster that outlined and explained our project. For the latter, we created a 20-minute presentation that explained our entire project from start to finish. At first this sounded like a long time, but we soon found out that fitting all of the information we learned into 20 minutes was really hard. We spent about two weeks preparing and polishing our poster and presentation, trying to make everything perfect for the competition.

As it turned out, because my team members all had scheduling conflicts, I was the only one from our team who could go to the competition. I was sweating bullets as the judges walked around during the poster session, inspecting our poster and asking me questions about how we came up with our project, how our project could be used as a consumer good, and how long we spent in the lab. The students from the other four schools looked just as nervous as I did, so I felt a little bit better. After about 30 minutes of that, the presentation session started.

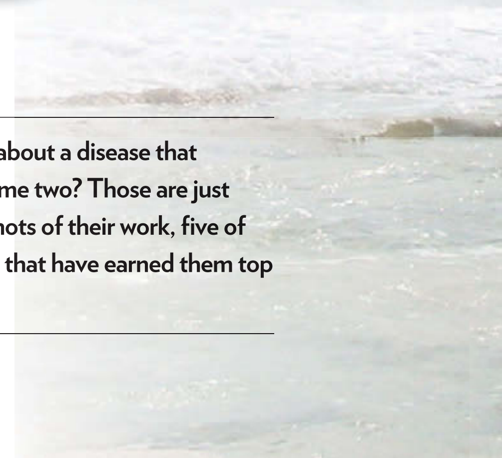
As I sat through the other schools' presentations, I found it pretty exciting to learn about their projects. One team worked on sensing *Pseudomonas* in water, and another worked on an arsenic metal sensor. I realized that I would have to do a great job on my presentation if our team were to stand a chance of winning. I got up in the front of the room and gave the presentation I had rehearsed so many times. The judges seemed fairly impressed by what we did, nodding their heads in agreement and looking surprised when I explained that we did the wetlab in only three weeks. After the presentation, they asked even more questions about our project. I answered them as well as I could, but there were a few I didn't know the answer to. Regardless, they said that we did a great job.

I waited in the hallway with the other teams until the judges finished deciding the awards. When they called us back in, I was nearly shaking with anticipation as I waited for the announcement. And when it came, I couldn't believe it: Our team won Best Poster, Best Presentation, Best New Part, and Best Overall Project!

This year, the high school division has expanded, and more than 20 high schools around the world have shown interest in competing. Even here at Greenfield-Central, our team grew from four people to nineteen! We're still in the brainstorming phase of the process, but we are considering a project centered on galactosemia, a condition in which the body can't break down the sugar galactose. Whatever we choose, I know we're going to have a great year because we can build on all that we learned last year. I already can't wait until the next Jamboree! i

Chris Thompson is a senior at Greenfield-Central High School in Indiana, where he is captain of the tennis team and vice president of the senior class. In his free time, he likes to play video games, read, and hang out with friends. Next fall, he will attend Purdue University to study biological engineering.

Young Biolog
Big Discove



by Amy Dusto

What if you could find a way to make cancer treatments more effective? Or answer vital questions about a disease that threatens amphibian populations around the world? Or study DNA to reveal how one species became two? Those are just a few recent advances in biology, and all were made by high school students. In the following snapshots of their work, five of these students talk about the creativity and persistence their research requires—and the discoveries that have earned them top honors in some of the most prestigious national and international science competitions.

ON THE TRAIL OF AN AMPHIBIAN PATHOGEN

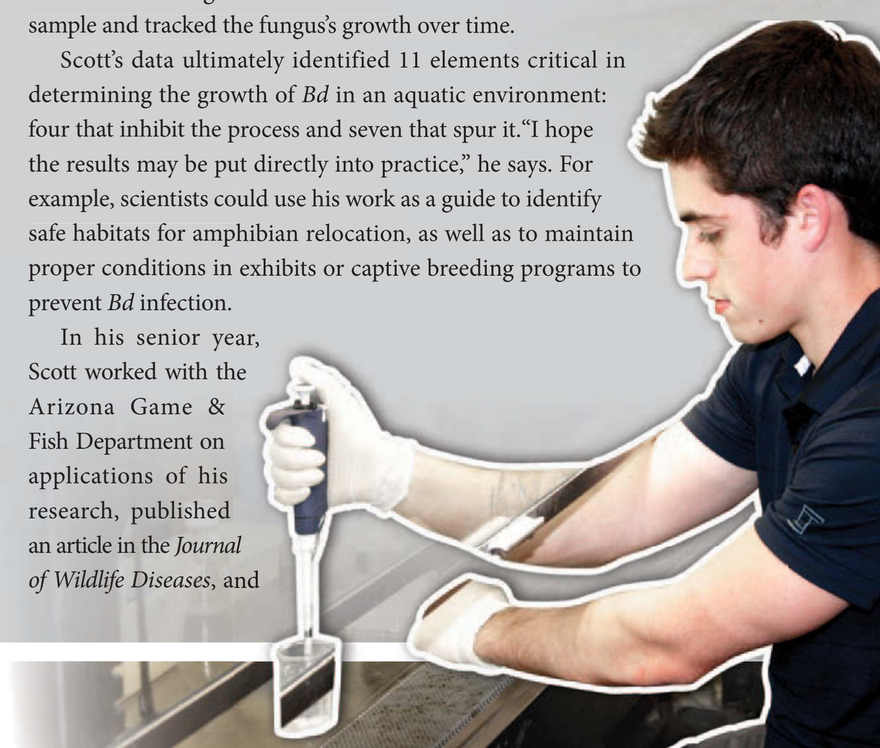
As a high school freshman in Chandler, Arizona, **Scott Boisvert** learned that 32 percent of amphibians worldwide are listed as threatened or extinct. Remembering many afternoons of frog-watching near his childhood home in Michigan, he made a decision. "I couldn't accept the idea that one day my children or grandchildren might not be able to enjoy these same experiences," he says. "I was inspired to find something that could help."

Scott began a project in the lab of University of Arizona researcher Elizabeth Davidson to see if amphibian population declines were linked to environmental causes. He studied the growth and movement of a particular fungus, *Batrachochytrium dendrobatidis (Bd),* known to cause a deadly disease in amphibians. *Bd* is considered a major factor in these creatures' worldwide decline.

For three years, Scott collected water samples from all around the state. "Traipsing down embankments and through prickly underbrush to collect my water samples was an adventure in itself," he says, "but [so was] finding the water, as we do live in a desert." In the lab, he analyzed the chemical composition of the samples, including both naturally occurring and human-generated contaminants from sources like erosion, animal life, and industrial or agricultural runoff. He also measured levels of *Bd* in each sample and tracked the fungus's growth over time.

Scott's data ultimately identified 11 elements critical in determining the growth of *Bd* in an aquatic environment: four that inhibit the process and seven that spur it."I hope the results may be put directly into practice," he says. For example, scientists could use his work as a guide to identify safe habitats for amphibian relocation, as well as to maintain proper conditions in exhibits or captive breeding programs to prevent *Bd* infection.

In his senior year, Scott worked with the Arizona Game & Fish Department on applications of his research, published an article in the *Journal of Wildlife Diseases*, and



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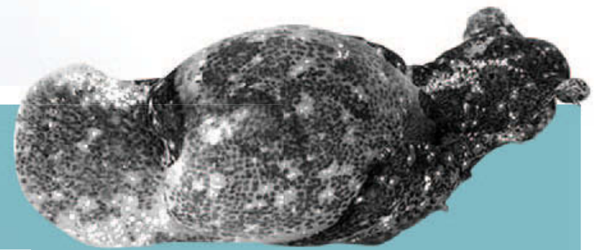


presented his findings at the annual joint meeting of the Arizona and New Mexico chapters of the American Fisheries and Wildlife Societies. He earned several awards for his project, including a Davidson Fellowship, an American Museum of Natural History Young Naturalist Award, and finalist awards at the Intel International Science and Engineering Fair.

Now a freshman at Duke University, Scott is studying global health and cell and molecular biology. He plans eventually to earn an MD/PhD. “Not only has my work with amphibians set my path,” he says, “but it has sharpened my appreciation for the natural world around me.”

TRACING SEA SLUGS’ FAMILY TIES

No one had studied the genetics of any creature in the family Aeolidiidae before **Bonnie Lei** did. The Walnut, California, native compared DNA from two species of tropical sea slugs and found that they are in fact identical. Then she looked at another population of the same slugs elsewhere, in the Bahamas, and found the opposite: they were genetically different enough to be considered a separate species. In all, her work provides clues about the evolution of sea slugs and promotes the idea that the Bahamas are a unique trove of biodiversity worth heightened conservation attentions.

Beginning as a high school sophomore, Bonnie worked for two years with her mentor, Ángel Valdés, PhD, at the California State Polytechnic University at Pomona. In addition to using his lab, she also traveled to the Natural History Museum of Los Angeles County and the Gulf of Mexico to obtain specimens. She examined each slug meticulously, dissecting it under a microscope and noting features ranging from coloring to the shape of jaws and reproductive organs.

For her genetic analysis, Bonnie used the technique known as polymerase chain reaction (PCR) to make multiple copies of small sections of DNA, which allowed her to determine their sequence with computer programs. “Some of the specimens I was working with have been preserved for a long time, and therefore it was difficult to obtain DNA data from them,” she says. “Experimenting with different methods to extract DNA from the tissue was an arduous process.” In addition to learning if or how the different slug species were related, Bonnie’s molecular analysis also showed when in history the Bahamas species diverged from the others: about 500 million years ago, which corresponds to the closing of a sea channel.

For her project, Bonnie won a Young Naturalist Award and was named an Intel Science Talent Search finalist. Now a freshman at Harvard, she aspires to be a research professor specializing in tropical and marine biodiversity. She’d also like to educate the public about conservation by writing for *National Geographic*, and she hopes to start a nonprofit that empowers impoverished communities in biodiverse places to protect their environments. “Biodiversity conservation is particularly significant today,” Bonnie explains. “It is a race against time as species are becoming extinct before they are even discovered.”

SWITCHING OFF DRUG RESISTANCE

Shree Bose's summer research on drug resistance in ovarian cancer led to a great discovery: not only did she find a relationship between a particular cell protein and chemotherapy drug resistance, but her work suggests a way to improve future ovarian cancer treatments. Her research earned her the grand prize in the Google Science Fair, a feature in *Glamour* magazine, and even a visit with President Obama.

Shree became determined to do cancer research after her grandfather passed away from the disease. After e-mailing professors near her home in Fort Worth, Texas, asking to work in their labs, she found a place at the University of North Texas Health Science Center under the supervision of biochemistry professor Alakananda Basu, PhD. Dr. Basu suggested that Shree look into drug resistance in chemotherapy.

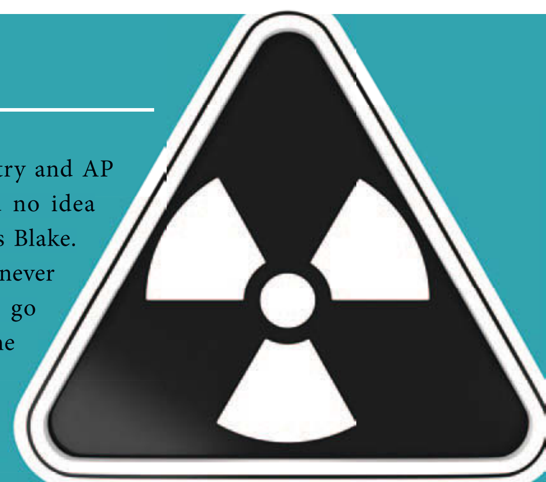
During the course of treatments, patients with ovarian cancer often develop resistance to the chemotherapy drug cisplatin, meaning that tumors stop responding to the drug. Shree wanted to know if a particular protein in the cells, called AMPK, affected this move toward resistance. She used a chemical to inhibit, or "switch off," the protein in both drug-resistant and non-resistant cancer cells. Then she looked at whether switching off the protein increased the amount of cell death, which would indicate that the drug was working.

Shree found that with the inhibitor, cells that were not cisplatin-resistant began developing resistance as usual. The reverse occurred in the resistant ovarian cancer cells: with the inhibitor, the drug appeared to become effective anew.

How AMPK has this effect is still a mystery, but there are immediate implications for improving medical treatment. "Basically this research proposes a possible new way to make patients who are resistant to treatment respond to drugs again," says Shree. If patients who have developed cisplatin resistance are treated with the AMPK inhibitor, their next chemotherapy treatment could be improved.

Shree is now applying to colleges and plans to continue combining her passions for research and medicine by pursuing an MD/PhD.

BOOSTING THE EFFECTS OF RADIATION

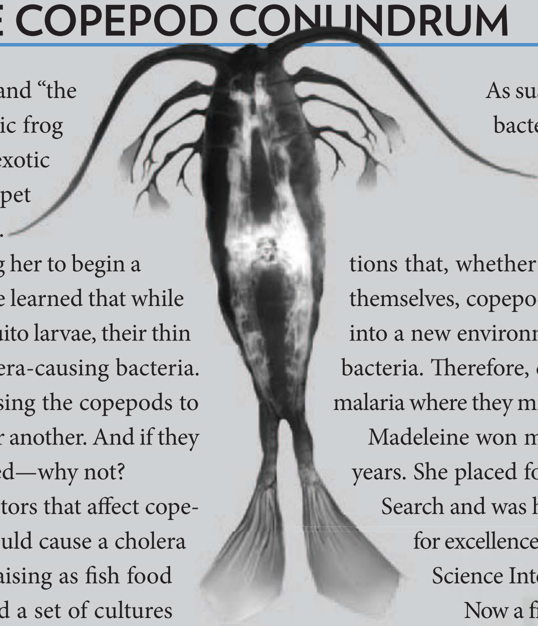


Neither **Blake Marggraff** nor **Matthew Feddersen** had participated in a science competition since the first grade, but in their last year of high school, the friends decided to work on a project together. All on their own, they developed a technique to boost the effects of low-energy radiation on tumors by more than 20 percent—and for less than $100, a price that could revolutionize cancer treatment in developing countries. Their project won first place, best in category, and the top award at the 2011 Intel International Science and Engineering Fair.

Working out of their biology classroom in Lafayette, California, they logged over 400 hours during and after school, at lunch, and occasionally at night when the janitor would let them back in. Their method uses tin particles placed very close to tumor cells. When hit with low-energy x-rays, the tin produces a secondary radiation that is localized, targeting only the tumor, and kills more cells than x-rays alone.

"I'd only taken AP Chemistry and AP Biology and, fortunately, had no idea exactly how little I knew," says Blake. "I'm sure if I'd known, I would never have had the confidence to go forward with any idea." Once he and Matthew had settled on the project idea, based on their desire to do something "using as much radiation as (legally) possible," they often found themselves with questions too detailed for their high school teachers to answer. Instead they relied on their own research—and lots of trial and error. They changed experimental design five times before getting it right. According

THE COPEPOD CONUNDRUM



Madeleine Ball won a goldfish in second grade, and "the next thing you know," she says, "I had an aquatic frog and then a 72-gallon saltwater aquarium." One exotic fish later and she was micro-farming specialty pet food: plankton-like crustaceans called copepods.

Her interest grew with the tiny beasts, leading her to begin a project with them in the eighth grade. Madeleine learned that while copepods excel at killing malaria-carrying mosquito larvae, their thin chitin exoskeletons are a favorite snack of cholera-causing bacteria. She wondered whether public health officials using the copepods to fight malaria were actually trading one disease for another. And if they weren't—such a link had never been documented—why not?

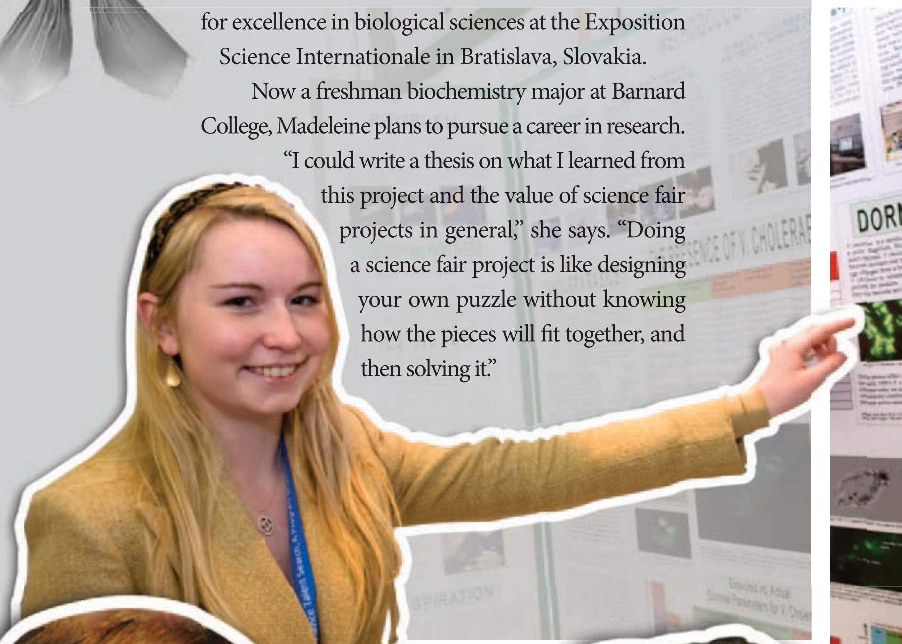
She decided to investigate environmental factors that affect copepods' ability to carry cholera and factors that could cause a cholera outbreak. Beginning with specimens she was raising as fish food at her home in Dallas, Texas, Madeleine created a set of cultures with different levels of pH, salinity, and population density. She had contacted researchers around the country who were studying predatory copepods, and several e-mailed her with advice and even shipped live specimens for her use. Her former science teacher also mentored her on the project through high school.

To effectively analyze cholera transmission, Madeleine needed real lab equipment. "It's hard for students to ask professionals for help, but there are many scientists eager to share their love of research with the next generation," she says. At her request, Dr. Joel Goodman at UT Southwestern Medical Center agreed to help. Although he didn't study copepods or cholera, he allowed Madeleine to use his lab and epifluorescence microscope to measure the density of copepods and cholera bacteria in each culture.

As suspected, the creatures did host cholera bacteria, but too few copepods survived at the concentrations of pH and salinity needed to cause an outbreak in humans. Still, Madeleine cautions that, whether or not they directly cause outbreaks themselves, copepods *are* carriers, and introducing them into a new environment could mean introducing cholera bacteria. Therefore, copepods should not be used to fight malaria where they might make contact with drinking water.

Madeleine won many awards with the project over the years. She placed fourth in the 2011 Intel Science Talent Search and was honored with a sponsor's choice award for excellence in biological sciences at the Exposition Science Internationale in Bratislava, Slovakia.

Now a freshman biochemistry major at Barnard College, Madeleine plans to pursue a career in research. "I could write a thesis on what I learned from this project and the value of science fair projects in general," she says. "Doing a science fair project is like designing your own puzzle without knowing how the pieces will fit together, and then solving it."



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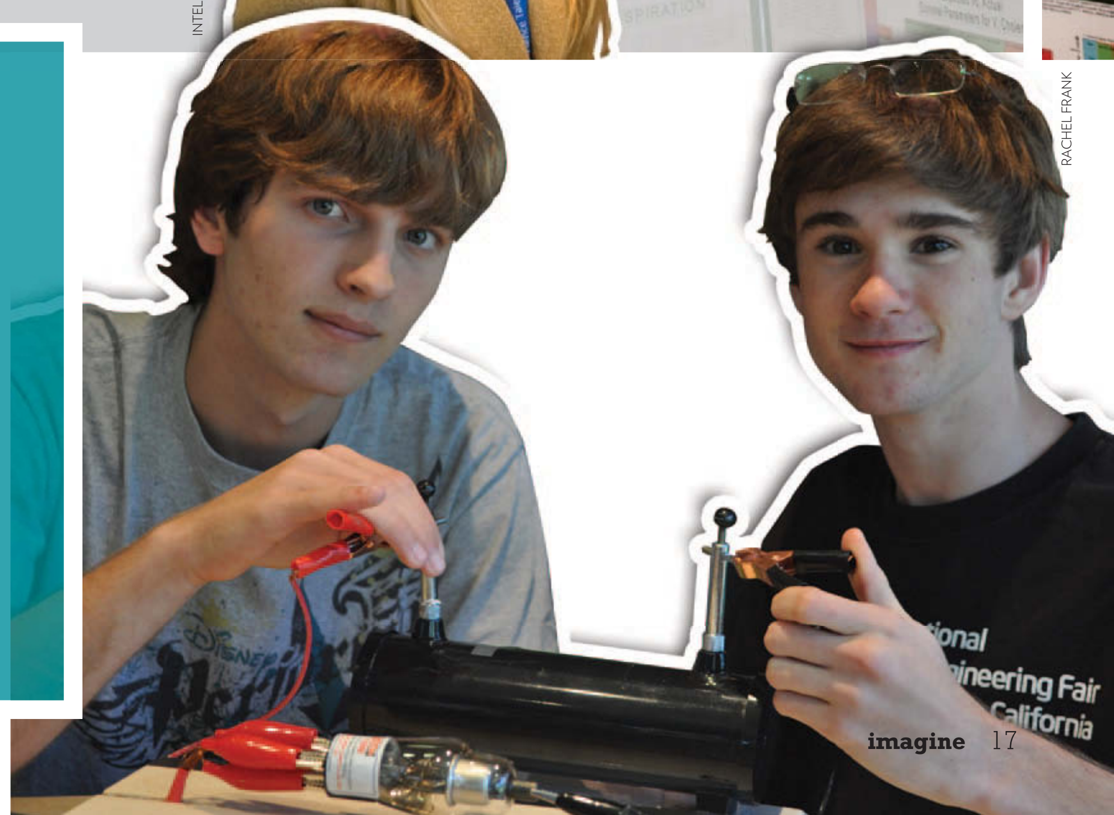
to Blake:

About a month into the experimentation phase, after over 100 hours of failure and redesigning, I clearly recall sitting in the back of the classroom, punching furiously at the calculator to calculate the results... my heart was pounding so fast I became light-headed. The numbers were all lined up, and I instantly realized that this version had worked! Granted, there were several more trials needed, but we had more than enough samples to show a large and statistically significant impact of the treatment.

Both are now college freshmen; Blake (right) is studying biology at Washington University in St. Louis, and Matthew (left) is studying engineering at the University of Illinois.



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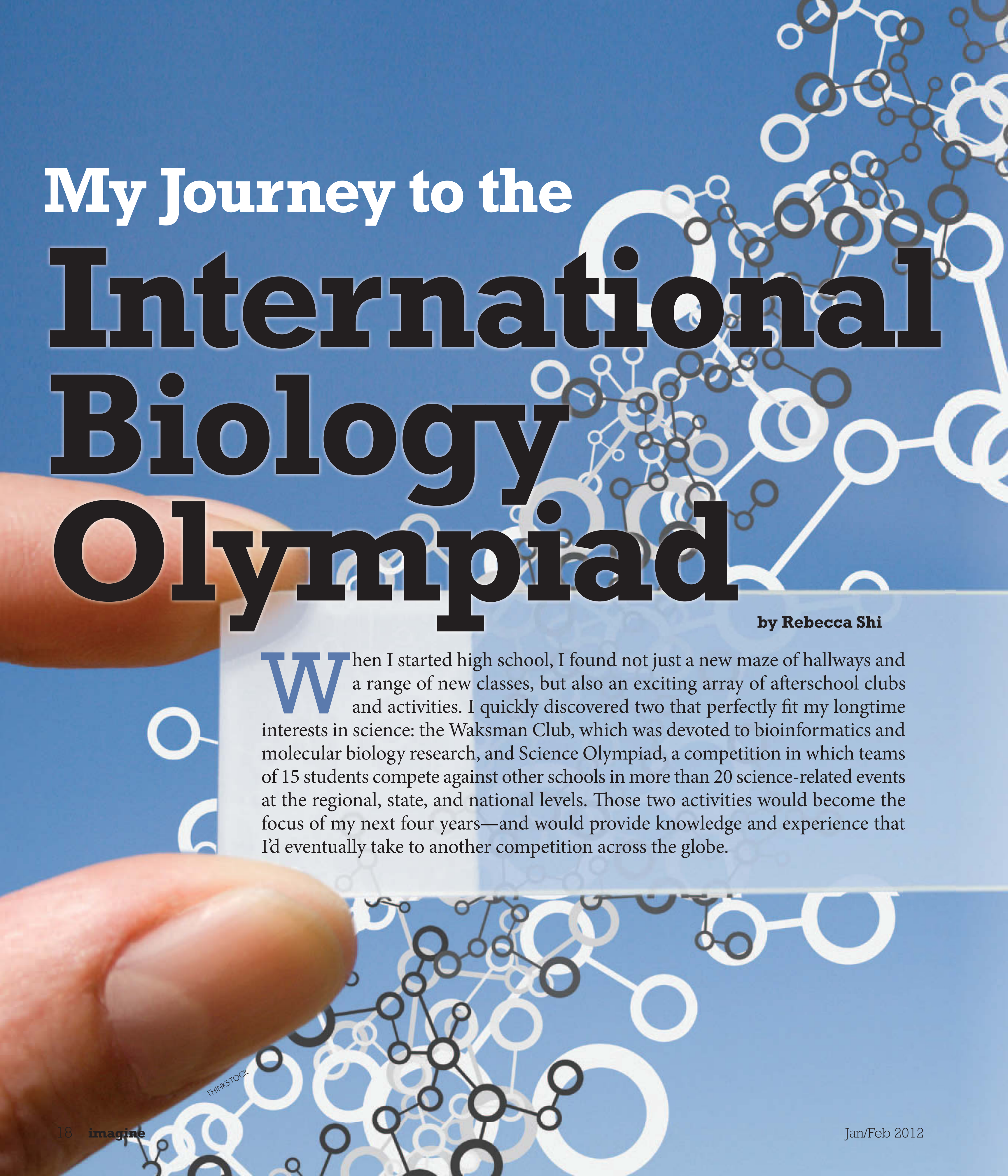

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My Journey to the International Biology Olympiad

by Rebecca Shi

When I started high school, I found not just a new maze of hallways and a range of new classes, but also an exciting array of afterschool clubs and activities. I quickly discovered two that perfectly fit my longtime interests in science: the Waksman Club, which was devoted to bioinformatics and molecular biology research, and Science Olympiad, a competition in which teams of 15 students compete against other schools in more than 20 science-related events at the regional, state, and national levels. Those two activities would become the focus of my next four years—and would provide knowledge and experience that I'd eventually take to another competition across the globe.

Stations for the practical exam at the IBO. At the 2011 IBO, the tasks Rebecca completed included stimulating bullfrog nerves and classifying spiders.

Bringing the USABO to School

In the Waksman Club, I met a senior named Daphne who introduced me to the basics of DNA. It amazed me that someone so close to my age had discovered mercury-reducing bacteria and written her own programs to analyze DNA. When I had the chance to work with her for Science Olympiad, Daphne inspired me to read Campbell and Reece's *Biology* in my spare time. Where my honors biology course and textbook had skimmed over the details of a process, Campbell added another layer, often explaining the *how* and *why*. I gradually discovered that biology was not a series of facts to memorize, but instead many concepts intricately linked together.

In my sophomore year, a friend on the Science Olympiad team expressed an interest in holding USA Biology Olympiad (USABO) exams at our school. I asked one of our high school teachers to proctor the exam, and she agreed. The USABO Open Exam would be held in February, right in the middle of our Science Olympiad competition season. I put the test away in the back of my mind, focusing instead on studying for the Science Olympiad's health science, cell biology, and ecology events.

In February 2009, I entered the classroom where the USABO Open Exam would be held, knowing only that it would be a 50-minute, 50-question multiple-choice exam. I was armed with my knowledge of the honors biology textbook, select chapters of Campbell, and my experience with molecular biology from Waksman. Although I walked out of the room feeling that my brain's synapses were dead, I later found out that I had scraped into the semifinal round with a 29 (the cutoff was 27).

The semifinal exam, held a few weeks later, was a two-hour exam consisting of three sections: Part A, with multiple-choice items similar to those on the open exam; Part B, with more complex questions that could have multiple correct answers; and Part C, an open-ended response. I was most worried about Part C. In glancing at the question, I was daunted—until I realized that the question was related to a concept I had learned in Waksman. Grateful for the hours I had spent performing polymerase chain reactions and restriction digests, I managed to answer the final question.

In April, I was shocked to learn that I was among the top 20 scorers in the country. I was invited to the national training camp, where the team to represent the U.S. at the International Biology Olympiad (IBO) would be selected. I had not even considered the possibility of making it past the semifinal round. While I was excited to have been selected, I was also scared that all the other finalists would know much more about biology than I did. Would I be able to measure up to these students?

Biology Bootcamp

In the first week of June, I took my final exams early, packed my suitcase, and drove down to George Mason University in Virginia for the two-week training camp. There, I met the 19 other finalists, the three previous IBO competitors who would be our mentors, and the professors who would be guiding us through our learning. Our days consisted mostly of intensive laboratory training—sterile technique, animal dissections, plant sections, gel electrophoresis, protein columns, zebrafish dechorionations, and more. We had occasional lectures by professors and evening sessions with the counselors to cover material such as biosystematics and statistics. It was up to us to study additional material as we saw fit in our spare time.

In the final two days of camp, we took theoretical and practical exams that simulated what we would encounter at the IBO. While the theoretical exam was similar to the semifinal round of the USABO, the practical was the most challenging experience yet. I had to apply all the laboratory skills I had learned in the past two weeks as I performed tasks in a small

Left: Team USA gathers for a chat and last-minute preparation before competing at the 2011 IBO. **Right**: The top three competitors at the 2011 IBO were Rebecca Shi (USA), Je-Rui Chang (Taiwan), and Charles Du (USA). All four members of the U.S. team won gold medals.

When I returned home, I continued to practice dissections on fresh fish, clams, and other specimens from a local supermarket, using the dissection kits that USABO let us borrow.

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amount of time. For example, one task involved cutting thin slices of two plants, staining them, identifying certain parts under a microscope, and answering questions about them—all in under 10 minutes. When I staggered out of the room an hour and a half later, I was exhausted but smiling.

After all our exams were over, I enjoyed a few hours of freedom with the other finalists before the awards ceremony, where the top four who would represent the U.S. at the IBO would receive gold medals. The next four would receive silver medals, and a third group of four would receive bronze medals. I was pleased to receive a silver medal.

Mastering the Practical

I missed the cutoff for attending the USABO training camp the next year, so for my senior year, I made sure I had read through all of Campbell as well as some additional material. I was excited to receive a second invitation to the training camp, now held at Purdue University.

Since I was now familiar with most of the material, I was able to focus on learning the details. I also made sure to get more sleep each night, which helped me better pay attention to what I was learning during the day.

Once again, the practical exam was the most challenging part of camp. This time, one of the more daunting tasks was a comparative dissection between a starfish and a mysterious brown, squishy lump (which I later learned was a sea cucumber). Still, since I had a better idea of what to expect, I felt more confident about my work and was able to finish most of the tasks I was given. At the awards ceremony, I was ecstatic to hear my name called for a gold medal. I had finally made Team USA.

As a team, the three other members and I stayed at camp for two more days to practice lab techniques and discuss our performance on the theoretical and practical exams. When I returned home, I continued to practice dissections on fresh fish, clams, and other specimens from a local supermarket, using the dissection kits that USABO let us borrow. I also practiced preparing plant sections with razor blades I bought at CVS, viewing my slides under microscopes at the pharmaceutical company where my mom works. In addition, I took the previous years' IBO tests that our coaches had given us. Finally, in mid-July, it was time to reunite with Team USA and travel to Taipei, Taiwan, for IBO 2011.

First Among Peers

The IBO experience involves much more than academics. I enjoyed the numerous cultural trips that the organizers in Taiwan had planned—touring Taipei, traveling to the mountains, visiting museums, and eating traditional foods. I had my first taste of dragon fruit, guava, and passionfruit. On most evenings, we attended performances and demonstrations by students from different countries that showcased their unique cultures. We were also treated to professional performances of Chinese opera and lion dances. My favorite part was meeting students from all over the world, whom I knew I would meet again in the future as colleagues and friends.

But of course it was the competition that had brought all of us together. I actually found the exam portion of the IBO less challenging than the USABO national camp. While parts of the IBO practical were unfamiliar—stimulation of bullfrog nerves, classification of spiders—my USABO experiences helped me remain calm and overcome these challenges.

On the day of the closing ceremony, we gathered to learn

the competition results: the top 10 percent of students would receive gold medals; the next 20 percent, silver medals; and the next 30 percent, bronze. As each bronze and then silver medalist was called to the stage, I cheered for the accomplishments of the friends I had made. In many previous years, the U.S. team had won four gold medals; so when all the bronze and silver medalists had been called, with none of the U.S. team members' names, we knew that we had all won gold. My team members and I hugged and high-fived each other in joy, while behind us, a resounding cheer arose from the Taiwanese fans—the host team had managed the same feat.

As the announcers called up each of the gold medalists, I kept expecting to hear my name at any second. When all but the top three medalists had been called, with my name still unmentioned, worries spun through my head: maybe I hadn't even earned a bronze, or maybe I had missed my name. Third place was awarded to Charles Du from the U.S. team, and second place was awarded to a Taiwanese team member. My fears and confusion grew, and then I heard it: "First place: Rebecca Doris Shi from the United States of America."

In a state of numbness, I hugged my coaches and team members, watching myself on the projection screen as cameras followed me to the stage. I went through the motions of accepting my medal, trophy, and a metallic orange box that I didn't recognize as a laptop in my state of shock. When the MC congratulated me and handed me the microphone, I stammered out an impromptu speech, thanking my parents, friends, coaches, and Science Olympiad team for supporting me through the years. After accepting congratulations from what seemed like a thousand people, I returned to my seat, still wondering if the past half-hour had really happened.

After the ceremony, we headed to the buses that would take us to dinner. As soon as I stepped on the bus, the entire bus rang with applause. The Chinese team said "*gong xi*" (congratulations) and nodded solemnly as I walked past, and I met smiles everywhere I looked. It was then that it started to sink in that it really had happened. I had won.

All too soon, it was time to say goodbye. The next morning, we took our last pictures with the other teams, exchanged contact information, and watched each delegation depart for the airport.

I would be staying in Taiwan for another week with my parents, so I saw Team USA off as well. I held back tears as I hugged my teammates goodbye. We had gone through so much together—USABO camp, the 40-hour trip to Taiwan, competing at IBO, winning our four gold medals. It was hard to believe it was all over, that we would now depart to our separate corners of the U.S. for our last summer before college. Still, I had enjoyed every second I spent with the other students in Taiwan, united by our interest in biology. I was sad to see it end, but glad to have been a part of it. **i**

Rebecca Shi is a freshman at MIT, where she hopes to major in biology or biological engineering. She fences foil on the fencing team, and enjoys birdwatching and playing board games in her spare time.

How to Start a USABO Club

Identify a teacher to sponsor the club, register for the USABO, and proctor the USABO exams.

Recruit students. Note that students do not have to be enrolled in a biology course to take the exams, but you might find peers who'd like to participate in such a class.

When you have a group of interested students, and with help from your sponsor or a biology teacher, hold a meeting in which you **go over the topics covered on the exams**:

- Cell Biology
- Plant Anatomy and Physiology
- Animal Anatomy and Physiology
- Ethology
- Genetics and Evolution
- Ecology
- Biosystematics

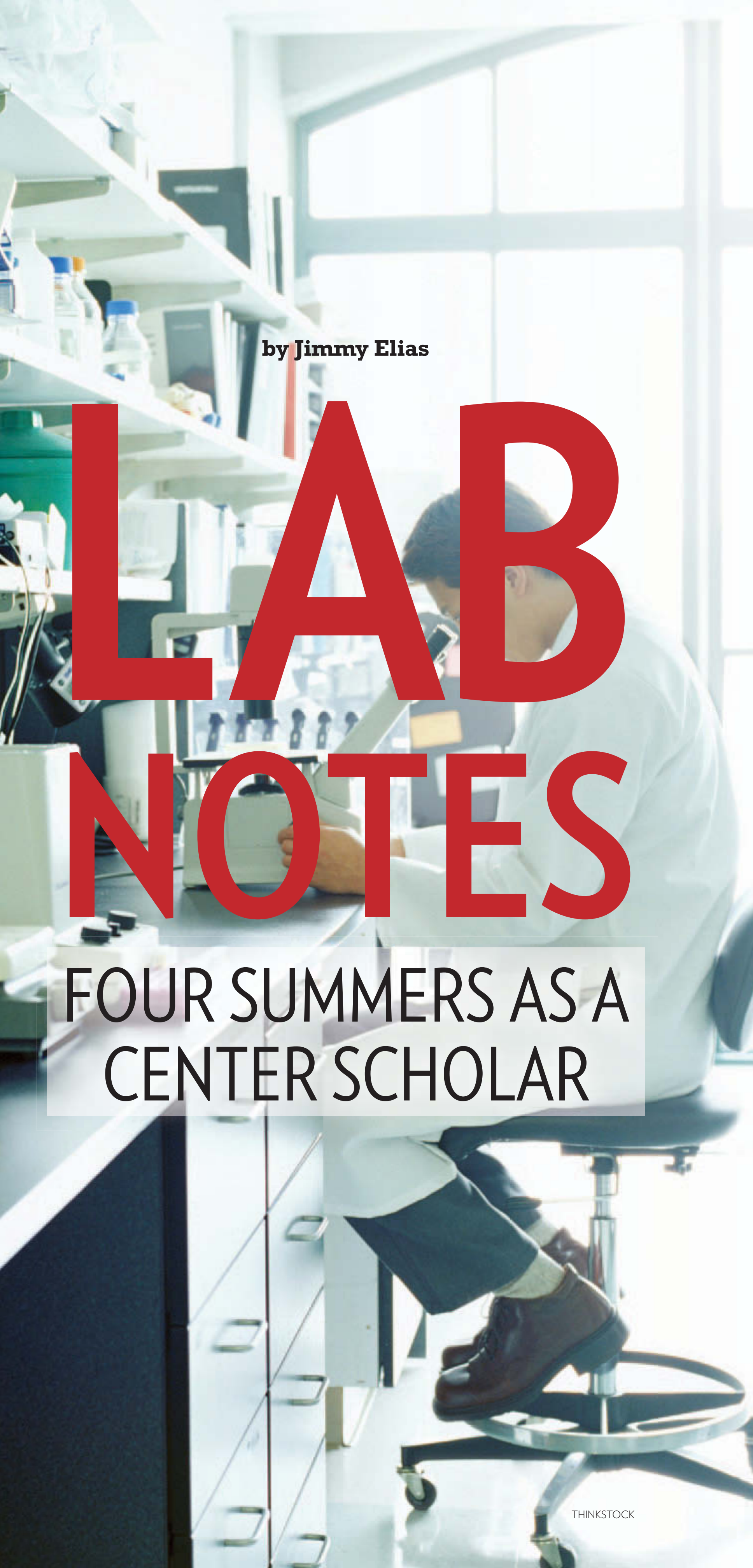
The group can also **explore the USABO website** for an overview of the program. The Student Resource Center, accessible to registered students, includes information regarding what to study and some tools to use for study.

Once the team is familiar with the format of the USABO and the topic areas, students should start to **strategize and form a plan of study to prepare for the exams.** This plan can include resources (such as study guides and textbooks), speakers, practice sessions, and lab time.

—adapted from www.usabo-trc.org/src-howtostartusaboclub.php, with permission of the Center for Excellence in Education by Jimmy Elias

LAB NOTES

FOUR SUMMERS AS A CENTER SCHOLAR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At age seven, when other kids were dreaming of becoming professional basketball players or superheroes, I was thinking about experiments, test tubes, and becoming a scientist. But I didn't really pursue my interest in science in depth until the summer before ninth grade, when I took CTY's Fast-Paced High School Biology course and learned a year's worth of biology in three weeks. I loved everything about the program—I met amazing people, made awesome friends, and left with an even greater interest in science.

The next year, wanting to build on what I'd learned, I applied for and was accepted to the CTY Center Scholars Program, which provided both additional coursework and lab internships. That experience set me on the path I dreamed of as a seven-year-old.

Laying the Groundwork

In my first summer as a Center Scholar, I took a double session of CTY: the three-week Genetics and Genomics courses, back to back.* These two courses introduced me to a world of new information. Genetics covered everything from phenotypes and alleles to recombination and DNA amplification—and taught me the valuable skill of reading scientific papers. This is a skill I would rely on every summer thereafter—and still do today.

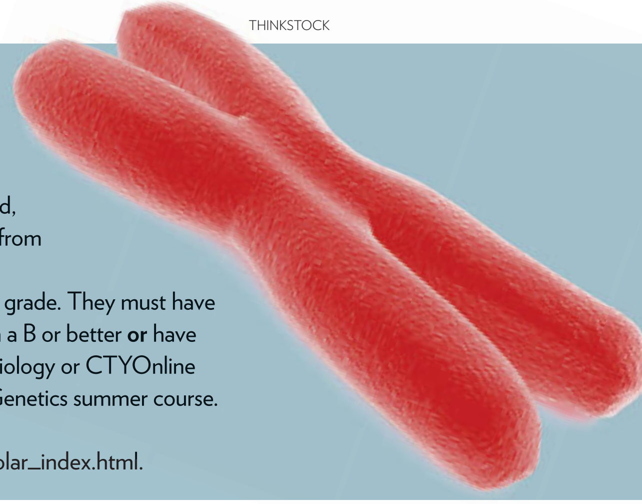
The Genomics course immersed me in the world of bench work. I held micropipettes for the first time and learned how to use a microcentrifuge. We learned to perform techniques such as gel electrophoresis and polymerase chain reaction (PCR), and then applied them in our main project: after taking a swab of any surface within the lab, we had to culture any bacteria from the swab and then isolate one type of bacteria and its DNA. Finally, we sequenced the bacteria's genetic code and used it to identify the bacteria. If someone had told me at the beginning of the summer that I'd be able to identify bacteria by its DNA, I wouldn't have believed it. But now that I'd done it, I looked forward to putting these new skills to use in an internship, the next phase of the program.

Designing Primers & Vectors

The following summer, I was placed for six weeks in the genetics laboratory of Dr. Nicholas Katsanis on the Johns Hopkins Medical Campus. With my mentor, postdoc Norann Zaghloul, I studied mutations in the TCOF1 gene, which is associated with the development of Treacher-Collins Syndrome, a disorder characterized by craniofacial deformities.

In the CTY Genomics course, I had learned how to create multiple copies of a gene by doing PCRs. Now my job was to create DNA primers, a sequence of about 25 base pairs

**Note: Center Scholars now take Genetics the first summer and Genomics the next.*



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The Center Scholars Program

Developed by CTY and Dr. Andrew P. Feinberg's Epigenetics Center at the Johns Hopkins School of Medicine, the Center Scholars Program supports groups that have been historically underrepresented in STEM disciplines as they explore careers in scientific research, particularly the field of genomics.

Over three summers, students take CTY's three-week Genetics and Genomics courses and participate in a six-week research internship in a laboratory of the Johns Hopkins Medical Institutions. For the CTY portion of the program, students receive scholarships to cover tuition and fees, room and board, and travel to and from CTY. For the six-week laboratory internship, scholars receive a stipend, room and board, and travel to and from Baltimore.

Students typically apply in ninth grade. They must have completed high school biology with a B or better **or** have completed CTY's Fast-Paced HS Biology or CTYOnline Biology before they may take the Genetics summer course. For more information, see http://cty.jhu.edu/about/centerscholar_index.html.

that serve as a sort of flag to indicate what section of DNA should be copied, or amplified, during PCR. We were seeking to amplify TCOF1 genes containing different mutations that had been identified in patients with Treacher-Collins Syndrome. Once we had copies of these genes with mutations, the next step was to insert them into a DNA vector, a molecule that allows foreign genetic material to be inserted into another cell. In Dr. Katsanis's lab, this vector would ultimately be inserted into the DNA of a zebrafish embryo to see how it affected the zebrafish's development. Because I had only six weeks to spend in this lab, I never got to this last stage, but I was proud to have created DNA vectors to help with the research.

Introduction to Epigenetics

With that research experience under my belt, I thought I'd be able to get started the next summer in Dr. Andrew Feinberg's lab without having to learn many more new skills. I was wrong. I soon realized that every lab requires specialized skills and some training to get up to speed. In Dr. Feinberg's lab, I learned to perform pyrosequencing, a type of analysis used to measure DNA methylation. In addition to the training I received from my mentor, postdoc Hong Ji, I had to read a lot of journal articles to get the background I needed.

It used to be thought that cancers were caused by mutations in genes. Now, scientists are learning that epigenetics—changes to the genome that don't alter the DNA sequence but affect how genes are expressed—are more often the cause. DNA methylation plays a role in epigenetic gene regulation in both development and disease. In Dr. Feinberg's lab, I used pyrosequencing to measure the varying methylation levels in cancer cells of the liver and pancreas. We wanted to see if the methylation varied across tissue types and if the methylation was different in cancerous and non-cancerous cells. There were significant differences, and I was excited to share my data in a poster session at the end of that internship.

Studying Cytokines

In my final summer before starting college, I worked in Dr. Gregg Semenza's lab, where I studied cytokines that cancer cells produce in low-oxygen environments, such as in a solid tumor. Understanding the role of those cytokines could help identify a possible target for treatment.

My mentor, postdoc Pallavi Chaturvedi, gave me even more independence than I'd had in previous years. First, she taught me a new technique called quantitative polymerase chain reaction (qPCR), which, along with amplifying a certain sequence of DNA, allowed us through the use of a fluorescent marker to measure exactly how much DNA was amplified—and to see exactly how much cytokine was produced by the cells. When Pallavi saw that I knew how to do the protocol correctly, I began to perform the experiments myself. That summer taught me the importance of repetition in science: I performed almost the same experiment every day to prove that the results I was producing were indeed true. Diligence and patience, I realized, are as necessary as specialized lab skills.

Every lab experience I had during the Center Scholars Program helped me in further lab work. I have continued to do research since starting my undergraduate career at Johns Hopkins University, and thanks to the Center Scholars Program, I know that this is what I want to do for many more years to come. **i**

I thought I'd be able to get started the next summer in Dr. Andrew Feinberg's lab without having to learn many more new skills. I was wrong. I soon realized that every lab requires specialized skills and some training to get up to speed.

Jimmy Elias is a sophomore at Johns Hopkins University, where he is majoring in biomedical engineering. When he's not in class or the lab, he likes to spend time with friends, play soccer, and enjoy all there is to do in Baltimore. Last summer, he returned to the Center Scholars Program as a mentor.

MACRO MENAGERIE

Photos by Igor Siwanowicz

Igor Siwanowicz has a gift for showing us insects as we've never seen them. In 2010, he won the International Olympus BioScapes Photo Competition for a photo he took through a light microscope of the eyes of a Daddy Longlegs. In 2011, he won the Nikon Small World Photography Competition, another contest for photos taken using microscopes, for a 20X magnification of a green lacewing larva. But when he turns a macro lens—specifically, a 100mm lens—on insects, we see even more than the beauty of their colors and intricacy of their forms. We see what looks like personality. Last fall, Deviantart.com honored Siwanowicz with a Deviousness Award, citing the photographer's ability to "capture human-like qualities in the smallest creatures." We chose a few of our favorites (from among hundreds of stunning images) and asked Igor to tell us about these creatures.

See more of Igor Siwanowicz's photos at http://photo.net/photos/Siwanowicz and http://blepharopsis.deviantart.com.

African Mega-Mantis *Plistospilota guineensis* showing off.

The mantid's primary defense tactic is camouflage; looking like a leaf, it blends in with the background, becoming invisible to predators. When that tactic fails, the mantis still has an ace up its sleeve: it throws its arms up, raises its wings, and assumes a bold stance, making it appear twice as large. Confusing a predator for a second is all it needs to disappear by taking a dive into the foliage.

Dead-Leaf Praying Mantis *Deroplatys lobata* in a threatening pose.

Giant Malaysian Shield Mantis *Rhombodera basalis* shows its colors in a threatening display.

A cluster of a stink bug's eggs shortly before the nymphs hatched. The fully formed red-pigmented eyes are visible through the eggshell.

Female jumping spider *Phidippus regius*. Measuring almost 3 centimeters in length, it is one of the world's largest jumping spiders. Its sophisticated principle eyes (the larger pair in the middle) offer excellent high-resolution color vision. Jumping spiders have the most acute vision among terrestrial invertebrates.

The Giant Green Pill Millipede from Madagascar is the size of an egg when rolled. The ability to roll into a near-perfect ball—its segments, or tergites, interlock to form a seal—protects it from predators and dehydration.

Caterpillar of *Actias dubernardi* (Chinese comet moth) munching on needles of larch. The caterpillar is adorned with pearl-like and golden nodules, making it look like a Christmas ornament. It is definitely one of the most extravagantly decorated caterpillars I had the pleasure to photograph.

My Summer

As a child, I loved to wander the labyrinths of my father's university laboratory. I was intrigued by the white lab coats and the incubators. Sometimes, my prayers were answered and my father would allow me into his testing room, where I would sit on a tiny stool in the corner, a silent observer of his practiced agility. My father was a molecular biologist, and his lab, another world—one free of emotions and distractions, where the goal was the pursuit of truth.

by Rebecca Hu

Last summer, after years of observing and fantasizing, I was handed my own lab coat. I had been accepted as a medical intern in the Stanford Institutes of Medicine Research Program (SIMR). In this eight-week summer program, high school students from around the country perform research alongside Stanford faculty. I was overjoyed at the prospect of designing and conducting my own research experiment.

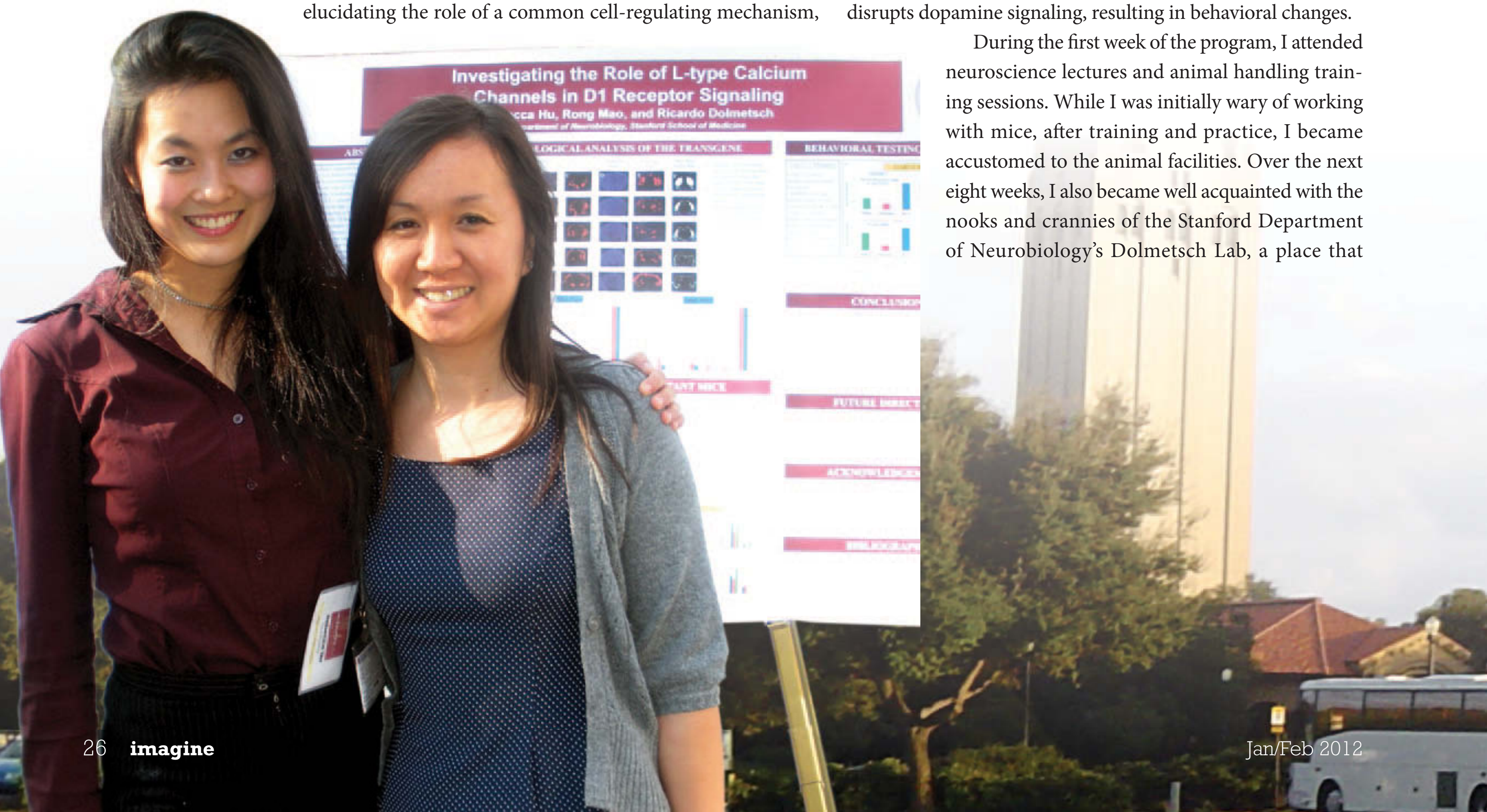
Upon acceptance into the program, each of the 58 interns selected a research focus such as cancer, cardiovascular, digital anatomy, immunology, neuroscience, or stem cells. I decided to follow my fascination with brain anatomy and signed up, along with 11 other interns, for the neuroscience institute.

The following week, I received my specific lab assignment: elucidating the role of a common cell-regulating mechanism, known as L-type calcium signaling, in the dopamine system of the brain. Having studied the dopamine system in my AP Biology class at school, I was eager to bring my conceptual knowledge of neurological systems to the laboratory bench.

A Brainy Journey

Recent evidence had suggested that calcium signaling that occurs in L-type calcium channels (LTCCs) is a critical component of dopamine systems in the brain widely implicated in psychomotor function, reward-based learning, and addictive disorders. To study the role of LTCCs in these pathways, I would focus on a mouse model that expressed a mutant form of Ca_v1.2, a subunit of LTCCs. I hypothesized that Ca_v1.2 dysfunction disrupts dopamine signaling, resulting in behavioral changes.

During the first week of the program, I attended neuroscience lectures and animal handling training sessions. While I was initially wary of working with mice, after training and practice, I became accustomed to the animal facilities. Over the next eight weeks, I also became well acquainted with the nooks and crannies of the Stanford Department of Neurobiology's Dolmetsch Lab, a place that



Rebecca Hu with her mentor, Dr. Rong Mao.

at SIMR

The Stanford Institutes of Medicine Research Program

reminded me of my father's laboratory so many years before.

Dr. Rong Mao, a research associate, acted as my mentor and oversaw my experiment planning. After a couple of weeks of close supervision and assistance in the lab, I began to acquire a clear sense of direction and independence.

To test my hypothesis, I worked with mouse models that expressed a mutation of $Ca_v1.2$ in the form of Timothy Syndrome, a developmental disorder characterized by autism, irregular heart rhythm, and the fusion of adjacent fingers and toes. I studied the behavior of the mutant mice to determine the consequences of $Ca_v1.2$ dysfunction in a subtype of dopamine receptor known as D1 receptor-expressing cells. A SHIRPA test—a basic behavior test that measures autonomic, cerebellar, sensory, muscle, and neuropsychiatric function—showed a decrease in many stress-related functions in the mutant mice compared to mice without the mutation. For example, the mutant mice defecated less, were less responsive to touch, and were less active when transferred from one location to another. In addition, our data from an open field activity test, in which we measured the activity of mice in an enclosed space, suggested the presence of hypoactivity, or reduced motion, in these mutant mice. These observations supported the prediction that the mice with mutant $Ca_v1.2$ channels exhibited certain behavioral alterations. Future goals could include further specifying these behaviors through behavior tests that target the factors of stress and motor activity.

A Lesson in Safety

As my days in the lab grew longer, sleep became more difficult to come by. My lab table was cluttered with scribbled notes, carefully stacked slide boxes, and half-eaten cups of ramen noodles.

I had grown accustomed to the equipment and procedures that comprised my daily routines: microscopy work, tissue sectioning, genotyping. But as I soon came to learn, even practiced routines aren't always error-proof.

The cryostat machine is used to slice thin sections of tissue specimens for mounting on slides. One day, rushing to complete the seemingly never-ending pile of sectioning work, I sliced my finger on the cryostat blade. An unbelievably large amount of blood gushed from my finger, and I fainted. Luckily, there were people in the lab to help revive me and take me to the emergency room, where I was treated with a skin adhesive to protect the wound from infection. I returned to the lab bench the next day.

I soon healed from the accident, but realized that if I wanted to pursue my passion for science, I needed to concentrate and focus on my work in order to avoid accidents.

The Home Stretch

As the end of my internship neared, I began compiling the results of my experiments for the required poster and PowerPoint displays that would be presented to the entire Stanford School of Medicine. The last two weeks were especially demanding: in addition to designing and running last-minute experiments to confirm my results, I had to organize my data to summarize the main points of my project. Thankfully, we were given helpful guidelines from SIMR faculty and staff on how best to present our research abstracts and final projects.

My 16-hour workdays and midnight experimental runs paid off. I completed my independent research project, and the results may contribute to a future paper for submission to a scientific journal.

The final poster presentation was a time of mixed feelings: while I had contributed to scientific discovery, I was sorry to see the summer come to an end. My experience at SIMR has given me a profound appreciation for unknowns in the field of medicine and for the immense potential for exploration. Perhaps most importantly to me, my summer at SIMR has given me confidence to pursue my curiosity and taken me one step closer to my aspirations of a career in neurosurgery. i

In the Dolmetsch Lab with Stanford med school student Anna Krawisz.

Rebecca Hu is a senior at Aragon High School in San Mateo, CA, where she leads the math, debate, and journalism organizations. When not in the lab, she enjoys playing the piano, Chinese folk dancing, runway modeling, playing volleyball, and relishing good food.

To learn more about SIMR, visit http://simr.stanford.edu.

Opportunities and Resources in the Biological Sciences

This list features some excellent opportunities available to middle and high school students. Visit our website at www.cty.jhu.edu/imagine for links to additional summer programs, competitions, and recommended websites.

ACADEMIC COMPETITIONS

4-H Wildlife Habitat Evaluation Program

Each state sends a team of 3–4 members, ages 14–19, to the national contest each year. Scores are based on the participants' ability to identify common wildlife foods, judge quality of wildlife habitats from aerial photographs, recommend wildlife management practices, and write rural and urban wildlife management plans. Students ages 8–13 can participate at the state level only. ***www.whep.org***

AAN Neuroscience Prizes

Students in grades 9–12 submit original laboratory research on neuroscience topics. Four winners receive prizes of $1,000 each, and three winners and their teachers receive a trip to present the students' work at the AAN Annual Meeting (2012: New Orleans). ***www.aan.com/science/awards/?fuseaction=home.info&id=11***

BioGENEius Challenge

High school students submit descriptions of biotechnology-themed research projects to the Biotechnology Institute. Two finalists from each state advance to the regional challenge. Two finalists from each region advance to the international competition, where they present their projects to a panel of experts for judging. First- through fourth-place winners receive $7,500, $5,000, $2,500, and $1,000, respectively. In addition, 10 honorable mentions receive $500 each. ***www.biotechinstitute.org/programs/biogeneius_challenge***

Canon Envirothon

Teams of students in grades 9–12 demonstrate their knowledge of soils and land use, aquatic ecology, forestry, wildlife, and a current environmental issue (2012: Nonpoint Source Pollution/Low Impact Development). Prizes include scholarships, trophies, and Canon products. ***www.envirothon.org***

Davidson Fellows Awards

Students ages 17 and under submit a significant piece of work in science, technology, mathematics, literature, music, philosophy, or "outside the box." Eight to fifteen students are typically selected each year and named Davidson Fellows. Fellows receive a $50,000, $25,000, or $10,000 scholarship and are recognized for their achievements in Washington, DC. ***www.davidsongifted.org/fellows***

Discovery Channel Young Scientist Challenge

Students in grades 5–8 begin their journey to the DCYSC by submitting a video entry in which they explain a scientific concept. The field of semifinalists (one student from each state and the District of Columbia) is narrowed to 10 finalists, who receive an all-expenses-paid trip to Washington, DC. There, students compete in a series of individual and team challenges for the top prize of a $25,000 savings bond. The second- through tenth-place finishers each receive a $1,000 savings bond. ***http://youngscientist.discoveryeducation.com***

Intel International Science & Engineering Fair

Two individuals and one team from each of 500 Intel ISEF-Affiliated Science Fairs advance to the international competition. These high school students compete for scholarships in 17 categories. The top winner at the international competition receives a $75,000 scholarship, and two $50,000 scholarships are awarded in Best in Show categories. Additional prizes include cash awards, scholarships, grants, and trips. Multiple special awards are also presented. ***www.societyforscience.org/isef***

Intel Science Talent Search

High school seniors submit a written description of their independent research and a 12-page entry form. From the 300 semifinalists, 40 finalists are selected to travel to Washington, DC, for final judging. Ten finalists receive one of the following four-year scholarships: one $100,000, one $75,000, one $50,000, one $40,000, one $30,000, two $25,000, or three $20,000. The remaining 30 finalists each receive a $7,500 scholarship. ***www.societyforscience.org/sts***

International Brain Bee

Students in grades 9–12 who win their respective local and national bees compete at the international contest, held in Maryland, on such topics as intelligence, memory, emotions, and neurological diseases. ***www.internationalbrainbee.com***

International Genetically Engineered Machine Competition (iGEM)

Teams of high school students design and build biological systems and operate them in living cells. The competition culminates in a jamboree where teams present their research. Medals are awarded in a variety of categories. (See page 11 for an article about this competition.) ***http://igem.org***

Junior Science and Humanities Symposium

Students in grades 9–12 who have completed original research in science, engineering, or mathematics may apply to attend JSHS regional symposia. Three winners from each regional event win scholarships of $2,000, $1,500, or $1,000 and are invited to attend the National Symposium, where seven first-place, seven second-place, and seven third-place winners receive scholarships of $12,000, $8,000, and $4,000, respectively. Each first-place finalist also receives an all-expenses-paid trip to the London International Youth Science Forum, an exchange program bringing together over 400 participants from 60 nations. ***www.jshs.org***

National Ocean Sciences Bowl

Teams of high school students from across the nation participate in a timed competition in which they answer questions about the marine sciences, including biology, chemistry, physics, and geology. Regional winners advance to the national finals, where first- through fourth-place teams win prizes and trips to places such as Costa Rica, Bermuda, and Hawaii. Participating students are also eligible to apply for internships and scholarships through the competition. Also available is a contest in which high school students submit a two-minute video on a theme (2012: Living on the Ocean Planet). First prize is a waterproof video camera. ***www.nosb.org***

President's Environmental Youth Awards
Individuals or teams of students in grades K–12 who have completed an environmental project are eligible to receive this award. Ten winners are recognized at an EPA-sponsored award ceremony, where they receive a Presidential plaque. ***www.epa.gov/enviroed/peya***

Siemens Competition in Math, Science, and Technology
As individuals or as members of two- or three-person teams, high school students submit research projects in one of 14 categories. Up to 300 projects are selected as semifinalists; from that group, up to 30 individuals and 30 teams become regional finalists. Individual winners of regional competitions receive $3,000 scholarships; winning teams receive $6,000 in scholarships to divide among team members. Team and individual winners go to New York for the national finals, where they compete for scholarships ranging from $10,000 to $100,000. ***www.siemens-foundation.org***

U.S. Stockholm Junior Water Prize
Students in grades 9–12 conduct water-related projects at the state, national, and then international level. Prizes include cash, trophies, and trips. ***www.sjwp.org***

USA Biology Olympiad
High school biology students who are nominated by their school take a national exam; the top 500 scorers then take the USABO semifinal exam. Twenty semifinalists will be invited to represent the U.S. at the two-week USABO summer Program in June, where four students will be selected to attend the International Biology Olympiad. The 2012 IBO will be held in Singapore. (See page 18 for an article about this competition.) ***www.usabo-trc.org***

Young Naturalist Awards
Students in grades 7–12 undertake explorations in biology, astronomy, or earth science, and then write up their findings in an essay (word count varies by grade level). Two winners from each grade win a trip to the American Museum of Natural History, receive cash scholarships ranging from $750 to $2,500, and have their essays published. ***www.amnh.org/yna***

SUMMER PROGRAMS

Grades specified refer to students' 2012–13 status. All programs are residential unless otherwise noted. Many of these programs offer a diverse range of courses; these listings include only those courses related to biology.

Cornell University Research Apprenticeship in the Biological Sciences (NY)
Grades 11–12; 6 weeks. Students interact with Cornell professors, post-doctoral fellows, graduate students, and undergraduates, as they conduct research and participate in labs and seminars. ***(607) 255-6203; www.cornell.edu/outreach/programs/program_view.cfm?ProgramID=2261***

Cornell University Summer College (NY)
Grades 11–12; 3 or 6 weeks. Course offerings in the Veterinary Medicine Program include Conservation Medicine and Small Animal Practice; those in the Animal Science Program include Captive Raptor Management and Sustainable Animal Husbandry, while those in the Medicine Program include Biological Research and the Health Professions and Body, Mind, and Health. ***www.sce.cornell.edu/sc***

Duke University Field Studies and Institutes (multiple sites)
Grades 9–12; variable duration. Programs for eligible students include Biological Diversity in Costa Rica, the Institute of Advanced Cancer Therapies, and The Institute of Human Genetics. ***www.tip.duke.edu***

Earthwatch Student Fellowship Program (multiple sites)
Grades 10–11. Teams of students conduct field research on a variety of topics, from conserving coral reefs in the Bahamas to studying climate change at the Arctic's edge. ***www.earthwatch.org/ed/fellowships.html***

Exploration Summer Programs (CT and MA)
Grades 6–12; 3 weeks; residential and commuter. Courses for students in grades 10–12 include Immunology, Biomedical Ethics, and Anatomy and Physiology; those in grades 8–9 may take So You Want To Be a Doctor: Medical Careers, and students in grades 6–7 may take Physiology & the Human Body. Also available for students in grades 8–10 is a 2-week focus program on Sports Medicine and Orthopedics, while students in grades 6–7 may choose a focus of Veterinary Science or Emergency Medicine. Both include hands-on clinics, labs, classes, and field trips. Finally, workshops for students in grades 6–7 include EMT and First Aid Skills, and Dissection. ***(781) 762-7400; www.explo.org***

George Washington University Pre-College (DC)
Grade 12; 6 weeks; residential and commuter. Course offerings include Biological Anthropology and Contemporary Science. ***(202) 994-6360; www.gwu.edu/apply/precollege***

Harvard Secondary School Program (MA)
Grades 10–12; 7 weeks. Students take two courses which may include Introductory Biology, Genome and Systems Biology, Principles of Genetics, Stem Cell and Regenerative Biology, Principles of Biochemistry, Principles and Techniques of Molecular Biology, Neurobiology, and Darwin's Legacy and Advances in Modern Biology. Also available are a variety of study abroad options. ***(617) 495-3192; www.summer.harvard.edu***

Johns Hopkins University CTY Summer Programs (multiple sites)
Grades 7–11; 3 weeks; residential and commuter. Course offerings for qualifying students include Introduction to the Biomedical Sciences, Fast-Paced High School Biology, History of Disease, Neuroscience, Genetics, Genomics, and Paleobiology. ***(410) 735-6277; www.cty.jhu.edu/summer***

Johns Hopkins University Precollege Program (MD)
Grades 10–12; 1–5 weeks; residential and commuter. Course offerings include Introduction to Biological Molecules. ***(800) 548-0548; www.jhu.edu/summer/precollege/summer***

Joseph Baldwin Academy for Eminent Young Scholars at Truman State University (MO)
Grades 7–9; 3 weeks. Course offerings for eligible students include The Human Laboratory and Biomusicology. ***http://jba.truman.edu***

North Carolina State University High School Summer Workshops (NC)
Grades 11–12; 1 week. Students participate in hands-on labs, lectures, and field visits. Workshops are available in Biological (Environmental or Biofuels and Engine Cycles option), Chemical, and Biomolecular science. ***www.engr.ncsu.edu/theengineeringplace/summerprograms/high-school***

Northwestern University CTD (IL)
Grades 7–12; 1 or 3 weeks; residential and commuter. Qualifying students in grades 7–8 may take Topics in Biology, Introduction to Biomedicine, or Biology, while those in grades 9–12 may take Biology or Human Biology. ***(847) 491-3782; www.ctd.northwestern.edu/summer***

Smith College Summer Science Program (MA)
Grades 9–12; girls only; 4 weeks. Alongside Smith faculty, students participate in hands-on research and take two research courses from offerings that include Biomedical Engineering, A Laboratory in Human Genetics, The Human Nervous System, and Miniature Worlds: Visualizing Life's Hidden Structures. ***(413) 585-3060; www.smith.edu/summerprograms/ssep/index.php***

Stanford Institutes of Medicine Summer Research Program (CA)
Grades 11–12; 8 weeks. Students participate in research, attend lectures, and present their work to the Stanford community. (See page 26 for an article about this program.) ***http://simr.stanford.edu***

Stanford University Education Program for Gifted Youth (EPGY) (CA)
Grades 9–12; 3–4 weeks. Courses for eligible students include Investigations in Bioscience and Biotechnology, and Environmental and Earth Science. ***http://epgy.stanford.edu/summer/highschoolprogram.html***

Stanford University High School Summer College (CA)
Grades 11 & 12; 8 weeks; residential and commuter. Course offerings include Biochemistry, Genetics, and Molecular Biology; Introduction to Biological Research Methods; Introduction to Biology; Introduction to Biology Lab; and Introduction to Human Physiology. ***(650) 723-3109; http://summer.stanford.edu/programs***

Summer at Brown Precollege Program (RI)
Grades 8–12; 1–7 weeks. Course offerings for students in grades 10–12 include Biological Illustration, Introduction to Medicine, Introduction to Biomedical Science, Research Techniques in Biomedical Fields, Techniques in DNA-Based Biotechnology, Introduction to Stem Cells and Tissue Engineering, Introduction to Human Anatomy and Physiology, Exploring Infectious Disease, Medical Careers, The Biological Basis of Disease, and Stem Cells, Cloning, and Regenerative Medicine: Changing the Face of Biology. Courses for students in grades 8–9 include An Exploration of Anatomy and The Laboratory Detective. Also available for students in grades 10–12 is Environmental Leadership in Hawaii, where students spend a week studying the living history, culture, and geology of Hawaii, the human impact on the islands, and leadership skills for sustainable communities. ***(401) 863-7900; www.brown.edu/scs/pre-college***

University of Chicago Summer Research in the Biological Sciences (IL)
Grades 10–11; 4 weeks. Students who have excelled in a high school biology course may apply for this program that covers research in molecular biology, microbiology, and cellular biology. Students design and carry out their own research projects, which they present at the end of the course. ***http://summer.uchicago.edu***

University of Connecticut Mentor Connection (CT)
Grades 11–12; 3 weeks. Qualifying students choose a mentorship site and work closely with university mentors on research projects. 2011 projects included Beneficial Bacteria, The Genetic Puzzle of Evolution, Unraveling the Development of the Cerebral Cortex, Comparative Genomics: Gene Transfer, and Centromeres: Getting a Grip on Chromosomes. ***(860) 486-0283; www.gifted.uconn.edu/mentor***

University of Iowa Secondary Student Training Program (IA)
Grades 11–12; 6 weeks. Students spend approximately 40 hours per week conducting scientific research under the guidance of a faculty mentor and produce a research project/paper. ***www.education.uiowa.edu/html/belinblank***

University of Maryland Summer Scholars (MD)
Grades 10–12; 3 weeks. Students take one course and participate in lectures, field trips, and projects. Course offerings include Environmental Biology, The Biology of Prehistoric Life, and Kinesiology. ***(301) 405-7762; http://oes.umd.edu***

University of Miami Summer Scholars Program (FL)
Grades 11–12; 3 weeks. Students in the Health and Medicine Program take Health Promotion, Prevention, and Rehabilitation plus one of the following courses: Infectious Diseases, Neuroscience, or Oncology. Students in the Marine Science Program take Ecology of Fishes, Introduction to Aquaculture, and Marine Environments of South Florida. In addition to coursework, students in both programs participate in labs, lectures, and field trips. ***(305) 284-6629; http://miami.edu/dcie/index.php/ssp***

Worcester Polytechnic Institute Frontiers in Science, Mathematics, and Engineering (MA)
Grades 11–12; 2 weeks. Students in the Biology and Biotechnology Program participate in hands-on labs, projects, and more. ***(508) 831-5286; www.admissions.wpi.edu/Frontiers***

Note: *In addition to summer programs, a variety of internships are available to qualifying students. See our website for information on these and other programs.*

WEBSITES

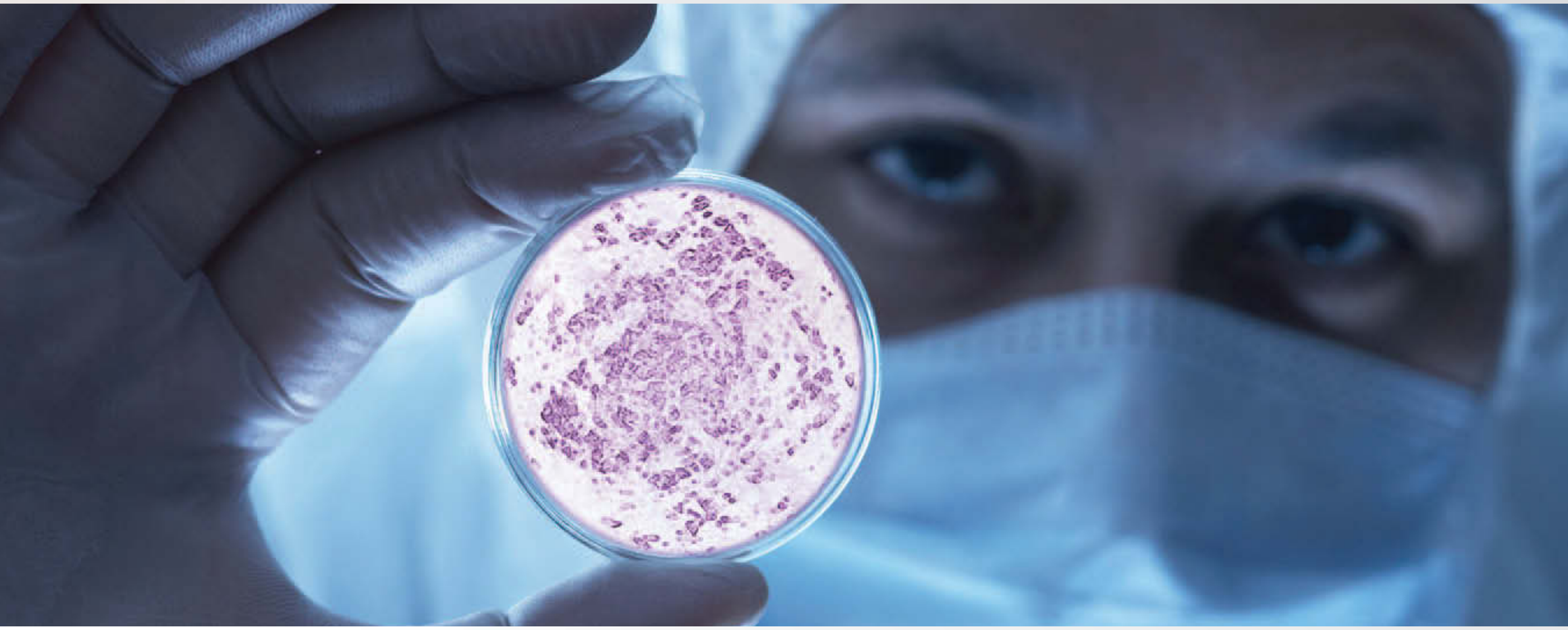
Actionbioscience.org
Why preserve life's variety? At this site of the American Institution of Biological Sciences, visitors can click on one of seven bioscience challenges to explore how a particular issue affects them. ***www.actionbioscience.org***

Bacteria Museum
Here you'll find information on 40 different specific bacteria from Anthrax to *Yersinia enterocolitica*, learn how bacteria are used in industry, and much more. ***http://bacteriamuseum.org/cms***

BioInteractive
Explore topics ranging from biodiversity to biological clocks at this site of the Howard Hughes Medical Institute. Features include a virtual museum, animations, an Ask a Scientist page, virtual labs, and interactive tutorials on infectious diseases, obesity, cancer, and more. ***www.hhmi.org/biointeractive***

Cogito.org
In this award-winning online STEM community for precollege students, members participate in forums, blogs, interactive interviews with experts, and more. ***www.cogito.org***

Dolan DNA Learning Center
Produced by Cold Spring Harbor Laboratory, this site features a variety of DNA-related information and links, including 2D and 3D animations on such topics as polymerase chain reaction, cloning, and stem cells; Genes in the News; online education opportunities; links to interactive sites on genes and health, and DNA Interactive, where you can view a timeline of DNA discoveries, explore applications, and more. ***www.dnalc.org***



The Encyclopedia of Life
With this vast resource, you can explore 914,677 (and counting) species, use virtual field guides, view podcasts, and take a Google Earth quiz to test your knowledge on the world distribution of various species. ***http://eol.org***

Exploratorium
Take a virtual trip to San Francisco's Exploratorium for a 360° panoramic view of the fascinating and informative Traits of Life exhibit. ***www.exploratorium.edu/traits***

Extreme Biology Blog
On this student-run, biology-related blog, you can read about topics from animal behavior to field trips, or be a guest blogger yourself. ***http://missbakersbiologyclass.com/blog***

iCell
Visitors to this site can interact with 3D plant, animal, and bacteria cells by zooming, rotating, and performing a simple mouse-over for annotations. Educational and addictive! ***http://hudsonalpha.org/education/digitaleducation/icell***

Institute for Species Exploration
What are the top ten new species of the year? View phenomenal photographs of some of life's most amazing creatures at this site of Arizona State University. ***http://species.asu.edu***

LifeWorks
Find information on over 100 careers in the life and medical sciences by title, education required, interest area, or median salary. Each career profile contains an interview with a specialist in each field. You'll also find a career planning timeline with information on everything from choosing a college to finding financial aid, and a guide on finding an "e-mentor." ***http://science.education.nih.gov/LifeWorks.nsf/feature/index***

micro*scope
View an amazing array of microbial images, including those from the International Census of Marine Life and the NASA Astrobiology Institute's microbes from extreme habitats. ***http://starcentral.mbl.edu/microscope/portal.php***

Mysteries of the Cell
At this site of *Science* magazine, you can listen in as researchers address fundamental questions about cells via live chats. ***http://news.sciencemag.org/sciencenow/2011/11/live-chat-mysteries-of-the-cell.html***

National Institute of General Medical Sciences
Download award-winning booklets on such topics as cell biology and genetics, read the Institute's in-house magazine, play interactive games dealing with Nobel Prize winners and proteins, and peruse a scientific image gallery. ***www.nigms.nih.gov/Education***

Planting Science
This site offers opportunities to engage in online dialogues with mentors and science experts about biology concepts and plant biology research projects. ***www.plantingscience.org***

The Tree of Life
Check out this site to explore thousands of divergence times among organisms in the published literature. ***http://tolweb.org/tree/phylogeny.html***

Woods Hole Oceanographic Institution
Here you can go on an online expedition with a scientist, explore marine careers, read about oceans in the news, and find multimedia presentations on marine science. ***www.whoi.edu***

BOOKS

Anthill: A Novel by Edward O. Wilson (W.W. Norton & Company, 2010).

Charles Darwin's On the Origin of Species: A Graphic Adaptation by Michael Keller (Rodale Books, 2009).

The Emperor of All Maladies: A Biography of Cancer by Siddhartha Mukherjee (Scribner, 2010).

Feathers: The Evolution of a Natural Miracle by Thor Hanson (Basic Books, 2011).

Microcosm: E. Coli and the New Science of Life by Carl Zimmer (Vintage Books, 2009).

Nature Stories by Jules Renard (NYRB Classics, 2010).

Ocean Soul by Brian Skerry (National Geographic Books, 2011).

The Restless Plant by Dov Koller (Harvard University Press, 2011).

Soul Dust: The Magic of Consciousness by Nicholas Humphrey (Princeton University Press, 2011).

Swan: Poems and Prose Poems by Mary Oliver (Beacon Press, 2010).

The World's Water by Peter Gleick et al. (Island Press, 2011).

Your Inner Fish: A Journey Into the 3.5-Billion-Year History of the Human Body by Neil Shubin (Vintage Books, 2009).

The World on Stage

by Fatima Husain

"We have become not a melting pot, but a beautiful mosaic; different people, different beliefs, different yearnings, different hopes, different dreams."

—Jimmy Carter

Behind the red velvet curtain, what will be the most popular act of the night, Bollywood Dance, prepares to perform. Already the crowd is enthusiastic: the two previous acts—Chinese Pop Music and Belly Dancing—were hits. As the curtain slowly opens, the hit Bollywood song "Sheila Ki Jawanne" begins to pour from the auditorium speakers and the audience cheers. The enthusiasm of the dancers delights the crowd. Afterward, the relieved and overjoyed Bollywood dancers thank the audience and exit the stage, while the next act prepares to enter. This is International Night.

When I started high school, I attended my school's Activity Fair. I was drawn to the colorful decorations and cultural items displayed on the World Cultures Club table. I wanted to learn about other cultures, and I welcomed the opportunity to share my Pakistani heritage with others.

During weekly meetings, World Cultures Club members have the opportunity to talk about their countries of origin. The club also hosts an array of cultural activities, including outings to ethnic restaurants, festivals, and cultural parties hosted by senior club members. At my first meeting, I helped design posters informing other students about the club. During my second meeting, I spoke to the group about Pakistani culture, which, I learned, bears similarities to Chinese and Japanese cultures with regard to family values and dynamics. I described the traditional dress, the *shalwar kameez*, and talked about India's influence on Pakistan. It was refreshing to see people respect and take an interest in my culture.

At one of our meetings, the president and vice president of the club began to talk about International Night, an annual event to raise awareness of cultural diversity. The club's largest event of the year, International Night is an evening filled with cultural performances and activities by students from our school district, as well as presentations by organizations such as Hope 4 Africa, Invisible Children, and Soccer Without Borders.

Come One, Come All

On the first Friday in March, hundreds of students and community members will flock to school for the third annual International Night. The attendees' three-dollar admission fee, along with all vendor proceeds from the night, are donated to a charity that club members select at the beginning of the school year. The recipient charity for 2011 was the Heifer Foundation, which provides microloans to families to start small businesses in developing countries.

We designed brochures for International Night, placing them in classrooms throughout school. To help advertise the event, I dressed in ethnic Pakistani clothing. When curious students in my classes asked why I was wearing the clothing, I explained that these were clothes from my native country, and that I was wearing them to raise awareness about International Night.

At meetings, we planned the layout of booths: the vendors would go along one wall of the hallway outside the auditorium, representatives of student organizations along another, and—to keep things as orderly as possible—the kids' area, where younger children could make cultural masks, would be separate from the two.

Hours before the event, club members prepared for the large crowd that was expected. In the auditorium, we constructed a catwalk for the International Night Fashion Show. Outside the auditorium, we set up ticket booths and vendor stalls. The artwork of students and staff from our school district was displayed along the hallway, to be auctioned at the event.

A Feast for the Senses

International Night begins in the hall outside the school auditorium, where fair-trade vendors display handcrafted items such as carved wooden salad tongs from Kenya and woven cloth shoulder bags from South America. Students wait in long lines for intricate henna tattoos and the chance to buy Buddha boards and handmade beaded leather bracelets.

In the nearby cafeteria, vendors prepare food for the hungry crowd. Graceful origami shapes are suspended from the ceiling above the lunchroom tables, and the tantalizing aromas of South American empañadas and Greek gyros waft into the hallway, beckoning the attendees.

Many attendees dress in the clothing of their native countries, providing a feast for the eyes: the stately silk kimonos of Japan, the Bollywood Dancers' colorful *shalwar kameezes* with intricate gold embellishment, and the brightly colored Mexican dresses with their delicate embroidery.

Cultural Diffusion

In the auditorium, members of the Valley High School Lion and Dragon Club prepare to kick off the show. The sound of the gong quiets the crowd, which nearly fills the 500-seat auditorium. A majestic, red-scaled dragon snakes hypnotically across the stage, momentarily transporting the audience to China. Next, an Irish fiddler from our school takes the stage. Quickly and skillfully, she weaves through the fast notes, providing an enthusiastic performance that leaves the crowd wanting more. The fiddler leaves the stage, and is replaced by a group of students clad in sombreros and colorful Mexican dresses. As the sounds of the bass guitar and softly sizzling maracas fill the auditorium, the boys and girls form separate lines, facing one another. When they begin their Mexican folk dance, some of the audience members begin to dance as well. In addition to the cultural performances, speakers from the Irish and Indian communities talk to the audience about issues such as extreme poverty in India and the economic crisis in Ireland.

The final act of the evening is the fashion show. Over 20 models take the catwalk to showcase colorful clothing from India, China, Germany, Japan, and Mexico. Some of the models joke around with the crowd, striking comical poses. Waves of praise and laughter follow each model as they take the stage. The show ends to thunderous applause, and attendees channel out into the hallway to mingle with vendors and students.

In just two hours, International Night 2011 raised over a thousand dollars for Heifer International. Attendees benefitted as well, by supporting important international causes, by learning about national student-run organizations such as Soccer Without Borders, and by better understanding different cultures in the community.

People may attend International Night for the performances, food, and fun, but it is our hope that they leave with a better awareness of people and the world around them. **i**

Fatima Husain is a junior at Valley High School in West Des Moines, IA. She is currently vice president of the World Cultures Club and a member of both the Principal and Multicultural Advisory Councils. In her spare time, Fatima enjoys writing short stories and traveling around the world.

Want to start a World Cultures Club in your school?

Whether it's Diversity Club, Multicultural Club, or World Cultures Club, many schools have organizations devoted to appreciating other cultures. If your school doesn't have such a club, talk to your teachers or administrators about starting one. For ideas on how to start a multicultural club in your school, go to www.tolerance.org/activity/starting-activist-club-school.

For a list of books on multiculturalism for teens, go to www.education.wisc.edu/ccbc/books/detailListBooks.asp?idBookLists=253.

Lessons from Chess

by Justin Karp

Suddenly, I remembered that I was not trying to win.

This time, it was different. Usually when I play chess, I push hard toward victory. Once, during a National Scholastic Chess Championship, I had been falling behind during the game that would determine the first-place winner. I started to wonder if I had a prayer of winning, and my energy began to lag. My arms felt heavier. “Stay alert!” I told myself. Then, I saw my best next move. I paused for a split second, appreciating how elegantly chess moves can tie things together. I made the move and prevailed! Another time, I had played for three hours straight at the World Open Chess Tournament. I struggled to keep my eyes open and my momentum going, but, exhaustion notwithstanding, I managed to win that game, too.

Today, however, I was not at a chess tournament. This time, I was moving chess pieces not to try to win, but to teach.

Game Plan

In recent years, especially since entering high school, I’ve realized that although I was able to participate in school chess classes as early as kindergarten, not everyone has such opportunities. Some students are limited by financial constraints at their schools. That’s why I decided to volunteer at an inner-city afterschool program that didn’t have a chess teacher.

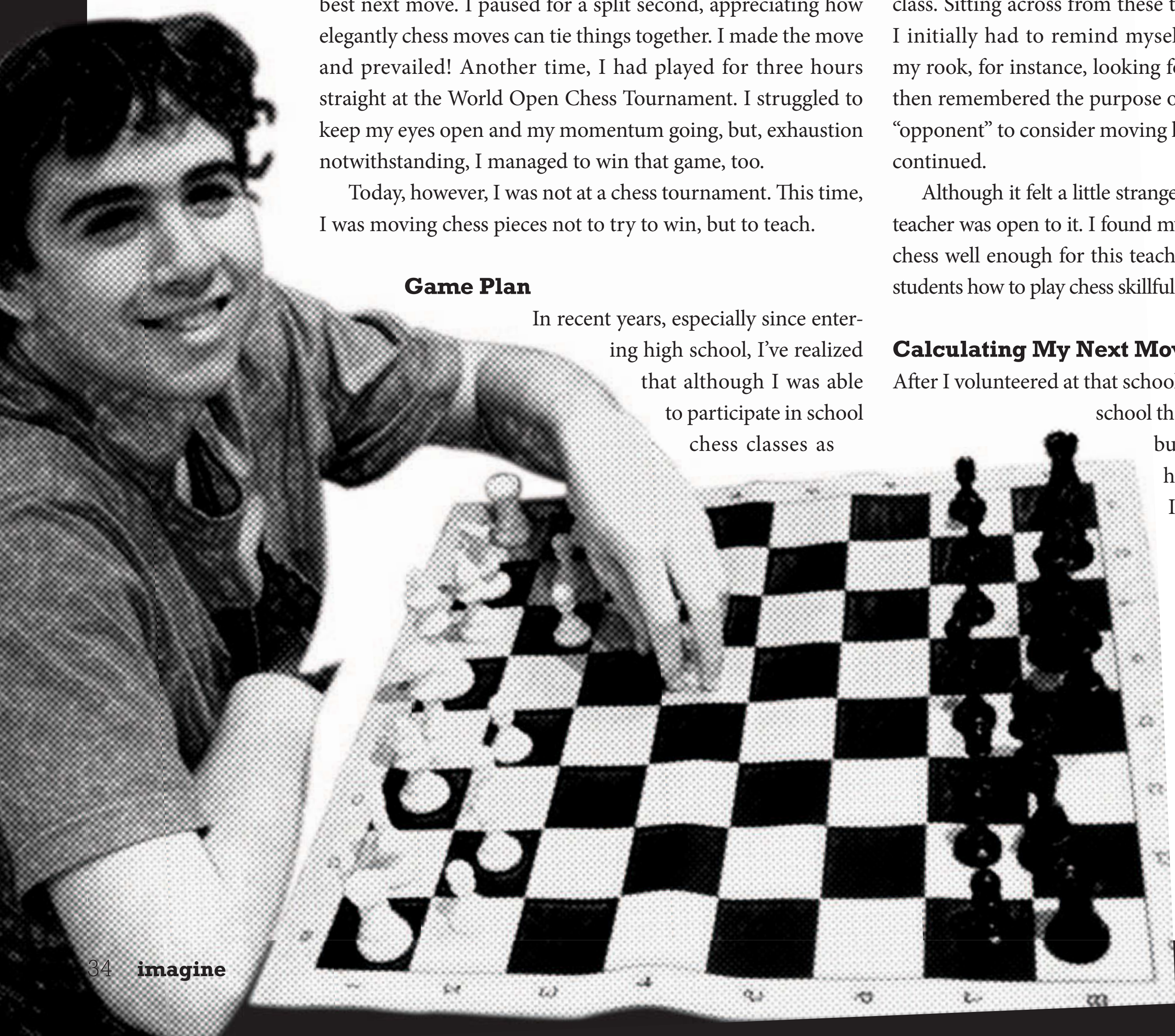
Over a long afternoon, I met with several elementary school teachers to try to help them improve their basic chess skills so that they could teach an introductory afterschool chess class. Sitting across from these teachers, moving chess pieces, I initially had to remind myself of my mission. I advanced my rook, for instance, looking for a way to win the game, but then remembered the purpose of the exercise and advised my “opponent” to consider moving his king. He did, and the game continued.

Although it felt a little strange to be counseling an adult, the teacher was open to it. I found myself hoping that I would teach chess well enough for this teacher and his colleagues to show students how to play chess skillfully one day.

Calculating My Next Move

After I volunteered at that school, I heard of a local elementary school that was experiencing significant budget cuts and that could use help with its chess program. I volunteered to teach chess there after school and during the summer. Armed with a chessboard and a projector, I showed the students how to move chess pieces. It reminded me of when I first learned to play chess.

I was four years old, recuperating from a tonsillectomy, and a family friend had bought me a small chess set and a children’s



Justin, left, with teachers in an afterschool program at a public elementary school.

book that explained how each chess piece moves. I'd spent countless hours studying that book and rearranging pieces on the chessboard.

With this memory in mind, I decided to set up the early moves of a mock game for the elementary students, asking them what they thought the next move should be. I pretended to make a terrible move, after which a few of the children shouted with laughter. "You're getting it!" I told them. Not only did they understand how chess pieces move, but they were also working together and having fun.

It occurred to me that there were students at this elementary school who greatly enjoyed chess but couldn't afford the private chess lessons that I had been lucky enough to receive. I knew several accomplished teenage chess players who might also be interested in volunteering to teach chess. I talked to one of them, a chess player who had recently won state and National Scholastic chess championships. I told him about the opportunity to teach one of these elementary school students, and he arranged to do so. Both he and his student enjoyed their first lesson together and looked forward to others.

While teaching students to play chess, I noticed how much the game promotes attention and socialization. Students have to collaborate and think hard as they analyze chess moves together. Thinking that chess seems like the perfect challenge for children with special needs, I contacted a summer program for children with such challenges and offered to teach a chess course there, which the staff enthusiastically arranged for me to do. I used both chess–related computer games and a chessboard to teach there. The 52 children in this program, ranging in age from seven to eleven years, were broken up into four age-matched groups. Many of the children in each group would gather daily around the chess games that I presented. They asked meaningful questions and seemed focused and engaged. Some of them spoke with me further about chess at the end of each day. When I completed my two weeks of teaching there, the staff and students gave me a giant, beautifully decorated card with a picture of a chess piece on the front. Inside, the card said, "Thanks so much for teaching us chess!" I still have that card in my room at home.

The Language of Chess

Chess is exciting and dynamic, and I hope to be able to play it always. As a member of the chess team at my school, I feel a sense of camaraderie, and I am especially proud that our team won first place in a National Scholastic tournament last school year. I've also seen that chess can promote problem-solving, concentration, and community. I appreciate the importance of chess as a safe activity in places where less wholesome ones beckon.

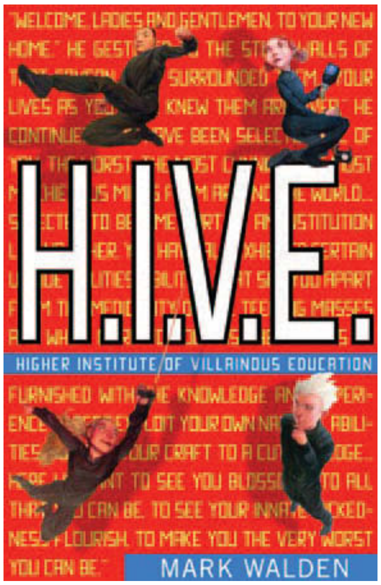
There is something truly universal about chess. Although I was unable to speak the languages of most of my opponents at the World Youth Chess Championship, I was able to interact with them through the language of chess. This reinforced for me the concept that chess can be more than a game.

I love to play chess, and I love to win. However, when those teachers whom I taught were able to start and maintain an afterschool chess club at their economically challenged school the following school year…well, that was one of the best victories of all.

Justin Karp is a junior at the Horace Mann School in Riverdale, NY. Justin has won four National and four New York State Scholastic Chess championships, as well as the North American Chess Challenge. He was a member of the All America Chess Team for three years and has represented the United States in the World Youth Chess Championship.

H.I.V.E.: Higher Institute of Villainous Education
by Mark Walden

Review by Hossain Md. Jihad Turjo



Hidden inside a volcano that only looks active, H.I.V.E. (Higher Institute of Villainous Education) was founded by Dr. Nero, with the purpose of gathering students from all over the world and nurturing the seeds of evil in their minds. This pool of students, however, is no result of random selection. Only those who have shown that they can use evil to become leaders are chosen to be a part of H.I.V.E. Only the truly extraordinary, who do not feel bound by rules of normal society, are given the chance to nourish their abilities at H.I.V.E.

Otto Malpense, in order to halt the British prime minister's policy that would close down the orphanage he has lived in and virtually controlled since his birth, literally annihilates the PM's career by tricking him into public embarrassment. Laura Brand, a Scottish girl, hacks into her local military base network in order to use surveillance aircraft for eavesdropping on school enemies. Shelby Trinity, an American girl, has become one of the most notorious anonymous jewel thieves alive by the time she reaches 13. These are the kind of youthful instigators who are discreetly captured and brought to H.I.V.E. Joining—or leaving the school for that matter—is no voluntary option, as Otto, Shelby, Laura and Wing, an Asian boy, soon find out the hard way.

Dr. Nero, the headmaster, reports to a shady figure called Number One, leader of G.L.O.V.E. (Global League of Villainous Enterprises), whose identity and past are unknown. The argument Dr. Nero presents to the students for their six-year-long studies at H.I.V.E. is that villains are always the better, more powerful ones. There are moments when everyone finds themselves secretly wishing that the villain wins. Why would that be if not for the fact that the villain is actually the better man?

But despite Nero's assurances, Otto and his friends feel that they are in effect prisoners. Hence, they plot their escape together, without realizing that they are merely playing into Nero's hands. There are things Otto doesn't know, including why he is so special to Number One that Nero has been ordered to keep an eye on him and make sure nothing happens to him. Immediately after they realize that their ingenious escape plan was known to Nero all along, the school comes under threat of a mutated plant—nurtured by genius biotechnology student Nigel Darkdoom—gone out of control. The book ends with a description of the fight against the plant, and leaves an enormous number of loose ends to tie up.

Overall, this book, the first in its series, provides a great adventure in a very "special ops" environment. For those who wish to take a break from standard views of right/wrong and good/bad, this book is a must read. Or, it could simply be read for the pure pleasure of delving into a sci-fi-like adventure novel.

Hossain Md. Jihad Turjo is an 11th grade student at Mastermind School, Dhaka, Bangladesh, preparing for the Edexcel GCE A-Level (Advanced Level) examinations. Turjo completed the Honors Chemistry and Honors Biology courses through CTYOnline and is currently continuing CTY's AP Calculus BC course. He also attended CTY's Investigations in Engineering program last summer at Johns Hopkins University. In his free time, Turjo enjoys reading novels and playing on the computer.

Also recommended

The Ear, The Eye and the Arm
by Nancy Farmer

This book is part science fiction, part mythology, and part adventure story. Set in Zimbabwe in the year 2194, it tells the story of 13-year-old Tendai and his two younger siblings, Rita and Kuda, who are children of a powerful general. When they leave home one day for an adventure but don't return, the general hires three detectives with special talents (hearing, vision, mind-reading) to bring them back. I liked the way this book wove together ancient legends and futuristic concepts, and the characters were great, too.

—Aidan Bowen, 14, NJ

Dovey Coe
by Frances O'Roark Dowell

Set in the 1920s, *Dovey Coe* is about a young girl who is accused of murdering her older sister's boyfriend, Parnell, when she is found in the same room as his dead body. Twelve-year-old Dovey never liked Parnell, but she also would never kill him. Dovey goes on trial and is found innocent, but then who did kill Parnell? That is the mystery of this book.

— Gillian Schullery, 11, CT

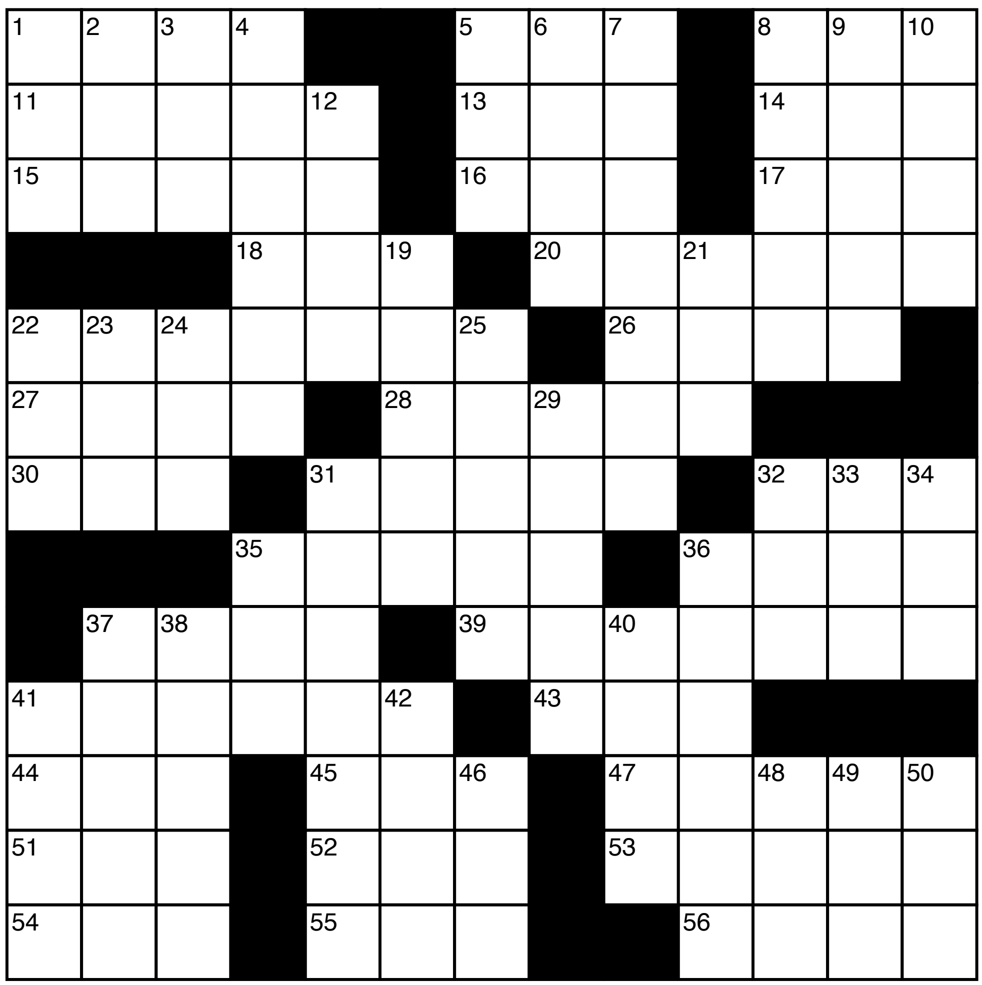
Life As We Know It

ACROSS

1 Spinning toys
5 ___ and downs
8 Spider creation
11 "No great discovery was ever made without a bold guess." –___ Newton
13 Eat
14 Female pronoun
15 "If I could remember the names of all these particles, I'd be a botanist." –physicist Enrico ___
16 Of the superfamily Hominoidea
17 Rock containing minerals or metals
18 Buddy
20 Subclass including ticks and mites
22 Containing two complete sets of chromosomes
26 Land surrounded by water
27 Organ of smell
28 Prestigious international prize
30 Social insect of the family Formicidae
31 Addio, adieu
32 Government worker
35 After peas, Mendel studied inheritance in these
36 Efficiently
37 Beverage produced using amylolysis
39 Divine
41 Small fish
43 Bad, ill, or defective (prefix)
44 Goddess of the dawn
45 Chiroptera
47 Wee
51 Only extant member of the genus *Dromaius*
52 Wrath
53 Simple photosynthetic eukaryotes
54 Golf equipment
55 Accountant
56 Roe

DOWN

1 Tagged image file
2 Suffix used for sugars
3 Standard
4 Specimen
5 America
6 Chrysalis
7 Group capable of interbreeding and producing fertile offspring
8 A revolution on a mollusk's shell
9 Spooky
10 Reproduced in a controlled environment
12 Hello (or goodbye) in Milan
19 ___ Danvers, Supergirl's secret identity
21 Sign language
22 Genetic code
23 Charged particle
24 Vancouver's time zone
25 "If we knew what it was we were ___, it would not be called research, would it?" –Albert Einstein
29 Chest
31 Organism requiring oxygen
32 Federal Bureau of Investigation
33 One of the world's largest species of deer
34 Tyrian purple, for example
35 Mr. Affleck
36 One of two or more versions of a gene
37 Ecosystem
38 To follow in order
40 *Star Trek*'s sentient android
41 "The garden suggests there might be a place where we can ___ nature halfway." –Michael Pollan
42 Bend out of shape
46 *Camellia senensis* plant
48 Ovum
49 King cobra in *Rikki-Tikki-Tavi*
50 Affirmative



Wildlife Biologist

Interview by Amy Entwisle

Brian Gratwicke, PhD

Wildlife Biologist, Center for Species Survival, Smithsonian National Zoological Park

Zimbabwe, where Brian Gratwicke grew up, is a land synonymous with elephants, lions, and giraffes, but it was the aquatic life that got the young Gratwicke's attention. Here, he explains how he turned his fascination into a career, and how he uses that career to help preserve the nature that he loves.

How did you become interested in biology?

I always knew I wanted to be a biologist. As a kid, I would go down to the public pond at the bottom of our street, catch little minnows, and put them in jars all over my bedroom. Eventually, I had 20 fish tanks lining my bedroom, I had dug up my mother's garden, and I had eight fish ponds.

How did you parlay that interest into a career?

I got my undergraduate degree in zoology and my master's in fisheries ecology. Then, as a Rhodes Scholar at Oxford, I did a PhD on coral reef fishes in the British Virgin Islands. Afterward, I knew that I didn't want to be an academic, per se, the kind that focuses exclusively on making observations and testing hypotheses. I wanted to use my personal values to guide my conservation actions.

What was your first job after grad school?

After I finished my PhD, I got a job with the National Fish and Wildlife Foundation working as a grant administrator for Save the Tiger Fund. What I really learned there was that my training as a biologist didn't give me all the tools I needed to be a conservationist. I was well prepared for species and habitat management, yet poorly equipped to raise money and hire staff to implement a conservation program. Conservation financing, land acquisition, policy, and education are some of the key areas in which conservation biologists work in order to save species or ecosystems.

Why did you decide to work with amphibians?

Amphibians are some of the most accessible forms of wildlife on the planet. Kids tend to love them. Parents like them because they're not especially dangerous for kids to play with. But amphibians also have an intrinsic value of their own. They're incredible little jewels with important ecosystem functions. They eat an enormous number of invertebrates, including pests that spread human pathogens and attack crops. There are chemicals in their skin that help them fight pathogens and diseases, chemicals that may be used to help develop medicines and cures for humans.

Amphibians are the sound of the rainforest at night. They are the wildlife in your own garden, but they're disappearing from ecosystems all over the world. They helped to greatly enrich my childhood, and I think it would be a shame if that piece were missing from the childhoods of our children, or our children's children.

What are you working on now?

I'm working on a novel disease that was actually discovered here at the National Zoo by one of our pathologists who was trying to identify what was killing some frogs in an exhibit. It's called *Batrachochytrium dendrobatidis*, or amphibian chytrid fungus, and it's causing massive amphibian declines and extinctions. It's now moving through Latin America, wiping out frogs along the way. Panama was the last Latin American country to be hit by this chytrid wave, but there are still some populations of frogs there that haven't been affected. I'm working there to try to stop it.

You're helping create what's been called a Noah's Ark for frogs whose population is threatened by chytrid fungus. Can you talk a little bit about that?

At the Smithsonian, we're working with the International Union for Conservation of Nature (IUCN) on the Amphibian Ark Program, a global project to create assurance colonies of amphibians that will otherwise go extinct in the next few years. We've put those frogs most urgently at risk of extinction in a captive breeding facility where we can keep the fungus out. We can cure chytrid fungus in frogs in captivity by using anti-fungal chemicals,

but that doesn't provide long-term immunity from it. We're collaborating with researchers at Virginia Tech, James Madison University, and Vanderbilt University to try to use bacteria that occur naturally on frog skin to produce anti-fungal chemicals as a metabolic byproduct that protects them from chytrid fungus. It's worked in mountain yellow-legged frogs and in red back salamanders. Now we're hoping to develop a probiotic cure for species such as the Panamanian golden frog, which is extinct in the wild.

Can you describe your job?
My role at the Smithsonian includes grant writing, communicating with collaborators about goals, and forming alliances to tackle these huge problems as a team. Developing a cure for chytrid fungus involves many different scientific and non-scientific disciplines, including fundraising, policymaking, and conservation financing. I work with scientists, veterinarians, and microbiologists who go to Panama to find species of bacteria that inhibit chytrid fungus 100 percent. I also work with geneticists, who help monitor the probiotic bacteria we've introduced on the frogs' skin, and with endocrine biologists, who study stress hormones to see if something in these bacteria might stress out the frogs. I work with a husbandry team that ensures that the things we're doing while searching for the cure won't compromise the frogs' health.

What's the most rewarding thing about your job?
I get to work with people who are way smarter than I am, who bring together lots of different skill sets from many different disciplines. I travel to places like Panama on a regular basis and see incredible wildlife up close. The real reward, though, is seeing the results of what we're doing—bringing the frogs into safe havens, breeding in captivity members of a rapidly declining species, and seeing them continue in captivity even as we witness their population crash rapidly in the wild. It's sad watching them decline, but it's satisfying knowing that we've managed to save some of them for the future. It will be even more satisfying to be able to put them back into the wild where they belong.

What skills and qualities does one need to be successful in a field like yours?
You should love what you do, because it's a tough job. You need to be able to communicate well and work well as part of a team. You also need to be quite bold and fearless of the unknown. I'm often doing things that I don't have a lot of training in, such as molecular methods, microbiology, pathology, disease ecology, and fundraising. You need faith in your own ability to understand some of these big problems, and the confidence to draw on experts who have the skills you lack in order to achieve something bigger than you could on your own.

What advice would you give to students who are interested in working in conservation biology?
Study subjects that are going to help you think outside your discipline. Take a course in English literature, or hardcore stats. Ask yourself, "What am I really good at? What really interests me?" If it's government or international affairs, then maybe some policy-oriented studies would be good for you. If you're interested in TV and media, go for it. Get some training in things that inspire you, because in the field of conservation biology, you'll use all kinds of skill sets. i

What wildlife biologists do
Wildlife biologists study animals in their natural habitats, including their origin, behavior, diseases, and life processes. They may experiment with animals and collect and analyze biological data to assess the effects of environment and industry. They disseminate information in papers, journal articles, and educational presentations. They may coordinate programs to control outbreaks of disease in animals.

Where they work
Many wildlife biologists work for government agencies and zoos. Others work for museums, historical sites, social advocacy organizations, and scientific research and development companies.

Education required
A PhD is generally required for independent research, but a master's or bachelor's degree may suffice for some jobs in applied research.

Salary range
According to the Bureau of Labor Statistics, the median annual wage for zoologists and wildlife biologists in 2010 was $57,430.

For more information:
American Institute of Biological Sciences
www.aibs.org

Association of Zoos and Aquariums
www.aza.org/careers-zoos-aquariums

Ecological Society of America
www.esa.org

Society for Conservation Biology
www.conbio.org

Common Sense for a Happy, Healthy Freshman Year

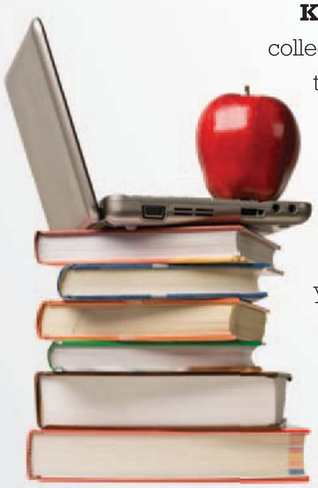
by James Barasch

Your first year at college will be a time of extraordinary change. For some of you, this will be the first time you've left home for an extended period. For me, leaving high school and entering my first year at Tufts was a kind of graduation from childhood. This transition can be disorienting, and I found myself quickly forgetting some common sense concepts. Here are a few basic habits that I forgot—but then relearned and now practice regularly. These might sound obvious, but once your schedule fills up with classes and social activities, it will be important to keep these at the front of your mind so that you don't forget them.

Eat consistent and balanced meals. It's almost scary how quickly you can get so caught up in your new academic and social life that you forget or don't make time for healthy meals. I quickly learned that taking even 30 minutes out of my day for lunch or dinner made a significant impact on my mental and physical well-being. (I also met some of my best friends at the dining hall.) It's very tempting and easy just to grab something quick, but the quick-access foods tend not to be the healthiest. Taking a little time for a good meal will pay off in better concentration and better health, which will allow you to keep up with your academics.

Get plenty of sleep. High school has probably already made you familiar with the challenge of getting enough sleep. College will provide even more challenge. It is important to take time for yourself, to rest your brain and recharge with fun activities outside class—but it's also important not to pillage your sleep hours for this purpose. While you might think you can survive on little sleep, that isn't the point of college. This is a time to *thrive*—which you can't do if you spend most of your waking hours in a state of caffeine-induced consciousness.

Keep on top of your academics. In my experience, college work comes in cycles of volume. A period of relatively easy workload can be followed by a few weeks seemingly designed to flatten you. I found that staying one or two assignments ahead in your classes can serve as a sort of academic buffer between you and the frenzy that can happen at the end of the semester. In the crush of finals week, you'll be very glad that you created that cushion for yourself.



Find your own balance. When you first arrive at college, you probably will be bombarded with advice and tips (like these) as to how to make the most of your college experience. You'll frequently hear the word "balance" thrown around, but there is no single formula for finding it, and ultimately you are responsible for your own college career. Yes, it will be disorienting and at times frightening, but having been through it myself, I can assure you that finding your own balance of work, social, and personal time will be a significant growth experience. If you keep an open mind, are not afraid to experiment with organization and time-management techniques (I personally recommend Google Calendar), and build good habits during your first year, your college experience will be much smoother.

Keep your perspective. As a new freshman, I had heard much about the "college bubble," but I didn't believe that I would become so wrapped up in college life that I would lose sight of the bigger picture. How wrong I was. College life can easily absorb all your attention, and it can become overwhelming. My advice is not to prevent this from happening—it's at least partially inevitable—but to come up for air every now and then. Take time for yourself, sit in a quiet place, and let your mind wander from your immediate, pressing concerns. Think about your future, the meaning of life, even the origin of the universe. Exercising this "gestalt muscle" has served me well many times. It relaxes, grounds, and reaffirms, promoting the mental well-being and balance that is so vital to the college experience—and to life itself. i

CTY alumnus **James Barasch** is a sophomore at Tufts University, where he is majoring in History, Classics and Political Science. James writes a bimonthly book review column, "Barasch on Books" (http://blogs.tuftsdaily.com/?author=74), for *The Tufts Daily*'s blog, Jumbo Slice. In his spare time, James enjoys ballroom dancing and participates in the Tufts History Society and TUPAC (Tufts University Presents Archaeology and Classics).

How I Review College Applications

by Daniel Creasy, Associate Director of Admissions, Johns Hopkins University

Every year just after the application deadline has passed, applicants begin to ask an array of questions: What happens to my application? Who reads it, and what are they looking for? What are the most important parts of my application? Are admissions decisions based just on numbers, or will someone actually read my essays and recommendations?

These are all legitimate questions, but unfortunately there is no clear-cut answer to any of them. Every college and university reads and evaluates college applications differently, deciding which factors carry the most weight and what type of student best fits their school. But I can tell you the approach I have formulated in my 14+ years as an application evaluator.

I think of this process as a conversation. Once I start reviewing a file, I begin a conversation with the applicant that typically lasts 15 to 20 minutes. I start by examining the high school transcript, standardized test scores, and any academic letters of recommendation, looking for strengths and weaknesses, trends (hopefully upward), course selection, and a myriad of other factors. When I evaluate a high school transcript, I see not just grades and courses, but a four-year record of one student's path through a well-rounded academic curriculum. I consider the decisions the applicant made, how the applicant performed, and ultimately if the applicant met or surpassed expectations.

Then I turn to the standardized test scores. In my analysis, the high school transcript is more important than the test scores, but I look at the test scores to see if they reflect what I would expect a student's standardized performance to be, based on the transcript. If they match, which they typically do, I move on. If they don't, I ask why and then move on. Finally, I analyze the academic letters of recommendation to compile a final academic evaluation of the applicant. My final questions include whether the student measures up to what we expect of Hopkins students and whether the student will make positive contributions to the Hopkins academic community.

Next, I examine the applicant's extracurricular and social experiences. The essays, extracurricular résumé, and letters of recommendation play a vital role as I ask about leadership skills, commitment to community and service, and dedication to specific activities. Does the applicant have passions? What are they, and how does she pursue them? How has the applicant spent his time outside the classroom? What impact has he had on his school, community, society? This analysis tells me how the high school years were spent when not studying and what interesting qualities the applicant brings to the table. Once again I consider past accomplishments while looking at future potential—what contribution will the applicant make to the Hopkins student body?

Finally, I reflect on those intangibles that can determine whether the applicant is a good *fit* for Hopkins. Will the applicant add to the fabric of the institution? Will this student stand out and make a difference?

After this thorough evaluation, I render a decision suggestion: admit, wait list, or deny. Then it is on to the next file. In an application review season, I will review 1,000 to 1,200 files as a first reader. The first reader of an application makes a decision suggestion, not a final decision. Application review will continue with an extensive committee process where multiple staff members evaluate groups of files based on a range of factors including academic interests, diversity, or special interests such as athletics or legacy status. The committee process is when the full admissions staff is shaping the final class. Applications may go through a number of rounds of review before a final decision is rendered.

As you can see, this process is comprehensive. The decisions we make are not based solely on GPAs, SAT scores, etc., but rather reflect the Admissions Committee's determination of which students will best fit and fulfill the promise of Johns Hopkins University.

I hope this sheds some light on how my colleagues and I do our jobs. In the coming months, we will be having "conversations" with each applicant and shaping the Class of 2016 with the best future Hopkins students out there. **i**

This article was excerpted from a longer entry on the Hopkins Insider blog, which offers advice, resources, and behind-the-scenes insights about the undergraduate admissions process at Johns Hopkins University. Learn more at http://blogs.hopkins-interactive.com.

The Students Review series is intended to aid prospective college students in their search by offering insiders' views of selected colleges and universities, as expressed by current undergraduates or recent graduates who have high academic ability. Note that the number of reviewers is small. Consider their personal perspectives as only one factor as you gather information and impressions from many sources.

Reviewers include 48 individuals, who major(ed) in aerospace engineering (1), animal science (1), Asian studies (1), astronomy (1), biological engineering (1), biological sciences (5), biology & society (3), biometry & statistics (1), chemistry (1), computer science (1), ecology & evolutionary biology (1), economics (2), electrical engineering (2), engineering physics (2), English (1), geology (1), government (1), history (3), human development (2), industrial & labor relations (3), math (2), mechanical engineering (6), natural resources policy & management (1), operations research & information engineering (2), physics (2), psychology (4), and sociology (1). The number of majors exceeds 48 because some reviewers completed double majors.

Cornell University

Quality of Academic Instruction for Undergraduates

A unique combination of public and private institutions, Cornell has both state-supported and private colleges and offers a range of undergraduate programs that is hard to match. Each of Cornell's seven undergraduate colleges has its own admissions requirements and core curriculum, although students can take distribution and elective courses across the entire university. Reviewers agree that Cornell has a lot to offer if you choose carefully.

➜ "In general, Cornell offers excellent instruction for undergraduates. Some freshman courses are large (200 students) lectures, but are divided into small groups for labs or recitation sections. In more advanced courses, classes are smaller and more interactive. Some introductory courses are taught by some of the university's best professors, which means that you don't have to major in a field to learn from its best teachers; you just have to do a certain amount of sleuthing to find out who they are and what courses they're teaching."

➜ "Perhaps Cornell's best feature academically is that it has so many very strong departments. Many students change majors in college, and it's wonderful to have the freedom to leave one world-class program and enter an entirely different one without compromising quality."

➜ "The variety of courses available is amazing. An engineering major, I've taken courses in Japanese, German literature, Indonesian music, and science illustration. The core curricula tend to be quite flexible, even in engineering. The facilities and the dozen or so libraries can't be beat. Many organizations provide tutoring; you can always find help if you need it."

➜ "Overall, I've found the quality of instruction to be very high, but I've also had teachers who, while brilliant and widely recognized in their fields, could not teach their way out of a wet paper bag. However, by asking around and sampling classes, you can find creative, effective instructors in nearly every department."

➜ "Despite Cornell's size, I never felt like 'just a number.' I got to know my professors through office hours, being a TA, and doing research. I found the faculty to be very accessible, down-to-earth people who care about how their students are doing."

➜ "You have to work hard. It takes real commitment to major in some departments, where the 'weed-out' courses are very effective. But by the time a course is over, you really feel you've learned something."

Social Life

➜ "The location is beautiful—on a hill overlooking a lake, with forests, botanical gardens, and a gorge with a waterfall (yes!) on campus. It's really a very picturesque setting, and the surrounding area is great for outdoor activities. A nearly infinite number of clubs and extracurriculars exist, although you have to choose carefully—the course load doesn't offer much free time. But even with heavy course loads, Cornell students find time to be activists about nearly everything imaginable."

➜ "Cornell offers everything from raging Greek parties to quiet time. All freshmen live on North Campus in a fun, comfortable community. Sophomores and juniors can choose from a wide variety of dorms on West Campus or may live in one of the fraternity or sorority houses. Most seniors live in Collegetown, a nearby district with coffee shops, restaurants, stores, and a performing arts center. Ithaca is a great college town—hip, socially and politically aware, and extremely multicultural. It's a wonderful place to be a student."

➜ "The specialty dorms play a huge role in campus culture. Risley Hall, the creative and performing arts dorm, has a theater, a recording studio, a darkroom, and a full calendar of cultural programs. The Music house puts on concerts regularly, while the Ecology house seems to perform endless community service functions."

➜ "With hundreds of extracurricular organizations, dozens of intramural sports, and thousands of other students, anyone who is bored just isn't trying very hard."

What Do You Like Best about Cornell?

The vast resources and the beautiful surroundings were most often singled out for praise.

➜ "The choices, the opportunities, the variety. There's so much to choose from—in your major, your courses, your spare time, and your parttime job. And the people here are really cool. You can easily find a niche."

➜ "First, the campus is far and away the most beautiful college campus I've ever seen. The gorges are breathtaking, the lake is beautiful, and there are miles of jogging trails through the woods. To find a place as beautiful as the Cornell campus, you'd be better off looking among national parks than among other universities. Second, the students are good people. Most have an excellent work ethic and are genuinely interested in learning, not just in their GPAs."

➜ "From nanotech to biotech, policy analysis to psychology, you can get involved in important research in any field as early as your freshman year. Professors will often go out of their way to get bright, interested students involved in research. I'm working with a faculty member who helped me design my own project and helped me successfully apply for a grant to support my work."

➜ "Our men's hockey players are supermen-on-ice."

What Do You Like Least about Cornell?

Not much disagreement here: the weather.

➜ "It's *cold*! Ithaca weather bites! Summer is beautiful and so is fall, but winter is miserable and spring doesn't come until May."

➜ "The weather in Ithaca is pretty horrible. The joke at Cornell is that Ezra Cornell told his friends he would found an institution 'where any person can find instruction in any study,' and that he would put it in a beautiful natural setting. His friends said, 'That's the perfect university—you'll have people practically beating down the doors to attend!' So Ezra said, 'Ah, but wait until you see where I put it.'"

Cornell University
Ithaca, NY 14850
www.cornell.edu

- 4-year coed public and private university
- 740-acre campus in upstate New York, on a hill overlooking 42,000-acre Lake Cayuga
- Full-time undergraduate enrollment 2010-2011: ~6,970 men; ~6,970 women
- Special features: Cornell's private colleges are Architecture, Arts & Sciences, Engineering, and Hotel Administration. State-supported colleges are Agriculture & Life Sciences, Human Ecology, and Industrial & Labor Relations. In addition to the campus, Cornell owns 3,000 acres of botanical gardens, arboretum, nature preserves, and trails.

➜ "I like the cold; it's the lack of warm, direct sunlight that bothers me. It can be very dreary to walk 20 minutes (did I mention that the campus is huge?) through dim light to get to class. Not seeing the sun for weeks at a time is a serious drawback."

➜ "The stress level gets pretty high, and big classes that grade on a curve don't help. I hate knowing that I have to do better than a certain percentage of my classmates to get a decent grade, and the extremely high student caliber makes it difficult to get on top of that curve. Despite this stress, students often work together in study groups, and coping with the workload fosters friendships."

Who Would Be Most Compatible with the Academic and Social Atmosphere at Cornell?

➜ "If you are intelligent and curious, enjoy diversity in academics and people, and don't mind snow—*in April*—Cornell could be a good choice for you. If big-city excitement is necessary for your happiness, or if you feel strongly that large lecture classes are not a good learning environment, maybe it isn't. But come look us over. The campus is beautiful, with an incredible mishmash of architectural styles."

➜ "Cornell is a great school, but it is BIG, and you have to actively seek out and choose from among the incredible resources it has to offer. There are countless ways to get involved, but it is important to do so."

➜ "Most anyone who gets in can feel at home. The most important thing is to find something you have a passion for—something that gets you out of bed and up an icy, 45-degree incline at 9:00 in the morning. Without it, classes are just something you have to fight the cold to go to. Once you find it, everything falls into place."

If You Had It to Do Again, Would You Go to Cornell?

Nearly all reviewers enthusiastically said yes.

➜ "Absolutely. I am doubtful whether any other university in America could offer me an undergraduate experience that measures up to the one I had at Cornell. So what if it snows on Easter—I love snow. The people are great and the academics are definitely challenging."

➜ "I loved Cornell. Some people say it's in the middle of nowhere, but honestly, that's half the beauty. It creates a deep and enduring community spirit. Go anywhere, and alumni will gladly help you."

➜ "Yes and no. I'd choose Cornell, but I'd have them put it in a warmer location!" **i**

Note: The reviewers quoted in the Students Review series are expressing their own views, which are not necessarily those of JHU or CTY.

Thank you to all who entered our fourth annual Creative Minds Essay Contest! We are thrilled to announce the winners here. Our Creative Minds Fiction Contest is now open through March 16, 2012. Winners will be announced in the May/June issue. Read submission guidelines and enter online at www.cty.jhu.edu/imagine.

First Place

Exhilaration

by Catherine Wong

Look look, the first words after the gauze came off. I read about this man in a book, blind for forty years; in the dehumanizing clinical style of a case study, the book reduces him to two letters, V.I, and in the interest of privacy strips him of even a name. Four decades of blindness, and then the brain scan, the miracle, one surgery to flip on a switch in the mind and lo, there was light. He reported new sight like a baby's, unfocused and unclear. A beige blur hovers by his hospital bedside, a gash opens in it and there is speech—he realizes that this is a face, his wife. I imagine opening eyes numbed by forty years of darkness into this world awash in colors, everything painted, sounds matched with newfound pictures. There are no laws of perspective, not yet. Every turn of the head brings another universe, all the colors shifting and swirling. The world was one of brightly-colored patterns to be filed away in the mind, by a lifetime of tastes and smells and once imageless sounds. If this were me, I would ask for children's books, candy-colored prints on the cardboard. I would beg for flashcards, photos, movies and paintings and picture windows, even while the world was a mess of blurs, paint spilled all over my vision in great sweeping swaths of color. Never mind *why* the sky is blue, just let it *be* blue.

In this story, there is a window. From his hospital bed this man, the real one, counts cars, colored confetti in his vision, taxis and school buses loud against the backdrop of black city streets. Little things make his breath catch in his throat—a flame dancing in its holder, the infinite illusion of a room in a mirror, the glint of a light on a glass of water, to be looked at once and twice and again. I imagine a room papered with eclectic patterns, stripes next to polka dots, a kaleidoscopic beauty to compensate for forty color-starved years, *look look*.

Maybe the gauze came off too quickly. Maybe the world was like fire on his eyes, every waking moment a dream, joy melting into pain. Within one day, he was tired; within one month, he wandered the halls of his home with his eyes closed, making soft sad moans. The sheer exhaustion of sight, this marvelous dream he had wished for since childhood, overwhelmed him; he had not imagined that vision had rules, that he might have to learn how to see. A cat was a thousand cats—without a mind trained to blend, to recognize that an object seen from every angle is still a single whole, his own pet was unrecognizable, a different image each time when seen from front or behind or the side. Without an understanding of depth, the world became an obstacle course. He reached out a hand to touch houses that were, in reality, miles away; he stumbled into poles on the sidewalk, and he had never been this disoriented, not even when he was blind, and groped his way through the world with his hands.

A few years later, something burst in his brain, the switch flipped back, no surgery to correct it again. Back in his hospital room, family members came sadly to his bedside; the nurses pulled a shade down over the window in mourning, veiling the city streets and the cars he had counted. He was pronounced a tragedy—all his colors gone—and yet peace was restored, the permanent shroud thrown over his eyes, calming. He stumbled back into the world with a brilliant orange and white cane, deliriously happy to be returned to the familiar black cocoon of his blindness.

Catherine Wong, 16, is an 11th grader at Morristown High School in New Jersey. She loves essays and hates editing. She has been recognized for her writing in the Scholastic Art and Writing Awards, and has published in numerous literary magazines as well as on Cogito.org. When not writing, she enjoys solving physics problems and managing the website Better Than Wikinotes.

Second Place

September Bear
by John Daniel Coburn, 17, DE

September Bear sits in my closet smooshed behind an old sleeping bag, a Mexican hat purchased at Epcot Center, Bavarian leather shorts, and ski pants that no longer fit. September Bear reclines in a corner, a solemn soul, a keeper of secrets, a dreamer of dreams, a half-deserted best friend from my past.

Read this essay in its entirety at www.cty.jhu.edu/imagine/creativemindscontest/contestresults.html.

Third Place

Pancakes and Potstickers
by Anais Carell, 16, IL

"*Allium madidum*." My lab partner said the plant name slowly and hesitantly, as if her voice was sliding through glue.

It was my first time working with this student, so a few minutes into biology class—given my racially perplexing appearance of rowdy dark hair and bronze skin—the inevitable question surfaced: "What are you?"

Read this essay in its entirety at www.cty.jhu.edu/imagine/creativemindscontest/contestresults.html.

Honorable Mention

In the Kitchen
by Ann Garth, 14, CA

As Dad works in the kitchen, I work at the table, my pen scratching as the dark creeps in on soft-pawed feet, covering my workspace so gradually that I don't even notice until, with a blink, I look up to find that it has overtaken me. Meanwhile Dad chops, cuts, mixes, and stirs, the tendrils of smell drawing me in like grape vines until I finally have no choice but to walk over and take a bite of whatever he's making. Some days it is mint, as fresh and green as a Christmas tree in winter, or olive oil, collecting on the cutting board with all the color of concentrated sun.

Read this essay in its entirety at www.cty.jhu.edu/imagine/creativemindscontest/contestresults.html.

About our judge:
Elissa Brent Weissman is the author of the novels *Standing for Socks, The Trouble with Mark Hopper,* and *Nerd Camp.* She earned her bachelor's degree in creative writing at Johns Hopkins University and her master's degree in children's literature at Roehampton University. She now teaches Writing for Children at the University of Baltimore and Towson University and runs creative writing workshops for adults, teens, and children. Learn more about Elissa and her writing at www.ebweissman.com.

mark your calendar

ISTOCK

with these February–March registration deadlines for selected academic competitions. View websites for competition format, dates, and fees.

FEBRUARY 1

Davidson Fellows Awards—Students ages 17 and under submit a significant piece of work in science, technology, mathematics, literature, music, philosophy, or "outside the box." ***www.davidsongifted.org/fellows***

Elizabeth Bishop Prizes in Verse, Fiction, and Playwriting—Students in grades 8–11 submit a piece of writing. ***http://thebluepencil.net***

ExploraVision—Teams of students in grades K–12 submit designs for new technology that benefits society. ***www.exploravision.org***

National Peace Essay Contest—Students in grades 9–12 submit an essay on an annual theme. ***www.usip.org/npec***

FEBRUARY 3

Kids Philosophy Slam—Students write, create poetry, music, or artwork about their personal experiences regarding a philosophical question posed each year. ***www.philosophyslam.org***

FEBRUARY 5

Quill and Scroll International Writing and Photo Contest—High schools may submit four entries in each of 12 categories. ***www.uiowa.edu/~quill-sc***

FEBRUARY 6

Christopher Columbus Awards for Community Innovation—Teams of students in grades 6–8 use science and technology to solve real-world problems. ***www.christophercolumbusawards.com***

FEBRUARY 9

Interdisciplinary Contest in Modeling—Teams of high school students participate in this online contest. ***www.comap.com/undergraduate/contests/icm/index.html***

FEBRUARY 14

Manningham Student Poetry Awards—Students in grades 6–12 submit original works of poetry. ***www.nfsps.com/student_awards.htm***

FEBRUARY 22

NCTE Achievement Awards in Writing—English departments nominate high school juniors, who submit prose or verse and write on a timed impromptu theme. ***www.ncte.org/awards/student***

FEBRUARY 28

International Philosophy Olympiad—High school students gather in a different country each May, where they have four hours to write a philosophical essay in a language other than their own. ***www.fisp.org/olympiad.html***

MARCH

Destination ImagiNation—Students in four grade divisions work in teams to solve engineering problems with a range of difficulty. Current problem summaries can be found online. ***www.idodi.org***

MARCH 1

EngineerGirl Survival Design Challenge—Boys and girls in grades 3–12 are given a scenario wherein they are lost and in possession of certain supplies. They write an essay describing how they would deal with one of three challenges. ***www.engineergirl.org***

Jostens Yearbook Photo Contest—Students in grades 6–12 submit photos that tell a story relevant to the middle or upper school experience. ***www.jostens.com/yearbooks/content/files/2012-jostens-photo-contest-entry-form.pdf***

West Point Bridge Design Challenge—Students ages 13 through grade 12 practice engineering skills by building a bridge. ***http://bridgecontest.usma.edu***

MARCH 1–28

National French Contest—French teachers register students in elementary through high school to take this exam offered at five levels. Check website for registration dates. ***www.frenchteachers.org/concours***

MARCH 5

Physics Bowl—Schools register to administer this 45-minute exam to students in grades 9–12. ***www.aapt.org/contests/physicsbowl.cfm***

MARCH 9

Young Naturalist Awards—Students in grades 7–12 undertake explorations in biology, astronomy, or earth science, and write an essay on their findings. ***www.amnh.org/yna***

MARCH 12

National Federation of Press Women High School Communications Contest—Students in grades 9–12 submit work in one of 12 categories. State deadlines vary; see website for details. ***www.nfpw.org/competitions.cfm***

USA Computer Olympiad—The USACO holds six Internet Contests from October through March. Students may register online up to and including the first day of each contest. ***www.usaco.org***

MARCH 15

Trinity College Fire-Fighting Home Robot Contest—Contestants in 8th grade and up build autonomous robots that navigate a model of a house to locate and extinguish a lit candle. ***www.trincoll.edu/events/robot***

MARCH 17

Rube Goldberg International Online Middle School Contest—Teams of students ages 11–14 design and build a machine and submit a video demonstration. ***http://rubegoldberg.com***

MARCH 30

National School Scrabble Championship—Students in grades 4–8 are eligible to compete. ***www.schoolscrabble.com***

LATE MARCH

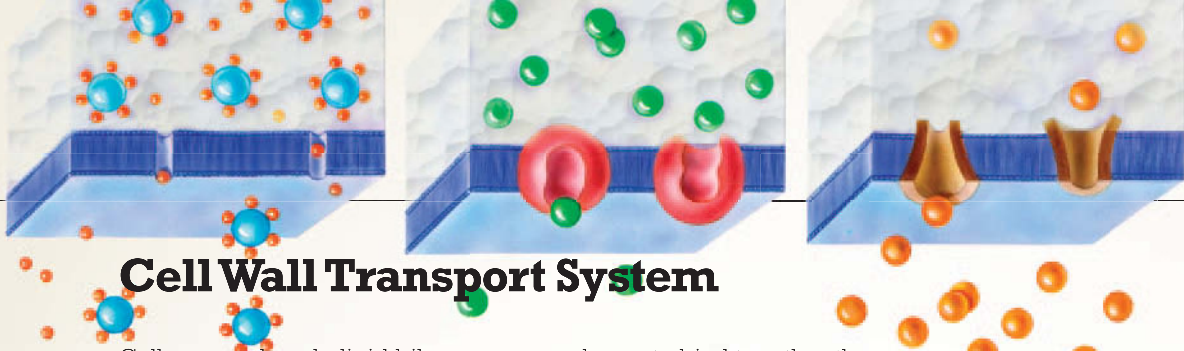
RoboFest—Teams of students in grades 5–12 design, build, and program autonomous robots. ***www.robofest.net***

National History Day—Students in grades 6–12 enter work in one of seven categories. State contest dates vary; see website. ***http://nationalhistoryday.org***

word wise solution

(from page 37)

T	O	P	S	■	■	U	P	S	■	W	E	B
I	S	A	A	C	■	S	U	P	■	H	E	R
F	E	R	M	I	■	A	P	E	■	O	R	E
■	■	■	P	A	L	■	A	C	A	R	I	D
D	I	P	L	O	I	D	■	I	S	L	E	■
N	O	S	E	■	N	O	B	E	L	■	■	■
A	N	T	■	A	D	I	O	S	■	F	E	D
■	■	■	B	E	A	N	S	■	A	B	L	Y
■	B	E	E	R	■	G	O	D	L	I	K	E
M	I	N	N	O	W	■	M	A	L	■	■	■
E	O	S	■	B	A	T	■	T	E	E	N	Y
E	M	U	■	I	R	E	■	A	L	G	A	E
T	E	E	■	C	P	A	■	■	E	G	G	S



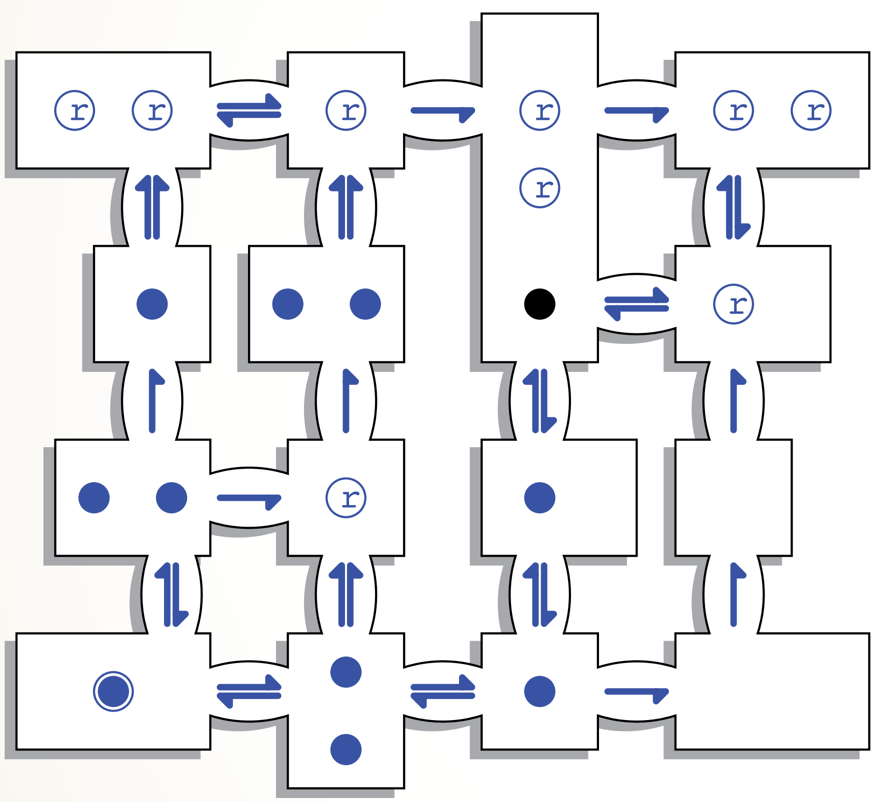
Cell Wall Transport System

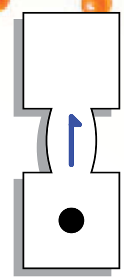
by Tim Boester

Cells use a phospholipid bilayer as a membrane to bind together the contents of the cell. In order to transport substances into and out of the cell, proteins serve as doors in the cell membrane.

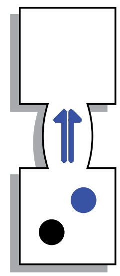
The goal: By moving the black ball, maneuver all the blue balls (objects) into the blue circles (receptors).

The rules: You control the black ball. In order to move around the cellular maze, you must use the cell wall transport proteins (arrows). Like their real-life counterparts, these transporters facilitate movement of objects according to certain rules:

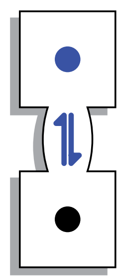




Uniport proteins allow only one-way movement of an object. In the puzzle, these will serve as one-way doors for the black ball.



Symport proteins allow an object to pass only when it is accompanied by a partner. You can move the black ball through a symporter only if a blue ball moves with you.



Antiport proteins allow one object to enter the cell only if another leaves. You can move the black ball through an antiporter only if there is a blue ball on the other side to switch places with you.

Remember, the blue balls can only move in conjunction with the black ball; they cannot move alone. The receptors (the blue circles) cannot move. The puzzle is complete only once all of the receptors are filled by one object each.

Solution to Knossos Games 19.2

Entry to altar, gateways begin closed:

E – E (O) – N (C) – S – S (O) – S (C) – S (O) – N – E – E (C) – E – S – E (O) – W – N – N (C) – W (O) – N (C) – N – N (O) – E (C) – N (O) – E (C) – W – S (O) – S (C) – E (O) – S (C) – E (O).

Altar to exit, gateways currently open:

W – S – W (C) – W (O) – N (C) – N – N (O) – E (C) – N (O) – E (C) – W – S (O) – W (C) – W (O) – W (C) – N (O) – S – S – S – W (C) – W.

Tim Boester is an Assistant Professor in Mathematics Education at Wright State University. You can find more puzzles on his website at homepage.mac.com/boester.

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**In the year of 1657
I discovered very small
living creatures in rain water.**

—Antonie van Leeuwenhoek