
JOURNAL USA
science
The New Frontier

U.S. DEPARTMENT OF STATE
VOLUME 17 / NUMBER 3
Published January 2013

The Bureau of International Information Programs of the U.S. Department of State publishes *eJournal USA*. Each issue examines a major topic facing the United States and the international community, and informs international readers about U.S. society, values, thought, and institutions.

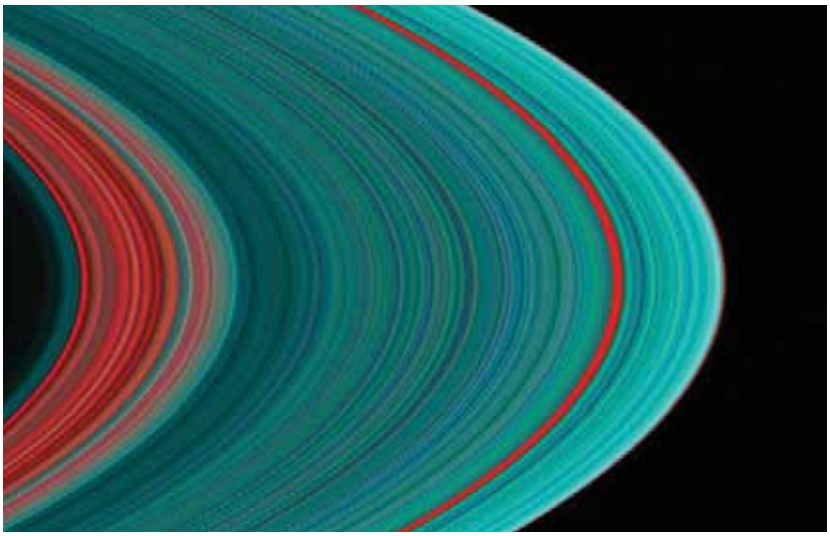
Each *eJournal* is published in English, followed by electronic versions in French, Portuguese, Russian and Spanish. Selected editions also appear in Arabic, Chinese and Persian. Each journal is catalogued by volume and number.

Editor, *eJournal USA*
IIP/CD/WC
U.S. Department of State
2200 C Street, NW
Washington, DC 20522-0501
USA
E-mail: eJournalUSA@state.gov

Cover image: An artist's depiction of nerve cells and virus molecules: ©Giovanni Cancemi/Shutterstock.com

"What's Best about Science?" portrait photos courtesy of authors.

About This Issue



Rings around Saturn as viewed from the Cassini spacecraft in July 2004.

"Somewhere, something incredible is waiting to be known."

— Carl Sagan, American astronomer (1934–1996)

Learning about "something incredible" through science is one of the greatest things about being a scientist. And scientists appreciate that about their profession. As one says in this issue, science "provides an infinite source of challenging problems to fit every taste and passion, and it inspires us to work hard to understand our world."

Unlocking the mysteries of nature has always been at the heart of science, but scientists today enjoy unparalleled opportunities to leverage technology in solving challenging problems. However, the increased use of ever-more sophisticated technology comes with a price tag. Scientific research now requires bigger teams, more money and more international cooperation. And it demands years of interdisciplinary study and collaboration by young scientists.

This issue of *eJournal USA* explores how science is conducted in the 21st century: how the Internet and other technologies are helping shape both the questions pursued by scientists and the ways in which scientists interact and share new knowledge. It also highlights some of the remarkable progress already achieved by younger scientists in understanding the genesis of disease, our place in the universe and the circuitry of the brain. Their scientific pursuits expand the horizons of human knowledge and hold promise for improving the lives of people today and far into the future.

— *The Editors*

Contents

QUICK READ

DEPARTMENTS

THE BIG THINK

MORE

FRESH IDEAS

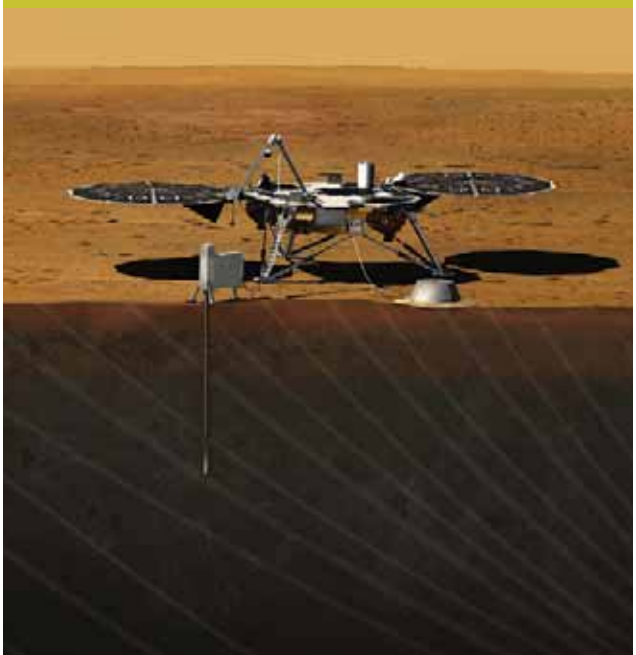
Fuel Science's Future

Tom Siegfried

©AP Images/Martial Trezzini

©AP Images/Tony Ding

©AP Images/Scott Muthersbaugh



©AP Images

From left (clockwise): The Large Hadron Collider: A big piece of equipment for big science. | All things nano: A nanotechnology lab at the University of Michigan at Ann Arbor. | An artist's rendition of the NASA Mars Lander designed to explore the Martian core. | Science is fun, even in high school.

Making big discoveries in science is like climbing Mount Everest. The higher you go, the tougher the challenge — and the more you rely on your climbing partner.

A century ago, Ernest Rutherford discovered the **atomic nucleus** with data collected by two assistants using an apparatus that fit on a table top. In recent years, a team of several thousand scientists from more than three dozen countries at the Large Hadron Collider (LHC), a particle accelerator, used house-sized detectors weighing thousands of tons to locate a new **subatomic particle** believed to be the **Higgs boson**.

See definitions of highlighted words at the ends of articles and on page 24.

If confirmed, this would be a step forward in realizing Albert Einstein's dream of unifying all physical laws in a single equation.

It's no surprise that big scientific discoveries are harder to make now. The German physicist Max Planck noted that a "new truth" is always found only with great difficulty: "If it were not so, it would have been discovered much sooner." And Planck made that observation almost nine decades ago. So revealing nature's remaining secrets won't be easy. And there are still many riddles to be unraveled.

Cooperation, Tools to Tackle Challenges

For all the achievements of modern science, countless enigmas continue to perplex experts in almost every research field. Astronomers and physicists, for instance, are challenged to understand **"dark matter,"** an exotic type of matter unknown on Earth, and **"dark energy,"** which drives the universe to expand at a faster and faster rate. Earth scientists are trying to discover ways to predict when big earthquakes will strike. Scientists studying the brain are trying to figure out the secrets of consciousness and how it arises from the chemical and electrical signals among billions of brain **cells.** And biologists investigating **DNA** seek to understand the relationship of **genes** to various diseases. Exploring these mysteries requires bigger teams, ever-more sophisticated (and costly) technologies, greater international cooperation — and, most important, a new generation of scientists with fresh ideas.

Advances in technology allow researchers to leverage their efforts and make progress on scientific problems. Better brain scanners allow us to map the brain's inner workings more precisely. New particle accelerators, successors to the LHC, will be needed to probe the properties of matter more deeply. Scientists may use **nanoparticles** to build tiny machinery to treat diseases in the brain and other parts of the body. Researchers in the new field of synthetic biology are figuring out how to build new versions of biological **molecules.**

You have to aim high to make it in science.

©AP Images/Scott Muthersbaugh

New Thinking to "Open Science"

While new devices may give rise to some solutions, new ways of thinking continue to be key to scientific advances. New fields of mathematics are a case in point. Recently developed insight into the math governing networks, for instance, aids the analysis of complex combinations of cells, or genes, or even people interacting via social media. Such novel mathematical methods may result in a better understanding of epidemics, the brain, the weather, or even social movements.

But all the potential progress will not happen by magic. Educational systems around the world need to be retooled to emphasize 21st-century questions and methods. Science should not be taught in compartments, a single discipline at a time, but must be learned in a way that breaks down disciplinary barriers that impede progress.

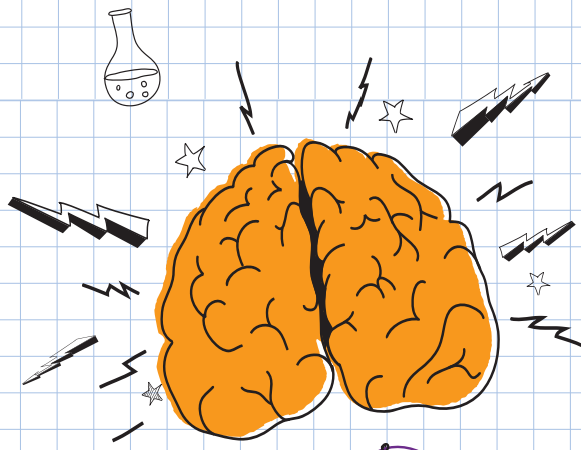
Other barriers must fall, too. Science has always valued international cooperation, but now more than ever the world needs to muster all its human resources, from all nations and cultures, to tackle the great scientific mysteries of the day.

For one thing, international cooperation makes it possible to fund large scientific projects too costly for any one nation. Cooperation also aids scientists in finding researchers with similar interests or valuable data that might not otherwise be available. And the scientific process itself is enhanced: "Scientists … report that working with foreign-trained researchers gives them new insights into how to

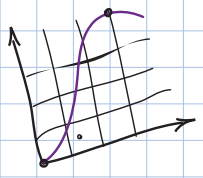
> "A new scientific truth does not triumph by convincing its opponents and making them see the light, but rather its opponents eventually die, and a new generation grows up that is familiar with it."
>
> — Max Planck, physicist, 1858–1947

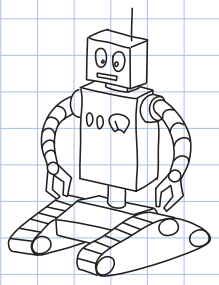
what do Americans think about science?

Most Americans (84%) **believe science has had a positive effect on society** and has made life easier for most people.



Americans rank scientists as the third group — after members of the military and teachers — that **contributes the most to society's well-being**.





Most Americans (60%) say that government investments in science, engineering and technology **pay off in the long run.**

Source: *2009 survey by Pew Research Center and American Association for the Advancement of Science*

Illustrations ©Roman Malyshev/Shutterstock.com

think about science," a 2002 RAND report stated. "Science is about creativity; these linkages enhance creative thinking."

So some of the tools needed to make progress will not be new versions of microscopes or telescopes or atom smashers, but new systems for enhancing communication and cooperation.

Already the "open science" movement has begun to catalyze the sharing of scientific information outside of the usual method of publishing only in peer-reviewed scientific journals. Publication in "open access" journals, where papers are freely available, is on the rise. In 2011 an estimated 340,000 articles were published in more than 6,000 open access journals. And online efforts such as ResearchGate are now allowing scientists to share their findings and data freely.

"These tools are … actively amplifying our collective intelligence, making us smarter and so better able to solve the toughest scientific problems."

— Michael Nielsen, physicist, *Reinventing Discovery*, 2011

Online tools for communicating and collaborating "are transforming the way scientists make discoveries," physicist Michael Nielsen notes in his 2011 book *Reinventing Discovery*. "These tools are … actively amplifying our collective intelligence, making us smarter and so better able to solve the toughest scientific problems."

As Planck noted, science is "a progressive development," not a "repose amidst knowledge already gained." Science is not a static body of facts collected in books. It's a voyage of exploration of worlds still unknown. In order to advance, it must welcome new explorers. With its transparency and spirit of sharing information with all who are interested, the open science movement offers an inviting environment for all of those new explorers, facilitating the ascent to new scientific heights. ■

Tom Siegfried is a science freelance writer and former editor-in-chief of Science News *magazine.*

Glossary of Terms

Atomic nucleus: The central core of an atom composed of protons and neutrons.

Subatomic particle: Any unit of matter below the size of an atom.

Higgs boson: A hypothetical elementary particle that has zero spin and large mass and is required by some theories to account for the masses of other elementary particles.

Dark matter: Nonluminous matter that cannot be directly observed, but whose existence is suggested because of the gravitational pull it exerts on the rotation rate of galaxies and the presence of clusters of galaxies.

Dark energy: A hypothetical form of energy that produces a force that opposes gravity and is thought to be the cause of the accelerating expansion of the universe.

Cell: An autonomous self-replicating unit that is specialized into carrying out particular functions in the organism.

DNA: Deoxyribonucleic acid, a nucleic acid located in the cell nucleus that carries hereditary genetic information for cell growth, division and function.

Gene: The fundamental, physical and functional unit of heredity made of DNA and containing instructions for making protein molecules.

Nanoparticle: A microscopic particle whose size is measured in nanometers (nm), typically less than 100nm.

Molecule: A group of atoms bonded together.

The opinions expressed in this article do not necessarily reflect the views or policies of the U.S. government.

Open Science on the Web

Ijad Madisch is the founder of ResearchGate, a social network that allows scientists to share data and collaborate. Established in 2008 and headquartered in Berlin, ResearchGate.net has some 2 million users from more than 190 countries.

©ResearchGate/Andy Kaczé

You had a promising career in virology. Why did you decide to shift gears and launch a social network for scientists?

Because I saw big problems in scientific communication. I realized that we scientists don't share data efficiently. Much raw research data or inconsistent or bad results are not published, preventing scientists from making faster progress. If I fix this, I thought, I will help advance science at a much faster pace.

How does sharing research data improve and accelerate scientific discovery?

Much of scientific research ends up in failed experiments. You use data from failed experiments to come up with a different approach and try again. But so far this type of data has rarely been published. This has prevented other scientists working on similar projects from avoiding the same mistakes. In addition, many scientists don't know who to turn to when they have a research question.

That's why we need a platform like ResearchGate where scientists can exchange data and know-how.

I understand your users are mostly young scientists. Why is that?

When I told my 62-year-old professor in Germany that I wanted to share my time between my research job and ResearchGate, he told me: stop thinking about this nonsense, scientists are not social. Several months ago this professor signed up with ResearchGate. So it takes time for the older generation to catch up. But the new generation of scientists brought up on social media and open science is already moving into labs. Most scientists on ResearchGate are between 27 and 32 years old.

"If I fix this, I thought, I will help advance science at a much faster pace."

ResearchGate challenges the traditional model of scientific research — a scientist does research, submits results for peer review and then publishes paper in an established scientific journal. What's wrong with that model?

That model was developed when there was no Internet and huge amounts of data generated by computers. Today it doesn't work that well. It is not transparent and doesn't allow for checking and discussing reproducibility of results. On average, it takes about 6 to 12 months to publish an article in a science journal. Using the Web, we can open up and speed up the publication process. ResearchGate is a path to a better process.

But as a scientist you need to have a number of published papers to advance your career. How can ResearchGate help in this respect?

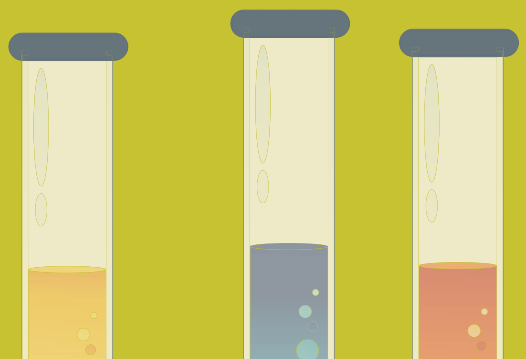
We recently launched our own scoring system to measure scientific reputation. The score represents the usefulness and quality of an individual scientist's publications, datasets and discussions. For example, if you upload a dataset from a failed experiment and it helps two or three other scientists, you boost your score. For now, it is designed to work alongside the established process, but my vision is that in several years scientists will be applying for jobs or grants based on scores from ResearchGate rather than on publications in science journals.

©RAStudio/Shutterstock.com

How do you convince labs, academia and governments to accept your scoring system?

It will take time, but ResearchGate and similar sites are growing. In the last two years, the number of publications uploaded to ResearchGate has gone up exponentially. It's becoming difficult to ignore us. ■

Hypothesis — A proposition made as a basis for reasoning, without any assumption of its truth.



how a scientist arrives at a DISCOVERY

1. Asks a question.

Does background research (a lot of reading and talking to other scientists) and thinks about the question.

2. Formulates a hypothesis.

3. Designs an experiment to test the hypothesis.

4. Tests the hypothesis.

5. Collects and analyzes experimental data.

6. Comes to conclusions based on data.

7. Evaluates the hypothesis and decides whether the data supports or refutes the hypothesis.

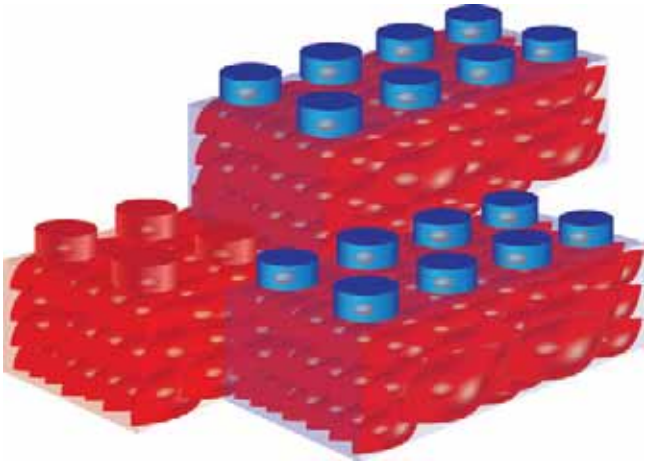
Revises the refuted hypothesis (likely to conduct more experiments and repeat the above process).

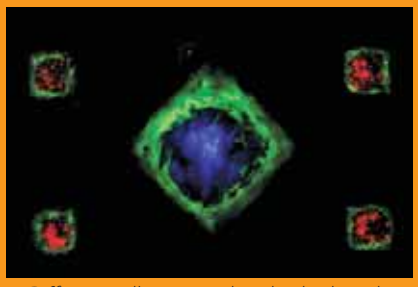
8. Writes and submits a paper to a science journal for publication.

"I wonder if this color is calming?"

Ali Khademhosseini

Living Legos Save Lives





Different cells encapsulated in hydrogels in Ali Khademhosseini's lab.

Courtesy of Ali Khademhosseini and Halil Tekin

Illustration: Dori Gordon Walker

By Mary T. Chunko

For patients who need an organ transplant, the news that a compatible organ has been found brings joy mingled with gratitude and sadness. The unfortunate fact is that for one person to receive a transferable organ, sometimes another person has to die.

Ali Khademhosseini, whose achievements include some 16 patents and numerous awards, wants to change that.

Growing Tissue

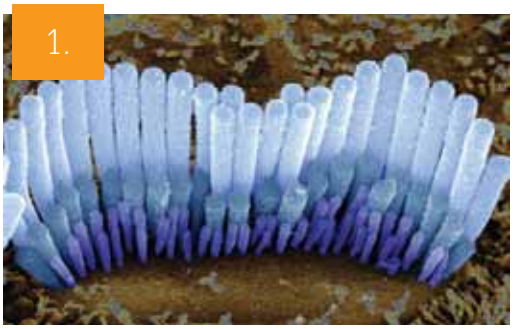
The Iranian-born bioengineer, who is an associate professor at the Harvard-MIT Division of Health Sciences and Technology, believes that one day scientists will be able to use patients' own cells to grow **tissues** and organs to replace those damaged in the body.

Khademhosseini's laboratory combines cells from patients — such as heart cells — with other types of cells to replicate the kinds of interconnections that cells have in the human body. They build what Khademhosseini and his colleagues call "living Legos" — tiny **fibers** and particles of various shapes studded with cells — which can self-assemble into complex structures resembling those found in natural tissues. The interconnected cells form a kind of scaffolding for growing tissues.

This innovation addresses many problems with conventional tissue engineering in which cells are seeded onto **biodegradable** scaffolds.

Looking to the future, Khademhosseini said: "I would like to pursue some of the work we are

1.



©David Furness

2.

©Anne Weston

3.

©David Gregory and Debbie Marshall

cellular beauty — can you guess what these are?

(answers on next page)

White House

President Obama addresses the winners of the 2012 awards.

what is best about science?

We asked several recipients of the 2011 and 2012 Presidential Early Career Awards for Scientists and Engineers what is best about science. Their answers follow.

Mariel Vazquez

ASSOCIATE PROFESSOR OF MATHEMATICS, SAN FRANCISCO STATE UNIVERSITY

The best thing about being a scientist is the fun you have. Science is fun. Math is fun. I use math and computers to tackle scientific problems which involve DNA and the interactions of **proteins** with DNA. In my work I get to draw a lot of pictures. I play with rope and with ribbons. I also create cool movies that help me understand and solve the problems I am working on. As a scientist, I also get to travel a lot, to meet people from all over the world and to work with them. What is wonderful about science is that it provides an infinite source of challenging problems to fit every taste and passion, and it inspires us to work hard to understand our world.

Brent Waters

ASSISTANT PROFESSOR OF CRYPTOGRAPHY AND COMPUTER SECURITY, UNIVERSITY OF TEXAS AT AUSTIN

For me the best thing about being a scientist is that I get to choose what problems I work on. If there is a problem that interests me or piques my curiosity, I can make it my job to understand it and solve it.

doing in the lab and push it to be used clinically to treat patients. Translating our research into improving patients' lives is our goal, and seeing it happen over the next few years would be great." ■

Tissue — An aggregate of cells in an organism that have similar or identical structure and function.

Fiber — Any elongated cell or threadlike structure such as a muscle fiber or nerve fiber.

Biodegradable — Capable of being decomposed by living organisms such as bacteria.

Protein — Large molecules of amino acids that are an essential part of the function of all living organisms.

Answers to the quiz on page 10:
1. Inner ear hair cell of a guinea pig.
2. Human connective tissue of a knee.
3. Human kidney cells.

Courtesy of Julie Turner/ Vanderbilt

SCOTT GAUDI

Planet Hunter

By Andrzej Zwaniecki

When planet-hunting season begins, Scott Gaudi rarely sleeps a whole night. Gaudi is an astronomer at Ohio State University who searches for **exoplanets.**

His best hunt so far started in 2006 when a star in the constellation Scorpius was about to pass in front of another star 21,000 light-years away from it. Gaudi issued a worldwide call for observation to his international team of professional and amateur astronomers who call themselves OGLE-2006-BLG-109. Two years later, they found a solar system similar to our own. "It looks like a scale model of our solar system," Gaudi said at a news conference announcing the discovery.

Mapping Other Worlds

The team made the discovery using a method of gravitational lensing, or microlensing, which is used when a planet or star crosses between another cosmic object and Earth. The nearer star can bend and magnify the light from the more distant one, causing it to shine brighter for a few days.

Since then, Gaudi has received several prestigious awards and other forms of recognition. A monetary award he was given by the National Science Foundation (NSF) in 2011 is likely to make the most difference in his work as it will support his new project — a map of all known exoplanets. Gaudi is comparing different methods for finding exoplanets and plans

Planet hunters found a solar system similar to our own. "It looks like a scale model of our solar system," says Gaudi.

(top) Planet discoveries leave a lot to the imagination: Artist's interpretation of an exoplanet orbiting a hot, fast-rotating star that was discovered in 2012. (left) Artist's rendition of sunrise over CoRoT-7b, one of the smallest-known exoplanets.

©ESO/L. Calçada

to stitch results together to create the Demographics of Exoplanets, as the project is called.

Gaudi, who teaches graduate students, is also involved in a follow-up project to OGLE-2006-BLG-109 that monitors stars crossing in front of other cosmic objects in the Milky Way. The project is often "frenetic and chaotic" as participants must analyze data in real time and react to results within hours, Gaudi told Examiner.com, an online news service. This makes it stressful but interesting, he said.

Gaudi says he likes working with amateurs because they are "excited by and dedicated to science." And, like them, he enjoys pondering still open questions: How exactly do planets form? How common are solar systems like ours? Are there Earth-like planets orbiting other stars? And, is there life on those planets? ■

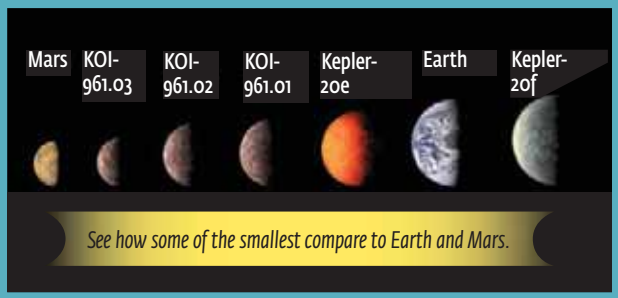
Exoplanets — Earth-like planets beyond our solar system.

what is best about science?

SCOTT GAUDI
ASSOCIATE PROFESSOR OF ASTRONOMY,
THE OHIO STATE UNIVERSITY

We are all incredibly fortunate and privileged to live in a completely unique time in human history. For the first time, the scientific pursuit of some of our oldest and most profound questions is possible: Are there other solar systems? Do they look like our own? Are we alone? I am incredibly grateful and honored to be able to participate in the effort to find answers to these questions. And I am astonished that I am, in fact, able to provide some answers. How cool is that?

Close-up of Exoplanets



©NASA/JPL-Caltech

most distant OGLE-2005-BLG-390Lb

- 21,500 ± 3,300 light years from the Earth.
- Orbits star OGLE-2005-BLG-390L in the Andromeda Galaxy.

closest Alpha Centauri Bb

- 4.37 light years from the Earth.
- Orbits Alpha Centauri B.
- With a mass about 1.1 times that of the Earth, it is similar in size to Earth.

hubble telescope

©NASA

The Hubble Space Telescope (left) took this picture of the Tadpole Galaxy (below).

Read more about Hubble at: www.nasa.gov

©NASA

Helen Saad

The Power of Networks

Courtesy of UC San Diego Jacobs School of Engineering

Helen Saad waxes poetic when she explains why she became interested in brain research. "The smell of a flower, the memory of the walk in the park, the planning of a trip … These experiences are made possible by the three pounds of tissue in our heads," she said.

But Saad is not a poet. She has a bachelor's degree in computer engineering and held managerial positions in multinational companies. In the end, the mysteries of the brain's communication network fascinated her more than the vagaries of computer networks.

When You Feel Like a Neuron in a Network

In her native Lebanon, the neural engineering that captured Saad's imagination was not yet well developed, and she felt like "a single neuron isolated in a petri dish." So she applied for a Fulbright Science and Technology Award to study neural engineering in the United States and became the first Lebanese citizen to receive one. Her hometown of Hammana on Mount Lebanon celebrated her achievement with a reception in her honor.

Saad pursues her doctoral degree at the University of California at San Diego (UCSD). Ever the poet, she said the Fulbright Award has allowed her to "sprout dendrites and connections to neighboring neurons," or to fellow scientists, and form with them "a complex and powerful network." She is forming other connections as well, and is involved in mentoring future entrepreneurs and organizing a business plan competition at UCSD.

Saad performs research on the rules that govern how signals and information are transmitted through a neuronal network. The ultimate goal of her research is to help find biotechnology cures for brain disorders such as Alzheimer's and Parkinson's. In Professor Gabriel Silva's bioengineering lab, Saad conducts research on the role of dendrites, threadlike extensions of neurons, in shaping the behavior of neuronal networks.

Saad plans to establish the first bioengineering research center and related business park in Lebanon when she returns to her country. She wants to help create a first-class nonprofit, nonsectarian research facility and to stimulate science-based entrepreneurship. Saad counts on networking to help her reach potential supporters. Using her cross-cultural experience, Saad also hopes that the center will help people in Lebanon to transcend ethnic, religious and political boundaries. ■

—A.Z.

what is best about science?

Curtis Huttenhower

ASSISTANT PROFESSOR OF COMPUTATIONAL BIOLOGY AND BIOINFORMATICS, HARVARD UNIVERSITY

When I finish a task, my two highest priorities are that the results be correct and that they add to our understanding of human health. There aren't a lot of jobs that have such great priorities. As an added bonus, I get to work with some of the smartest people in the world, and to help myself and others learn from each other every day. That's a privilege.

Bioinformatics — The use of computer technology for organizing, storing and analyzing biological and biochemical data.

Courtesy of Bassem

A pine forest on Mount Lebanon: The site of a future research center?

"The smell of a flower, the memory of the walk in the park, the planning of a trip … These experiences are made possible by the three pounds of tissue in our heads."

— Helen Saad

Neuron — A type of cell that receives and sends messages from the body to the brain and back to the body via electrical current.

Courtesy of Prakash Project

The proof is in her eyes: In India, this 7-year-old girl, center, who was born blind, gained sight after surgery.

PAWAN SINHA

Casting Light on Blindness

By Heather Regen

For Pawan Sinha, a 2002 trip to his native India proved an eye-opening experience. He noticed hundreds of blind children begging on the streets and decided to do something about it. A professor of brain and cognitive sciences at the Massachusetts Institute of Technology (MIT), Sinha thought that eye surgery and follow-up observations of the patients not only would help some blind children regain partial sight, but also expand understanding of how the brain perceives visual signals from the eyes. Since then, he has literally brought light to thousands of blind children — and cast light on the brain's visual circuitry.

He noticed hundreds of blind children begging on the streets and decided to do something about it.

Project Prakash

In 2005, he launched Project Prakash (the Sanskrit word for light). Working with Indian **ophthalmologists** and MIT researchers, Sinha started treating children's curable vision problems such as **cataracts** through surgery and then teaching the patients to make sense of the visual stimuli their eyes were receiving. As of mid-2012, more than 28,000 children have been screened and nearly 2,000 have been treated for various eye problems. Related scientific observations have never been done on such a massive scale.

By studying some of the patients after surgery, Sinha has dispelled many long-held views about the treatment of blindness. Previously, medical experts had thought that children were doomed to be blind forever once they had passed a critical period of sight development — around 6 or 7 years of age. But Sinha and his colleagues have found that even blind teenagers can be treated and learn to see some objects. Thanks to this insight, many eye surgeons in India have become more willing to operate on older

Courtesy of Pawan Sinha

what is best about science?

PAWAN SINHA

ASSOCIATE PROFESSOR OF COMPUTATIONAL AND VISUAL NEUROSCIENCE, MASSACHUSETTS INSTITUTE OF TECHNOLOGY (MIT)

Humans are, by nature, empathetic beings. We feel badly when we see suffering. To my mind, the best thing about science is that it gives you the training and tools to do something concrete to alleviate human suffering. Think about the happiness a mother feels when a medicine, created through the process of scientific discovery, cures her child of a dreaded illness. Imagine the joy a person feels when she reaches out to her friend who is feeling lonely in a strange foreign country; science makes that communication possible. One can come up with countless such examples.

We feel good about ourselves when we do one good deed. As a scientist, one has the opportunity to do many. Every day of a scientist's life is filled with the possibility of transforming lives near and far for the better. No wonder scientists are a happy lot!

Neuroscience — The study of the nervous system, including fields such as in neurochemistry and experimental psychology, that deals with the structure and functioning of the nervous system and brain.

children. At MIT Sinha and other researchers are now studying the development of the brain's ability to distinguish faces.

Sinha's charitable work continues too. He learned that many children who regained partial sight after surgery were not able to receive regular education or get a job. "We need to change that," he said in an interview with Anne Trafton published in the July/August issue of *Technology Review,* an online magazine published by MIT.

So Sinha plans to build an eye surgery and research center in India that will include a school for newly sighted children. "Every child that we are able to help, it's like a personal victory," Sinha told *Technology Review.* ■

Ophthalmologist — A medical doctor who specializes in eye and vision care, including research, disease diagnosis and surgery.

Cataract — An opacity of the lens of the eye that causes impairment of vision, which can be corrected by surgery.

BLOG

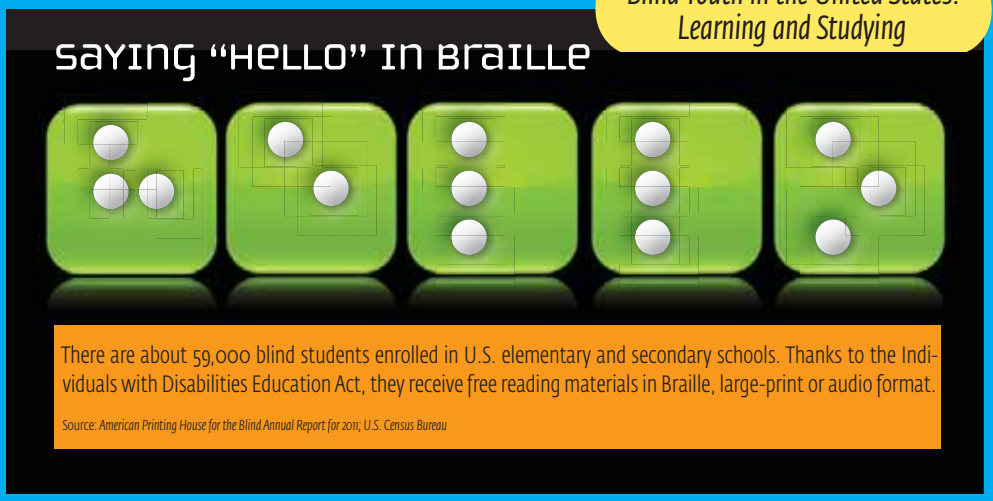
Hi there. My name is Justin Daubenmire. After losing my eyesight at age 18 from diabetic retinopathy, I eventually went to university for a degree in computer programming. Upon graduation, in 2001, I founded www.BlindSoftware.com. At BlindSoftware.com I create software for the blind and computer games for the blind. It is my deep respect and personal identification with the blind community that fuels my desire to create software for the blind and computer games for the blind. My company's staff is comprised of dedicated programmers, sound engineers, content writers, musicians, sales support, technical support, technical writers, marketing, and beta testers — all of whom are blind or visually impaired.

(Excerpt from a blog published on LivingBlind.com)

Photos courtesy of Prakash Project

Learning to see: Pawan Sinha examines the visual skills of newly sighted children.

Blind Youth in the United States: Learning and Studying



Courtesy of Luis von Ahn

Luis von Ahn

Gamer Defeats Spam

Luis von Ahn found his life's calling in 2000 when Internet giant Yahoo! asked him for help in combating spam, the annoying email messages sent indiscriminately by computer robots to large numbers of recipients. The same year, he and his doctoral adviser at Carnegie Mellon University in Pittsburgh, Manuel Bloom, developed CAPTCHA. CAPTCHA, a string of slightly distorted characters people can read but computers cannot, which prevents automated programs from entering websites, was embraced by about 60,000 websites as defense against spam.

He has released a number of "games with purpose," each aimed at harnessing players' brainpower to achieve a specific useful goal.

But spammers didn't give up. They used the CAPTCHA technology to defeat CAPTCHA defenses while online users were wasting time solving CAPTCHA puzzles. Von Ahn started thinking about how to use that wasted time for public good. The solution he came up with in 2007 — reCAPTCHA — not only improves Internet security, but also helps digitize old books and newspapers. Today, some 60 million to 70 million people use reCAPTCHA to transcribe about 100 million words a day. It is also used by the Internet Archive, Google Books and the *New York Times*.

Von Ahn had turned these and other innovations into profitable commercial ventures he sold or licensed to large companies. He said the profits gave him freedom to choose his preferred way of life. "I could have retired [early]," he said. "But I chose not to because I like new challenges and teaching." So he teaches at Carnegie Mellon and pursues more innovations.

Beyond reCAPTCHA: Human Computing

Throughout his career, von Ahn has focused on how to leverage human brainpower to solve computational problems that computers cannot solve on their own. He has noticed that "people will contribute their brainpower … only if they're given an enjoyable … experience in exchange," he told *Wired* magazine.

©RAStudio/Shutterstock.com

JULY 2008
500
iPhone apps:

1,400% increase in apps

With that in mind, he has released a number of "games with purpose," each aimed at harnessing players' brainpower to achieve a specific useful goal. The latest Duolingo allows players to "learn a language for free while helping to translate the Web" to languages other than English.

Born in Guatemala, he visits his native country twice a year to "help kick-start technology research and innovation," he said. High-tech stirrings are still weak, but they are growing stronger. He predicts that "in five to 10 years, you will see some [high-tech] things coming out of Guatemala." ■

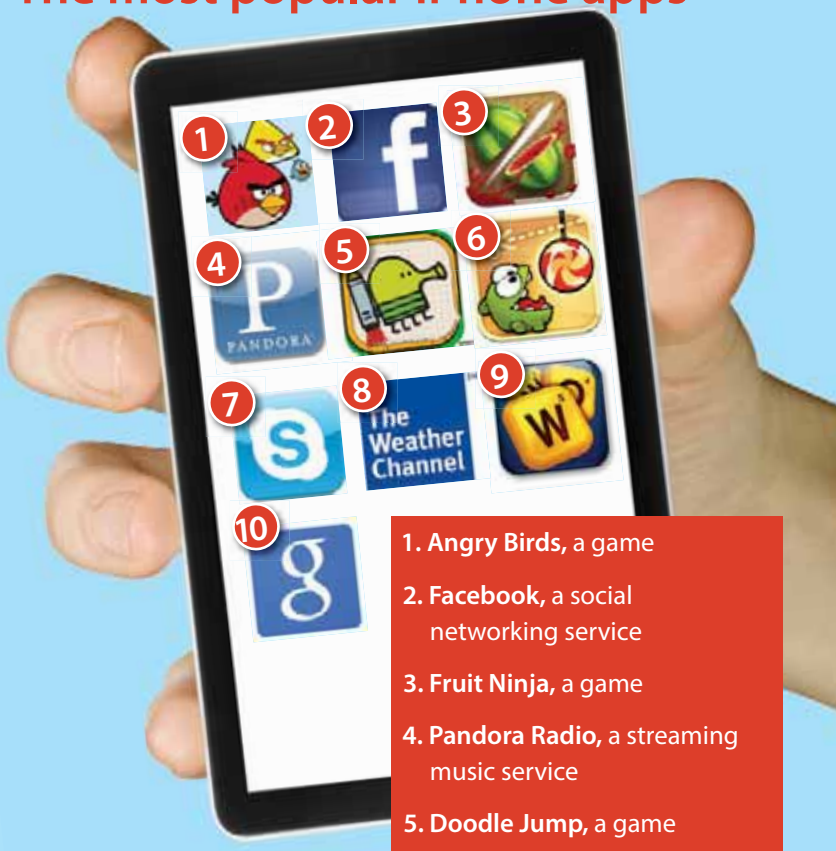
—*A.Z.*

what is best about science?

David Noone
ASSOCIATE PROFESSOR OF ATMOSPHERIC AND OCEANIC SCIENCES, UNIVERSITY OF COLORADO AT BOULDER

Science is about discovering how things work. Searching for answers is outrageously exciting. There are few things more exhilarating than examining newly collected observations, or seeing measurements that no one has seen before and asking: "Does this show the world works in a way that is different from what I expected?" My research takes me to spectacular places like the top of volcanoes in Hawaii, the ice sheet in Greenland and alpine forests near my home in Colorado. We look at the movement of water molecules between snow, air and leaves to discover how the land, atmosphere and clouds are connected at the scale of the whole planet. Water is so critical for our shared environment, agriculture and societies. Helping solve important problems is rewarding. But science is also great fun, and more than a little addictive.

The most popular iPhone apps



1. **Angry Birds,** a game
2. **Facebook,** a social networking service
3. **Fruit Ninja,** a game
4. **Pandora Radio,** a streaming music service
5. **Doodle Jump,** a game
6. **Cut the Rope,** a game
7. **Skype,** a calling, video calling and messaging service
8. **The Weather Channel,** a weather forecasting service
9. **Words With Friends,** a game
10. **Google Search,** an Internet search service

Source: *CNN Money, 2012*

Cel phone photo ©ovan/Shutterstock.com

over 4.5 years

DECEMBER 2012

700,000 iPhone & iPad apps

Irene Ballagh

A New Zealander in New York

Courtesy of Irene Ballagh

Irene Ballagh is interested in frogs, the South African *Xenopus laevis* in particular. Not as pets, mind you, but as a model for her research on how the neurons and neural circuits within our brains control our muscles and our behavior. She used fluorescent dyes and electrical stimulation to map the neural connections that allow frogs to hear and make the appropriate responses to other frogs' "singing."

"Frogs change what they're saying to each other depending on what they hear other frogs saying back to them, much like we do," Ballagh said. Understanding how neural circuits work in the frog brain might shed some light on how they work in the human brain. As a member of Darcy Kelley's laboratory at Columbia University in New York, Ballagh also researches how hormones work in the frog brain to change the animal's social behavior.

In 2007, Ballagh, a New Zealander, received a Fulbright International Science and Technology Award to become a candidate in the neurobiology and behavior doctoral degree program at Columbia. The award provides outstanding foreign students with an opportunity to pursue **Ph.D.** study at top U.S. universities. Ballagh is a second-generation Fulbrighter as her father, Robert Ballagh, earned a Ph.D. in physics at the University of Colorado in 1973.

New York, New York

When Irene Ballagh moved to New York from the University of Otago in New Zealand, she immediately got a kick out of her new environment.

"I love the amount of stuff going on here," she told the *Otago Daily Times,* a local paper in her home region. Columbia has 80 faculty members in neuroscience, compared to 15 or 20 at Otago, and a Nobel Prize winner in chemistry worked just down the hall from Ballagh's lab. Genetic techniques for identifying, labeling and manipulating parts of the brain are regularly used. Cutting-edge technologies such as **functional magnetic resonance imaging** and **confocal microscopes** are more common and more available than in New Zealand, she said. Ballagh also fell in love with New York on her first morning in the city.

"It's an amazing place for so many reasons," she said. "Everything is happening right outside your door." But at times she misses the green hills of the Otago province. ■

—A.Z.

Understanding how neural circuits work in the frog brain might shed some light on how they work in the human brain.

A pair of *Xenopus laevis* show off their colors.

Courtesy of Tim Vickers

Ph.D. (Philosophiae Doctor or Doctor of Philosophy) — An advanced graduate degree awarded following at least four years of study, completion of comprehensive examinations and the defense of a dissertation, a major written work of original research.

Functional magnetic resonance imaging (fMRI) — A form of magnetic resonance imaging of the brain that can identify areas of the brain associated with a given process by detecting changes in blood oxygenation and flow.

Confocal microscope — A light microscope with an optical system that rejects background information from outside the focal plane and allows serial sections of a specimen to be seen.

what is best about science?

Ali Khademhosseini

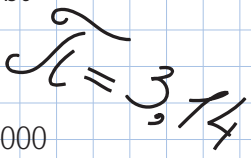
associate professor, Harvard-MIT Division of Health Sciences and Technology, Brigham and Women's Hospital, Harvard Medical School

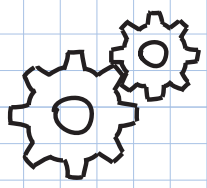
I think that there are many great things about doing science. However, aside from discovering new things that can potentially improve people's lives, I really enjoy making a very direct impact on the lives of my students and inspiring others to pursue a career in science and engineering. I have now trained a few individuals who have become scientists themselves, and it is always very satisfying to see them develop their own careers and make an impact in the world.

Science & Engineering education

AROUND THE GLOBE

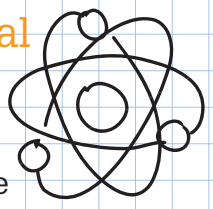
Who awarded the most **Undergraduate Degrees?** (2008)
China: 1,150,000
European Union: 950,000
United States: 500,000

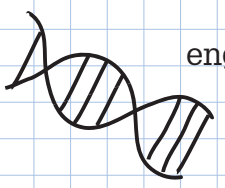




Who awarded the most **Doctoral Degrees?** (2008)
United States: 33,000
China: 28,000
Russia: 15,000
Germany: 11,000
United Kingdom: 9,500

Women earned 41% of science and engineering doctoral degrees in the United States, about the same percentage as women in Australia, Canada and the European Union. (2008)

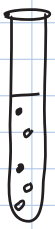




Nearly **half** of U.S. science and engineering graduate students were **women.** (2009)

Source: *National Science Foundation, 2012*

In 2009, more than 60% of foreign-born scientists and engineers in the United States were from Asia, **mostly from India, China, the Philippines and Taiwan.**



Source: *Population Reference Bureau*

Science without Borders

NOT YOUR SCHOOL MATH

Timothy Gowers challenged readers of his blog to solve a mathematical conundrum: Find a new combinatorial proof to the density version of the Hales-Jewett theorem.*

Gowers' challenge sparked an unprecedented online collaboration among the world's mathematicians. Gowers, a prominent British mathematician, set ground rules and, with help of mathematician Terence Tao, managed the effort that has become known as the Polymath Project.

Numbered among the 275 participants were winners of the Fields Medal — mathematics' Nobel Prize — and secondary school mathematics teachers. In a few weeks, they accomplished some highly nontrivial mathematical feats, according to Justin Cranshaw and Aniket Kittur of Carnegie Mellon University.

Following on the success of Polymath 1, which produced two science papers, Gowers has posted five more problems.

*The Hales-Jewett theorem concerns the degree to which high-dimensional objects must necessarily exhibit some combinatorial structure.

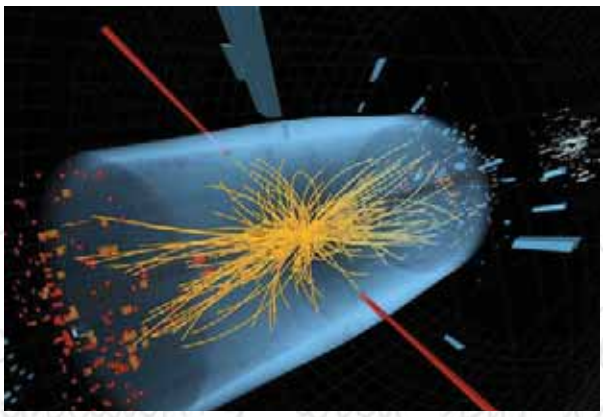
WEIGHTY QUESTION OF SPACE WEIGHTLESSNESS

The International Space Station is turning science fiction into reality. Experiments conducted on the space station will help us explore the moon and fly to the asteroids and Mars, said NASA astronaut and Expedition 30 commander Dan Burbank. Those experiments are also allowing us to study the effects of long-term zero-gravity exposure on the human body.

Since 2000, an orbiting laboratory maintained primarily by the United States, Russia, Europe, Japan and Canada has hosted a rotating international crew and more than 500 experiments designed by scientists from 16 nations.

(Above) NASA astronaut Sunita Williams, ISS Expedition 33 commander, finds the lightness of weightlessness bearable — and fun.

Courtesy of NASA



©AP Photo/CERN

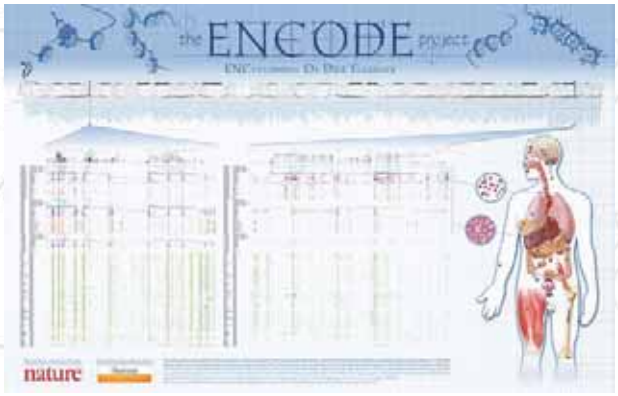
The Higgs boson? We take CERN's word for it.

COUNTING BUGS THAT MAKE US RUN

The diversity, variety and function of the microorganisms populating the human body surprised scientists participating in the Human Microbiome Project (HMP) launched by the U.S. National Institutes of Health in 2008. Using powerful new computational methods, a group of nearly 250 scientists from about 80 research institutions around the world conducted a census of the bacteria, viruses and other microbes — all together about 10,000 microbial species — that reside in the mouth, intestines and other parts of our bodies.

It turns out that each of us carries around about 10 times as many microbial cells as human cells and they have about 100 times as many genes as we do, according to Curtis Huttenhower, who helps coordinate the project. Microbial flora differ from one person to another to a large degree. Nevertheless, different microbes perform the same sort of functions in specific areas of the body.

The findings can help scientists understand the roles microbes play during changes associated with diseases.



Courtesy of ENCODE/*Nature* magazine

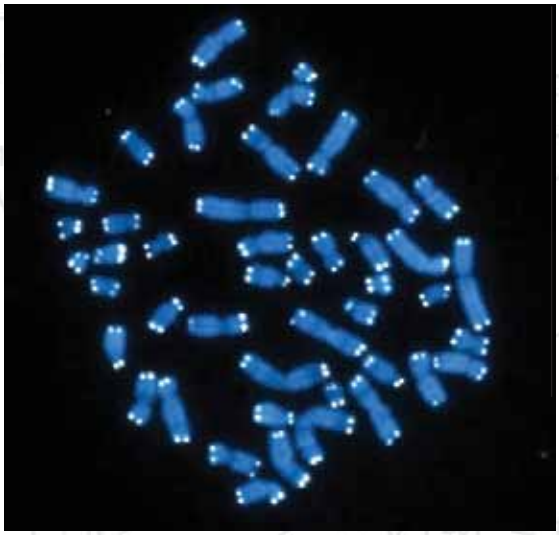
(Background) Simplification of algebraic radicals.
Courtesy of Giustino Carinci

SMASHING ATOMS AND BORDERS

In particle physics, a sole scientist has no chance. It took a joint effort by some 10,000 scientists and engineers from 600 institutions in more than 100 countries to discover a subatomic particle that could be the Higgs boson. The Higgs boson is the only particle in our understanding of particle physics that has never been observed, but has been postulated through math. Its existence has been supported by two independent experiments run on the Large Hadron Collider, an atom smasher, at the European Organization for Nuclear Research, known as CERN.

CERN is a prime example of international collaboration in science and has played a substantive role in improving international relations, especially during the Cold War. Established in 1954 near Geneva, CERN has grown to include 20 European member states and host scientists from more than 20 nations, including the United States.

As of November 2012, the two teams were running additional experiments to see whether the particle they discovered was actually the Higgs boson.



©AP Photo/National Cancer Institute

Human chromosomes, where DNA resides and does its work.

SWITCHING ON LIGHT ON HUMAN DNA

Genes — like trains — don't work without switches.

That is the conclusion of some 400 scientists working on a project called the Encyclopedia of DNA Elements (ENCODE). In conducting more than 1,600 experiments over five years, they discovered that the bulk of DNA in our cells is not useless as previously thought, but involved in turning genes off or on, thus influencing their output, controlling their timing and coordinating their activity with other genes.

"The complexity of our biology resides not in the number of our genes but in the regulatory switches," said Eric Green, head of the U.S. National **Human Genome** Research Institute, which funds ENCODE. The discovery can help in the identification of genetic risk factors for disease and development of new drugs and treatments. ENCODE, launched in 2003, is designed to create a comprehensive list of functional elements in the human genome, and to find out how they work together.

Human genome — All the genetic information in a person — about 3 billion base pairs of DNA.

Glossary

A

Atomic nucleus

— The central core of an atom composed of protons and neutrons.

B

Biodegradable

— Capable of being decomposed by living organisms such as bacteria.

Bioinformatics

— The use of computer technology for organizing, storing and analyzing biological and biochemical data.

C

Cataract

— An opacity of the lens of the eye that causes impairment of vision, which can be corrected by surgery.

Cell

— An autonomous self-replicating unit that is specialized into carrying out particular functions in the organism.

Confocal microscope

— A light microscope with an optical system that rejects background information from outside the focal plane and allows serial sections of a specimen to be seen.

D

Dark matter

— Nonluminous matter that cannot be directly observed, but whose existence is suggested because of the gravitational pull it exerts on the rotation rate of galaxies and the presence of clusters of galaxies.

Dark energy

— A hypothetical form of energy that produces a force that opposes gravity and is thought to be the cause of the accelerating expansion of the universe.

DNA

— Deoxyribonucleic acid, a nucleic acid located in the cell nucleus that carries hereditary genetic information for cell growth, division and function.

E

Exoplanets

— Earth-like planets beyond our solar system.

F

Fiber

— Any elongated cell or threadlike structure such as a muscle fiber or nerve fiber.

Functional magnetic resonance imaging (fMRI)

— A form of magnetic resonance imaging of the brain that can identify areas of the brain associated with a given process by detecting changes in blood oxygenation and flow.

G

Gene

— The fundamental, physical and functional unit of heredity made of DNA and containing instructions for making protein molecules.

H

Higgs boson

— A hypothetical elementary particle that has zero spin and large mass and is required by some theories to account for the masses of other elementary particles.

Human genome

— All the genetic information in a person — about 3 billion base pairs of DNA.

Hypothesis

— A proposition made as a basis for reasoning, without any assumption of its truth.

M

Molecule

— A group of atoms bonded together.

N

Nanoparticle

— A microscopic particle whose size is measured in nanometers (nm), typically less than 100nm.

Neuron

— A type of cell that receives and sends messages from the body to the brain and back to the body via electrical current.

Neuroscience

— The study of the nervous system, such as in neurochemistry and experimental psychology, that deals with the structure and functioning of the nervous system and brain.

O

Ophthalmologist

— A medical doctor who specializes in eye and vision care, including research, disease diagnosis and surgery.

P

Ph.D. (Philosophiae Doctor or Doctor of Philosophy)

— An advanced graduate degree awarded following at least four years of study, completion of comprehensive examinations and the defense of a dissertation, a major written work of original research.

Protein

— Large molecules of amino acids that are an essential part of the function of all living organisms.

S

Subatomic particle

— Any unit of matter below the size of an atom.

T

Tissue

— An aggregate of cells in an organism that have similar or identical structure and function.

Sources: *Astronomy Today, Biology Online, Google, Free Online Dictionary, MedicineNet, Merriam-Webster Online Dictionary, National Institutes of Health, National Cancer Institute*

Additional Resources

©tovovan/Shutterstock.com

International science programs and online courses

Coursera, a nonprofit company that partners with the top universities in the world to offer free online courses.

https://www.coursera.org/#about

---

edX, free online courses offered by the Massachusetts Institute of Technology and Harvard University.

https://www.edx.org/

Fogarty International Center, a U.S. National Institutes of Health program that supports basic, clinical and applied research and training for U.S. and foreign researchers working in the developing world. It facilitates exchanges among researchers, provides training opportunities and supports promising research initiatives in developing countries.

http://www.fic.nih.gov/Pages/Default.aspx

Khan Academy, a nonprofit group that hosts on YouTube more than 3,000 educational videos designed mostly for secondary-education students. It also offers automated practice exercises and a curriculum of computer science courses.

https://www.khanacademy.org/

Science Technology and Innovation Expert Partnership, a partnership between the U.S. Department of State and 10 science and engineering professional societies that allows U.S. experts to engage overseas audiences through hands-on demonstrations, lectures, mentoring sessions, video conferencing, webchats and webcasts.

Student Research Network, part of the U.S. National Science Foundation's Physics of Living Systems Program, is an international network of graduate students and educators working on the physics of living systems. The program includes visiting research internships and workshops.

http://pols.ucsd.edu/

Udacity, another initiative that offers free university-level online courses.

http://www.udacity.com/

Udemy, a company that lets instructors set up courses online on a broad range of subjects from computer programming to photography to yoga.

http://www.udemy.com/

Virtual Science Libraries (PDF, 1.1MB), a program of the U.S. Civilian Research and Development Foundation, a public-private partnership. The program provides research communities in developing countries with access to full-text science and engineering publications and databases.

http://www.crdfglobal.org/docs/cibi-documents/virtual-science-libraries.pdf


UNITED STATES DEPARTMENT OF STATE
BUREAU OF INTERNATIONAL INFORMATION PROGRAMS