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20 Best Brains Under 40

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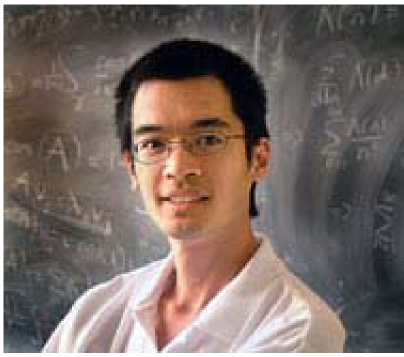
Young innovators are changing everything from theoretical mathematics to cancer therapy.

by Andrew Grant, Sarah Webb, Emily Anthes, Yudhijit Bhattacharjee, Jullianne Pepitone, Elizabeth Svoboda


Terence Tao
Photo: UCLA

Terence Tao
Mathematician, University of California Los Angeles

Many of the great mathematicians of our era probably scored a perfect 800 on the math section of their SATs. Terence Tao squeaked by with a 760—when he was 8 years old.

A quarter century later, Tao, now 33, is one of the most prolific and esteemed mathematicians in the nation. In 1999 he became UCLA's youngest professor at age 24 and later won the 2006 Fields Medal, considered the Nobel Prize of math. In a discipline where one can spend a lifetime working on a single problem, Tao has made major contributions in a number of categories ranging from nonlinear equations to number theory—which explains why colleagues continually seek his guidance.

"In every generation of mathematicians, there are a few at the very top," says Charles Fefferman of Princeton University, a mathematical giant in his own right. "He belongs in that group."

Tao's best-known research involves patterns of prime numbers (numbers divisible only by one and themselves). While he mainly sticks to the theoretical, his breakthrough work in compressed sensing is allowing engineers to develop sharper, more efficient imaging technology for MRIs, astronomical instruments, and digital cameras.

"Research sometimes feels like an ongoing TV series in which some amazing revelations have already been made, but there are still plenty of cliff-hangers and unresolved plotlines that you want to see resolved," Tao says. "But unlike TV, we have to do the work ourselves to figure out what happens next."

Tao says there are big puzzles he'd love to solve, but the only way to reach that point is by chipping away at smaller, more manageable problems. "If there is something that I should know how to do but don't, it bugs me," he says. "I feel like I have to sit down and work out exactly what the problem is." *—Andrew Grant*

Jeffrey Bode
Organic Chemist, University of Pennsylvania

Organic chemists don't have many ways to stitch complicated molecules together, says Jeffrey Bode, 34, who has discovered a new method that could prove a boon for producing expensive peptide-based drugs such as insulin and human growth hormone. Many organic chemists had thought the established methods for building these proteins—adding individual amino acids like beads on a string—worked pretty well, Bode says. "That is true as long as you want to make relatively short ones or you want to make only small amounts of them." As the strands get longer, if an individual bead doesn't make it onto the peptide string, it becomes harder to separate those mistakes from the correct sequence.

To remedy this, Bode discovered a new chemical reaction that creates amide bonds (a reaction between alpha-keto acid and hydroxylamine), which he uses to connect small, easily synthesized peptides—strands of amino acids—into longer peptides. Bode notes that in organic chemistry, "it's possible to come up with a way of doing something that is perhaps better and more elegant and more efficient than what's already out there." —*Sarah Webb*


Arctic ecologist Katey Walter in the field.
Photo: Dmitri Drakluk

Katey Walter
Ecologist, University of Alaska

Examining the effect of greenhouse gases on local ecology and global climate keeps Katey Walter, 32, chasing the methane that bubbles up from seeps in Arctic lakes. As temperatures warm, the Arctic permafrost thaws and pools into lakes, where bacteria feast on its carbon-rich material—much of it animal remains, food, and feces from before the Ice Age—and churn out methane, a heat trapper 25 times more potent than carbon dioxide. More methane leads to warmer temperatures and even more thawing permafrost.

"That means you're opening the freezer door and you're going to defrost everything that's there," Walter says. In Alaska and eastern Siberia, she and her colleagues are cataloging the Arctic freezer's carbon contents, trying to understand how much will be converted to methane as the ice melts. In 2006 she and her team discovered that nearly five times as much of the gas was being released as previously reported. —*S. W.*

Amy Wagers
Stem Cell Biologist, Harvard Stem Cell institute

Amy Wagers was finishing her doctoral degree in immunology in 1999 when she got a call from the National Bone Marrow Registry. Having volunteered to donate her bone marrow years earlier, there was now someone who needed it. Wagers was inspired to research bone marrow stem cells and did her postdoctoral work on adult stem cells.

Today Wagers, 35, is a leading researcher of adult stem cells—those that generate blood and muscle. She works to isolate populations of these cells, discover how the body regulates them, and understand how they can be used to treat disease. Her research is identifying how blood cells migrate between blood and bone marrow and how they multiply. The work could help make marrow transplants more effective by improving the survival of transplanted cells.

This summer Wagers published research [subscription required] showing that when muscle stem cells were transferred into mice with a type of muscular dystrophy, the rodents' muscle function improved. "They started immediately to produce new muscle fibers," Wagers says. "There's obviously a long way to go to translate those findings into humans, but it's encouraging." —*Emily Anthes*

Joseph Teran &em; his mathematical modeling helps train surgeons.
Photo: Reed Hutchinson

Joseph Teran
Mathematician, UCLA

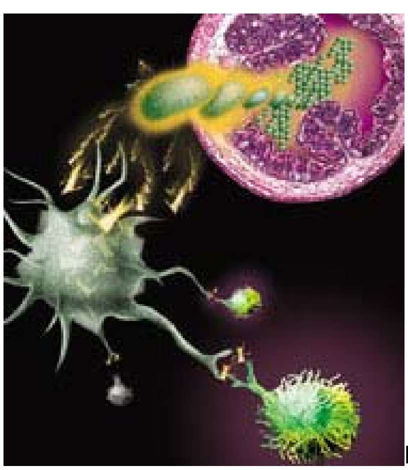
Imagine knowing, before you go under the knife, not only that your surgeon has performed the procedure hundreds of times before but that he has practiced on a replica of you. Joseph Teran, 31, is helping make this scenario a reality, using mathematical modeling to simulate surgeries involving a patients' tendons, muscles, fat, and skin. "We have governing mathematical equations for how those tissues operate," Teran says. The first step is to turn those equations into a standard digital human that can react, in real time, to a surgeon's virtual actions.

Then the idea is to allow doctors to customize this tool. In the future, medical imaging such as CT and MRI could reveal that one patient, for instance, has tendons that are stiffer than average, allowing the doctor to adjust the "digital double" [pdf] accordingly. "You want it to be as close to the real experience as possible," Teran says. —*E. A.*

Jack Harris
Applied Physicist, Yale University

Quantum mechanics describes a crazy microscopic world where particles whiz around at blistering speeds and routinely violate the classical laws of physics we take for granted. Jack Harris's goal is to take advantage of the "really strange, even mystical" laws of the microscopic and apply them to problems in our macroscopic world. "The ultimate eureka moment would be to suddenly realize that a [macroscopic] object is doing something that is absolutely forbidden by classical physics," he says.

Harris, 36, studies the minuscule pressures exerted by individual photons (electromagnetic particles) when they bounce off small, flexible mirrors. To illustrate the scale of these pressures, consider that on a clear day, the sun's rays push against your body with only a millionth of a pound of force. Harris wants to harness light photon by photon, which could lead to unbreakable cryptography and ultrasensitive astronomical instruments able to detect invisible phenomena created nanoseconds after the Big Bang. —*A. G.*

Beneficial gut bacteria that help the immune

system, studied by Sarkis Mazmanian,
Image: Sarkis Mazmanian

Sarkis Mazmanian
Biologist, California Institute of Technology

Of the 100 trillion bacteria living inside the human gut, some are pathogens that can trigger disease and vicious immune responses, while many work with the immune system to protect the host. Sarkis Mazmanian, 35, devotes himself to understanding how the good ones promote health. “They couldn’t care less about us except that we provide them a stable and nutrient-rich habitat,” says Mazmanian, who sees this symbiotic relationship between the human body and microbes as a gold mine of potential therapies for a number of illnesses.

Mazmanian believes the interaction between the body and intestinal bacteria might hold the key, for example, to how an abnormal immune response to these microbes may be responsible for the development of colon cancer. “The potential of beneficial microbes appears to be limitless,” he says. Mazmanian says the philosophy that underpins his research is that “anything is possible in the natural world. Therefore, I am willing to entertain any possible cause of or outcome to a scientific problem.” *—Yudhijit Bhattacharjee*

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Doug Natelson
Condensed-Matter Physicist, Rice University

Doug Natelson, 37, is the Benjamin Franklin of the microscopic world: He studies electronic properties at the atomic scale, where the overlap of classical and quantum physics gains importance. Natelson’s research involves complicated electron flow through single-molecule transistors, as well as organic semiconductors—carbon-based materials that are intended to replace silicon transistors in some electronic devices. This burgeoning technology holds the promise of making thin, ?flexible organic electronic devices a reality.

Unlike those who focus on the very large aspects of physics (superenergetic particle accelerators and massive black holes, for instance), Natelson is an evangelist for condensed matter and nanoscale, sharing his excitement on his popular blog (www.nanoscale.blogspot.com). “I’m an experimentalist at heart, playing with these fancy toys,” he says. “It’s a lot of fun to learn how to get down and really work at these scales.” *—A. G.*

Michael Elowitz
Biologist, Caltech

In 2000 Michael Elowitz, now 38, designed a genetic circuit that made E. coli blink in a culture dish. It was a huge moment, he says, recalling the cells’ behaving like fluorescent green Christmas lights. But the experiment was also a fortunate failure. Although the cells blinked, they did so at different rates. That variability among cells containing the same program kicked off a whole new line of experiments that Elowitz says are focused on “what it is that is making different cells do different things.”

Today Elowitz is examining the mechanisms by which genetically identical cells exploit and control random fluctuations in their own biochemical components in order to generate cell-type diversity. “Understanding the role of ‘noisy’ fluctuations can help us understand how bacteria diversify to survive,” Elowitz says, “as well as how cells specialize to build multicellular organisms.” *—S. W.*

Changhuei Yang
Electrical and Bioengineer, Caltech

As the performance ability of microscopes has increased, so has their size and cost—and that has had an impact on research. “There’s a mismatch between what those microscope systems can do and what some of the basic needs are,” says Changhuei Yang, 36.

By combining chip technology and microfluidics, Yang has created an inexpensive miniature microscope. About the size of “a hair on a bumblebee,” he says, with a circuit the size of a dime, it contains no optical lenses and works by allowing a small volume of fluid to flow across a microchip, which then sends images of the sample to a computer.

The microscopes can be built into a small handheld display—a device about the size of an iPod. Yang imagines physicians in the developing world using this tool to examine patients' blood or the local water supply. "It would be a very rugged system that the clinician can just put into his pocket," he says. —*E. A.*


Adam Reiss showed that the universe's expansion is accelerating.
Photo: Monica Lopossay/Baltimore Sin

Adam Riess
Astrophysicist, Johns Hopkins University

Adam Riess turned astronomy on its head when he led a team of astronomers (the High-z Team) that discovered the expansion of the universe is actually speeding up. Scientists had accepted cosmic expansion since 1929, and prior to 1998 they assumed gravitational attraction would gradually bring it to a halt. But when Riess, 38, tried to use the data he uncovered from observing distant stellar explosions to reinforce this model, the numbers wouldn't jibe. A few days later, he proved that his data made sense only in an accelerating universe.

The finding showed that an overwhelming repulsive force—fueled by a mysterious dark energy that makes up 72 percent of the universe—overcomes gravity to drive this cosmic acceleration. "It's like throwing a ball up in the air and it keeps going up," he says. Now armed with a $500,000 MacArthur fellowship he won in September, Riess is determined to uncover the secrets of this dark energy and its influence on the universe. —*A. G.*

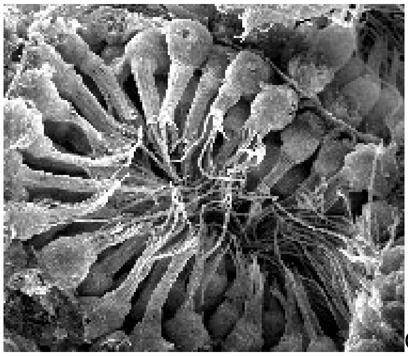
Choanocytes, the feeding cells of sponges, are part of Nicole King's study of early evolution.

Photo: Scott Nichols

Nicole King
Molecular and Cell Biologist, University of California at Berkeley

Nicole King, 38, is hunting for an answer to how the evolutionary leap occurred from single-celled organisms to plants, fungi, multicelled animals, and other forms of life. To find clues, she has trained her sights on choanoflagellates—a group of single-celled eukaryotes thought to be the closest living relatives of animals.

Sequencing the genome of one such organism, King and her colleagues found genes that code for pieces of the same proteins used for the binding of cells and communication between cells in animals —functions that would be unexpected in such an organism. King hypothesizes that proteins that the single-celled ancestors of animals used to interact with the extracellular environment—to capture bacterial prey by binding to their cell surface and to detect chemical signals—were later repurposed to enable cells to stick to and talk to each other. Interpreting the origins of multicellularity is key to understanding the origins of animals, King says, noting that her research "reaches back much further on the family tree than our common ancestors with other primates." *—Y. B.*

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Luis von Ahn
Computer Scientist, Carnegie Mellon University

Luis von Ahn, 30, has left his mark all over the Internet. When you buy tickets online and are asked to decipher an image of distorted words—that's the work of von Ahn. He helped develop this antispamming technology, known as CAPTCHA (Completely Automated Public Turing Test to Tell Computers and Humans Apart), in 2000. CAPTCHA works because it is solvable by man but not by machine. Still, von Ahn's ultimate goal is not to outwit computers; instead, he wants to exploit man's unique intelligence to eliminate the machine's shortcomings—while completing some useful tasks along the way.

One vehicle to close such an intelligence gap is reCAPTCHA. Each day it utilizes about 18 million computer users—perhaps ticket buyers—to key in words from scanned pages of text in order to digitize them, words that a computer is not yet able to recognize. (By next year researchers expect to finish digitizing *The New York Times* archive dating back to the 1850s.) Von Ahn also programs games with a purpose: The more you play, the more data you provide toward helping computers recognize images. "I don't think we've even scratched the surface of what we can do," he says. *—A. G.*

Tapio Schneider
Environmental Scientist, Caltech

The complex interactions of atmospheric turbulence and heat transport affect global climate. Tapio Schneider, 36, has developed computer simulations to better understand how. "Ideally, I'd like to build myself a climate in a laboratory," he says, "but we can't do that with a planet, so computers are the next best thing."

In a developing project, he recently used a model planet to show that monsoons can form even in shallow water like a swamp. Therefore Halley's traditional model for monsoons—that the different heat capacities of land and ocean surfaces cause these seasonal deluges—doesn't give a full picture. The movement of water vapor through climate systems remains poorly understood, Schneider says. "That's one set of questions that I will be working on for many years."

Schneider's goal is to build a set of fundamental laws of physics for climate. "The laws of thermodynamics give a macroscopic description of microscopic behavior," he says. "I would like to have something analogous for climate." *—S. W.*


Astrophysicist Sara Seager is looking for signs of distant life.
Photo: Len Rubenstein

Sara Seager
Astrophysicist, Massachusetts Institute of Technology

As questions swirled around the existence of extrasolar planets in the late 1990s, Sara Seager, 36, gambled that these distant flickers transiting in front of stars would grow into astronomy's next frontier. The bet paid off: Her theoretical models of the chemistry of extrasolar planets have helped researchers make the first atmospheric measurements of a distant world. Seager expects that we'll find a cousin to Earth in the next couple of years, but her ultimate goals are grander. "What I really want to do is figure out which kinds of gases extraterrestrial life might produce," she says. "These gases would accumulate in the atmosphere and might be detectable from afar." As a step in that direction, she's looking for signatures, other than oxygen-based ones, that Earth-like life might leave behind, such as hydrogen sulfide.

During Seager's childhood in Canada, her father exposed her to a variety of ideas—including that of a stargazing party. "Having that time to daydream," she says, "was so crucial to making me a good scientist." *—S. W.*


Computer scientist Jon Kleinberg revolutionized Web searching.
Photo: Jason Koski/Cornell

Jon Kleinberg
Computer Scientist, Cornell University

In the mid-1990s a Web search for, say, "DISCOVER magazine" meant wading through thousands of results presented in a very imperfect order. Then, in 1996, 24-year-old Jon Kleinberg developed an algorithm that revolutionized Web search. That is why today, that same search lists this magazine's home page first. Kleinberg, now 37, created the Hyperlink-Induced Topic Search algorithm, which estimates a Web page's value in both authority (quality of content and endorsement by other pages) and hub (whether it links to good pages).

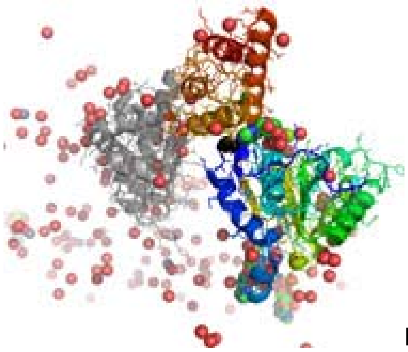
Kleinberg continues to combine computer science, data analysis, and sociological research to help create better tools that link social networking sites. He envisions an increase in how we can see information move through space over time, in what he calls geographic hot spots on the Web, based on the interests of a particular region.

Our social network links and friendships depend on these geographic hot spots, Kleinberg says, which makes searching easier by "taking into account not just who and when, but where." He is now studying how word-of-mouth phenomena like fads and rumors flow through groups of people, hoping to apply this knowledge to processes such as political mobilization. *—Julianne Pepitone*

Edward Boyden
Neuroengineer, MIT Media Lab

Certain species of bacteria and algae have genes that allow them to transform light into electrical energy. Edward Boyden, 29, has been able to show that inserting one of these genes into a neuron can make it similarly responsive. "When we illuminate these cells...we can cause them to be activated," he says.

Having created such genetically modified neurons, Boyden is engineering brain implants that can stimulate them with light pulses. Boyden's implants, he hopes, will be used to help control diseases like Parkinson's, which is sometimes treated with implanted stimulators that issue electric current. "There are things that light can do that purely electric stimulators can't," Boyden says. With this technology, researchers can be selective about which neurons they engineer to be responsive, and an optical implant can emit light in a variety of patterns, allowing more precise control over neural circuits. *—E. A.*



Protein structures help biologist Richard Bonneau map how organisms work.
Image: Richard Bonneau

Richard Bonneau
Systems Biologist, New York University

Chronicling the parts of cell anatomy class-style is all well and good, says Richard Bonneau, 33, but biologists' true holy grail is understanding how each part dictates the function of the others. "You might know that A is related to B, but if you don't have a dynamic picture of your system, you don't know which part is affecting which," he says. "I want to put the arrows on the lines, so to speak."

By tracking activity in almost all the genes of a free-living archaeon—which, like a bacterium, is a prokaryote—Bonneau was recently able to piece together how the genes affected one another's expression, enabling him to map the organism's "control circuit" as if it were a machine. In the process, he found something surprising: Instead of generating completely different responses to external stimuli like light and toxic chemicals, "the archaeon takes those environmental stimuli and puts them into the same integrator," he says. "There's not an infinite number of responses." Knowing the limited range of behaviors that microorganisms display, he adds, will prove a big help in engineering them to churn out drugs and biofuels. —*Elizabeth Svoboda*

Shawn Frayne
Inventor, Humdinger Wind Energy

Shawn Frayne, 27, has a knack for creating simple technological solutions that make a difference for people in developing nations. He was part of the team that introduced sugarcane-based charcoal as a cheap cooking fuel, and his solar disinfecting plastic bags purify water for drinking.

It is his Windbelt, though, that may have the most impact. Inspired by the dynamics of the 1940 collapse of the Tacoma Narrows Bridge, Frayne spent four years developing the world's first turbineless wind generator. When the wind blows, it causes a flap of Mylar-coated taffeta fabric to vibrate rapidly, moving magnets fitted on either end past coils to generate electricity. In the developing world, the 10 watts it produces can light a room at night by electricity rather than expensive and dangerous kerosene.

By selling intellectual property rights for his inventions to big companies, Frayne hopes to fund more innovative projects for developing nations. "That is where the biggest challenges are, and it's where I think most of the invention and innovation are going to come from in my lifetime," he says. "It would be crazy to work anywhere else." —*A. G.*

Jonathan Pritchard
Geneticist, University of Chicago/Howard Hughes Medical Institute

It's easy to think of evolution as something that happened millions of years ago, but Jonathan Pritchard, 37, has proved we're actually adapting to our environment in real time. Using statistical models to home in on genetic mutations that spread quickly throughout populations, Pritchard and his colleagues have identified hundreds of regions of the genome that have recently been transformed by natural selection. "If a new mutation arose in a certain population and it was strongly favored, natural selection would drive the frequency of that allele up very quickly," he says. "Most of the time there are only small frequency differences between human groups, so when there are big frequency differences, they really stand out." —*E. S.*