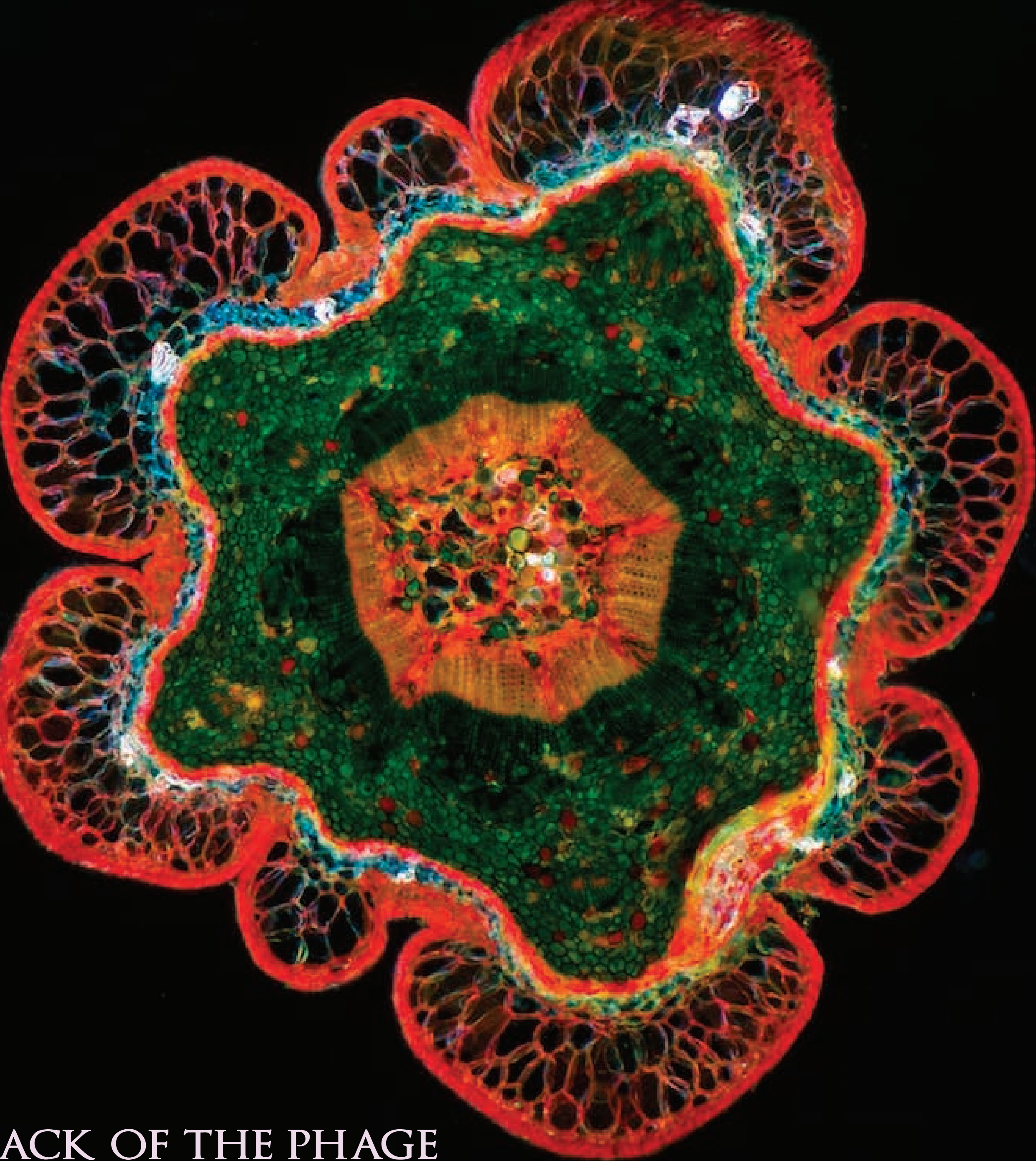
Columbia Science Review

Vol. 7, Issue 1: Fall 2010



Attack of the Phage
Bacteriophage against infection

A Musical Solution
An unlikely therapy for Parkinson's disease

The Brainiacs
Adventures in public school science

Editorial Board

The Editorial Board biannually publishes the Columbia Science Review, a peer-reviewed science publication featuring articles written by Columbia students.

Administrative Board

The Executive Board represents the Columbia Science Review as an ABC-recognized Category B student organization at Columbia University.

The Columbia Science Review strives to increase knowledge and awareness of science and technology within the Columbia community by presenting engaging and informative articles, in forms such as:

- Reviews of contemporary issues in science
- Faculty profiles and interviews
- Editorials and opinion pieces

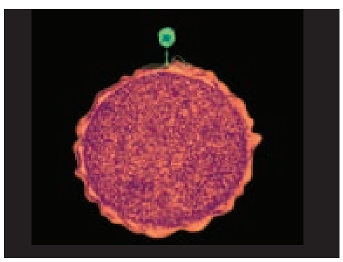
Sources and credits for this issue can be found online at www.columbia.edu/cu/csr.

contact us at
csr-eboard@columbia.edu

Columbia Science Review

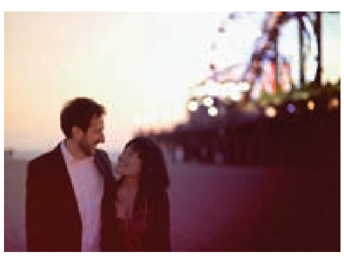
Cocktail Science 04
The Planets 06
Attack of the Phage 08
The Brainiacs 11
Geoengineering 15
Our Brain in Love 18
20 Cognitive Reserve
22 A Musical Solution
24 A Gift of Life
26 Forensic Accessibility
32 Stem Cell Science
35 Tri-space Races

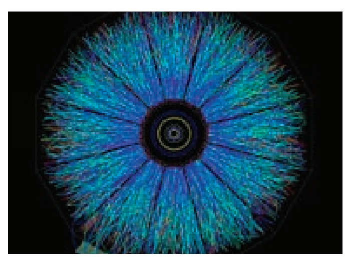
8
Attack of the Phage



11
The Brainiacs

18
Our Brain in Love





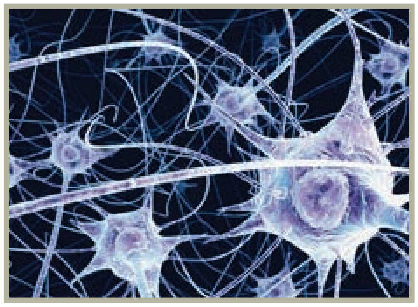
28
The Theology of Science

COVER PICTURE:
A cross-section of a fir tree twig stained with acridine red, acriflavine, and astra blue.
By: Eckhard Völcker,
http://www.flickr.com/photos/wunderkanone/4745639982

Elizabeth Robinson
Grace Baek
Christine Yeh
Chloe Ruan

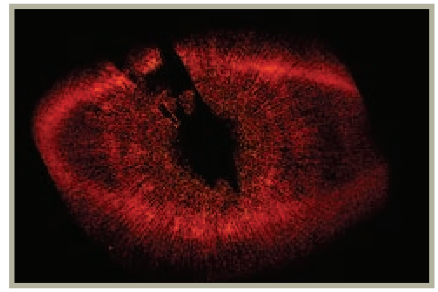
Cocktail Science

Kudzu, often called "the plant that ate the South," is a fast-growing invasive species of legume that engulfs entire forests of trees in the Southeastern United States with its thick foliage, smothering any native species in its path. It was originally imported from Asia to control soil erosion, but it quickly became a pest. In 2010, environmental scientists found that it's not just wrecking the soil—it's wreaking havoc on the atmosphere as well. Kudzu vines can more than double nitric oxide emissions, which contribute to "bad ozone," the kind that forms in the lower levels of the atmosphere. In the summers, when the weather is hot and humid, these nitric oxide emissions are responsible for a greater number of days with dangerously high ozone levels. As climate change leads to warmer temperatures in different regions of the U.S., it is likely that kudzu's range will expand, further exacerbating environmental problems.



Our brains' wiring includes networks of cells called neurons, and is typically fixed after undergoing a period of development during early childhood. Neurons transfer electrical and chemical signals throughout these neural communities, allowing—for instance—a stimulus to your arm be recognized by your brain, leading your arm to react to the stimulus. Without the flexibility to alter these neuron networks, people whose brains become disordered due to brain trauma, old age, or developmental disorders have a difficult time recovering control of their neural processes. Researchers at the University of California, San Francisco, have transplanted embryonic neurons in the visual cortices of mice (developed beyond their normal period of plasticity) whose visual capabilities were partially obstructed. These embryonic neurons produced an inhibitory neurotransmitter named GABA, which allowed previously damaged neuronal networks to heal on their own. As a result, the mice were able to regain their original visual capabilities despite their age. This discovery demonstrates that the human body's ability to rewire itself is virtually limitless.

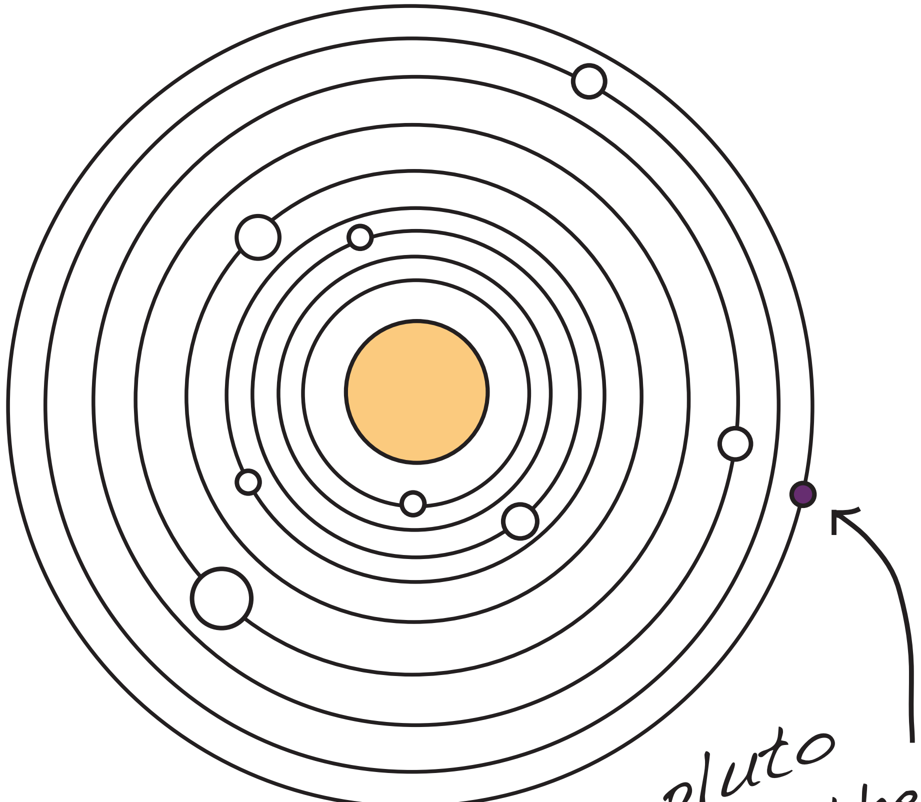
Ever wonder why ketchup doesn't immediately flow out of the bottle when you turn it upside down? Thank ketchup's non-Newtonian properties. Non-Newtonian fluids are substances with more than one constant viscosity. When pressure is applied to these fluids, their viscosities change. A common example is starch mixed with water, resulting in a suspension called "oobleck." Oobleck thickens into a solid when squeezed, but as soon as the pressure is released, oobleck drips as a liquid. Oobleck is a shear-thickening fluid whose states are characterized by a positive correlation between pressure and viscosity. Conversely, fluids with a negative correlation between pressure and viscosity are called shear-thinning fluids. Ketchup is a shear-thinning fluid. When pressure is applied by squeezing the bottle, ketchup flows out more easily because the viscosity decreases.



We may not be so special after all: 20 light-years away, life may be able to flourish. Scientists have discovered two exoplanets (planets existing outside of our solar system) orbiting a red dwarf star named Gliese 581. Gliese 581g, the smaller of the two, orbits within a "habitable zone" surrounding the star, where temperatures are stable enough to allow the presence of liquid water. Although Gliese 581g bears greater average surface temperature fluctuations than Earth, scientists predict that "eco-longitudes," or stable climatic bands, offer a haven for water to persist. So far, astronomers have gathered information about Gliese 581g using a technique that observes Doppler shifts in Gliese 581's light in response to orbiting planets' interactions with the red dwarf. Other techniques, such as watching a partial eclipse, can supplement information about the presence of biological organisms and the components of a planet's atmosphere. Scientists are hoping that technological advances will allow them to probe for more information about Gliese 581g, and its habitability in the near future.

the planets

Keri Lofftus



and why pluto isn't one of them

The planets have always captured the human imagination. The word "planet" comes from the Greek word meaning "wanderer." This is because the planets appear to move across relative to the background stars. For ancient civilizations, their importance was mostly religious, with planets identified with different deities and their movements considered relevant to predicting future events. Over time, the planets have been seen in an increasingly scientific light, their movements demystified by revolutions in science and mathematics.

The first records of planetary motion come from ancient Babylonia in the form of a tablet recording the risings and settings of the planet Venus. Although the exact date of the tablet is disputed, it probably originated in the first or second millennium BCE. However, the picture we currently have of planets originated mostly from the ancient Greeks. They recorded what are now called the "classical planets," including Mercury, Venus, Mars, Saturn, and Jupiter, which could be seen with the naked eye. They also classified the Moon and Sun as planets. Each of the five visible planets was associated with one of the Greek Olympian gods. The Romanized versions of these same gods eventually became the names of the planets we know today.

Originally, the planets were studied in the field of astrology. Many ancient peoples believed that the motion of celestial bodies could influence life on Earth and that one could understand how future events would unfold by understanding and predicting their motion. Also, because the ancient Greeks considered the Sun and the Moon planets, understanding planetary motion was important for other activities such as timekeeping and navigation.

The pinnacle of Greek astronomy came in the second century CE with the publication of Ptolemy's Almagest, a comprehensive and systematic guide to astronomy. For planetary motion, Ptolemy proposed a geocentric model, in which the Earth was at the center of the universe and was orbited by all the other planets. Although fundamentally flawed in its description of the solar system, Ptolemy's model was highly accurate in predicting planetary motion, making it the dominant model for over 1,000 years in Europe and the Middle East.

It was not until the Renaissance that there would be a significant advancement in knowledge of planetary motion.

In 1543, Nicolaus Copernicus published "On the Revolutions of the Heavenly Spheres." In contrast to Ptolemy's geocentric model, Copernicus proposed a heliocentric model, with the Sun at the center of the solar system and the planets, including Earth, orbiting around it. At first, Copernicus' model was not well received, especially by the Catholic Church, which felt that a heliocentric system contradicted the Bible. However, Copernicus had laid the seeds for a revolution in astronomy.

In 1609, Johannes Kepler published the Astronomia Nova. It contained his investigation of the movement of the planet Mars, based on observations taken by Tycho Brahe. After over ten years of work, Kepler realized that the orbits of the planets were ellipses, with the Sun at one focus. The combined work of Copernicus and Kepler successfully explained how the planets move. Next, Isaac Newton went on to explain why they move with his theory of universal gravitation.

Once the motions of the planets could be accurately predicated with mathematics, it was time for the solar system to expand. Using a telescope, William Herschel discovered the planet Uranus in 1781, initially believing it to be a comet. Although observed multiple times earlier because of its dimness and slow orbit, it was dismissed as a star.

Sixty years later, mathematical analysis of Uranus' orbit showed irregularities. It was theorized that the gravity of another, so far undiscovered planet, could be responsible for these perturbations. Urbain Le Verrier and John Couch Adams (independently of each other) mathematically worked out the position of this planet and in 1846 Johann Galle used the predicted position to discover the planet Neptune, making it the only planet discovered mathematically. Like Uranus, Neptune had been seen by several other astronomers, including Galileo, but was also thought to be just a star.

Then, in 1930, Clyde Tombaugh discovered Pluto by comparing photographs taken of the night sky. His discovery was not at first controversial. Pluto was quickly recognized as the ninth planet, despite some odd characteristics. The other eight planets orbit the Sun in roughly the same plane, called the elliptic, but Pluto's orbit is inclined 17° relative to the ecliptic. Also, its orbit has a much greater eccentricity (i.e., its orbit is much more elliptical) than the other planets.

It was not until the 1990s that Pluto's classification became suspect. With increasingly powerful telescopes, astronomers learned that Pluto was situated in part of the solar system now called the Kuiper Belt, which contains thousands of small objects with similar physical properties to Pluto. Larger and larger objects in the Kuiper Belt were discovered. Then, in January 2005, the object Eris was discovered by Michael Brown and found to be more massive than Pluto.

The discovery of Eris (aptly named for the Greek goddess of discord) was the final blow to Pluto. It became apparent that many more objects similar in size or larger than Pluto were likely to be discovered, expanding our solar system from nine planets to possibly dozens. To solve this problem, the International Astronomical Union (IAU) decided it was time to create a formal definition of a planet. After much debate, in 2006 the IAU set this definition of a planet: It is in orbit around the Sun, it has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape, and it has cleared the neighborhood around its orbit.

Although Pluto meets the first two of these criteria, it fails to meet the third. For Pluto and other objects who have not "cleared the neighborhood around its orbit", the "dwarf planet" category was created. So, our current picture of the solar system is:

8 Planets, separated into three categories:

Mercury, Venus, Earth, and Mars (terrestrials)

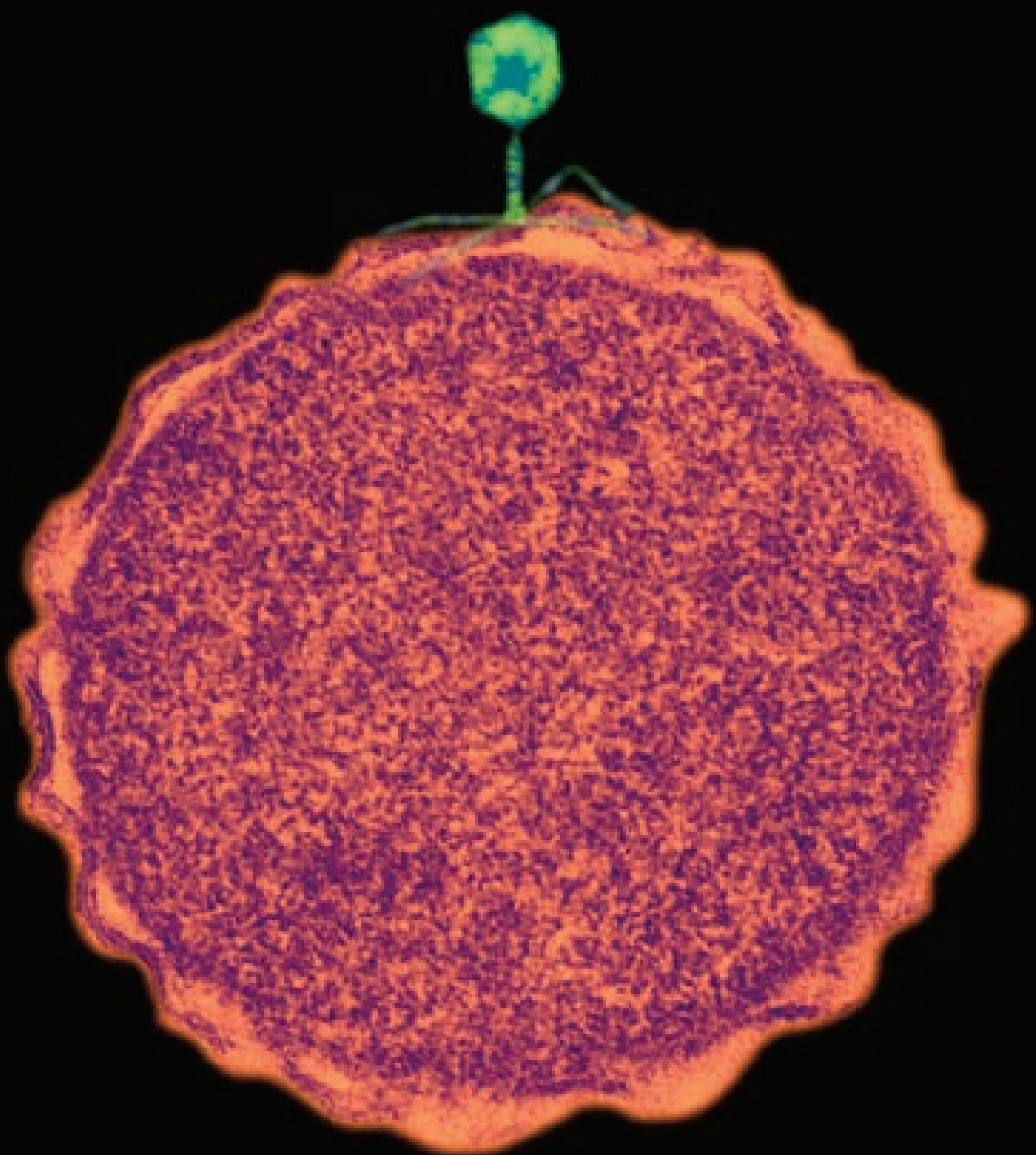
Jupiter and Saturn (gas giants)

Uranus and Neptune (ice giants)

Dwarf Planets: Eris, Pluto, Makemake, Haumea, and Ceres.

Small Solar System Bodies (includes asteroids and comets)

It has taken us thousands of years to create this picture. Our conception of the solar system has changed greatly since ancient Babylonia and Greece. We have expanded the solar system with new planets and mathematically modeled the way they move. The discovery of more dwarf planets will continue to expand our catalog of objects. Eventually, the definitions we have laid down must be analyzed with respect to the growing numbers of extrasolar planets. With constantly advancing technology allowing astronomers to make new discoveries at ever increasing rates, the way we see the solar system is likely to continue changing far into the future.



Amy Huang

attack of the phage

the future of phage lytic enzymes in treatments against bacterial infection

January 27, 2005. More than four hundred high school students and teachers from New York crammed into the auditorium of Rockefeller University for the 46th Annual Alfred E. Mirsky Holiday Lecture on Science. The title of the lecture, "Phage: Invasion of the Bacteria Snatchers", aptly named after the 1956 science fiction film, elicited the awe of both scientists and high school students interested in the fascinating world of viruses.

Vincent A. Fischetti currently professor and chair of the Laboratory of Bacterial Pathogenesis and Immunology at the Rockefeller University in New York, led the lecture. In it he described his research on the isolation and purification of bacteriophage, or phage, lytic enzymes and its implications on future treatments against bacterial infection. If perfected, lysin technology can be especially useful against antibiotic resistant bacteria, a global problem that has been exacerbated by inadequate hospital hygiene and the inappropriate use of antibiotics. The enzyme's highly specific and swift method of destroying bacteria makes it appealing to researchers looking to solve the problem of resistance.

An interest in viruses has been gaining impetus with Fischetti's momentous research on bacteriophages as well as in the Columbia community, with the addition of a new course in virology taught by Vincent R. Racaniello, Ph.D, professor of Microbiology at the Columbia Medical Center. To appreciate the destructive means of phage lysins, it is necessary to examine the complexity and ingenuity of the phage's bacterial hijacking mechanisms.

Life of the Phage

A virus is an obligate, intracellular parasite that invades a host and takes advantage of its biosynthetic machinery to create more copies of itself. Though debatable, viruses are not considered living organisms, as they do not possess cellular structure and metabolism, and cannot reproduce outside of a cell. They have a wide variety of shapes and sizes, and use different ways to enter and replicate within a cell. Despite the bad press given to viruses after the HIV and SARS outbreaks, not all viruses are disease-causing.

The bacteriophage is a special type of virus that specifically invades bacteria. They are one of the most common organisms on earth, infecting up to 70% of marine bacteria, and have been residing in the oceans for millions of years. Most of us have seen depictions of viruses as having an icosahedral head, long screw-like tail, and insect leg-like tail fibers, which is the typical structure of a T4 phage that infects our everyday E.coli. However, not all viruses possess this type of body.

During infection of a bacterium, the phage first recognizes and attaches to the membrane of the bacterium using its tail fibers or some similar structure. The head contains the viral genetic code that is injected into the cell upon attachment. Depending on the type of phage, it uses various mechanisms to get through the bacterial membrane and inject its genetic material, usually leaving the rest of the phage outside of the cell. Once inside, the genetic material hijacks the host's biosynthetic machinery, creating viral "body parts" and proteins. These are assembled to generate new copies of the virus, which then escape the cell in what is called the "lytic cycle." To do this, the viruses must secrete thousands of lytic enzymes, or lysins, to dissolve the membrane and release the cellular contents, including the viruses. Lysins poke holes in the bacterial cell wall, essentially killing the cell by "popping" it. A new cycle begins when the phages invade other hosts.

The Marvels of Lysins

Phages were the subject of many Nobel Prizes and references in literature, such as the 1926 Pulitzer prize-winning novel by Sinclair Lewis, Arrowsmith, in which a scientist discovers a phage that can destroy deadly bacteria and treat infections. Fischetti turned fiction into reality when his laboratory identified lysins that could destroy disease-causing bacteria such as Streptococcus pneumoniae, Enterococcus faecalis, Streptococcus pyogenes, and until recently, anthrax.

Its lethal method of swiftly

killing bacteria is astounding. While antibiotics are the carpet bombs that destroy both harmful and harmless organisms in the body by working slowly, giving bacteria time to build resistance, lytic enzymes are the guided missiles that rapidly destroy bacteria of a specific strain while doing no harm to cells of the body.

> "While antibiotics are the carpet bombs...lytic enzymes are the guided missiles..."

Decades ago, the notion of lysins almost instantly killing bacteria was nothing new. Antibiotics usually did the trick of treating an infection, and scientists did not take much interest in studying the lytic mechanisms of phages. Fischetti stated in a 2004 interview with The Lancet, "If we had published a paper 20 years ago describing our ability to kill gram-positive bacteria with enzymes, I don't think we would have received much interest. The idea of killing bacteria with lysins is a really simple concept, but there was no apparent need."

The advent of antibiotic resistant bacteria posed new problems to scientists, and Fischetti jumped at the opportunity. "We have resistant organisms, and the emphasis is on finding new ways of killing them. ... So the whole strategy is becoming much more accepted than it would have been," stated Fischetti. The Defense Advanced Research Projects Agency (DARPA) provided him and his team with two grants to work on lysins - the first is to research lysins to treat normal disease-causing, or pathogenic, bacteria, and the second is directed to lysins for biowarfare agents. Soon after September 11, 2001, he directed efforts toward identifying an enzyme that could destroy anthrax bacteria, afterwards publishing a paper in Nature on his research with this potential biowarfare agent.

Anthrax spores are hardy organisms, resistant to most chemicals used to sterilize contaminated areas. They have a tough outer coating that protects them from most forces of nature. However, even anthrax has its natural predators. The bacteriophage is able to drill holes into the cell using lysins to explode it and release viral progeny. In 2004, Fischetti's group identified one of the specific lysins, called PlyG, that targets anthrax and can be used to treat infected humans and animals. They also identified a second lysin, called PlyPH, that can be used to decontaminate areas and treat infection. The two lysins are so specific that when placed in a lawn of bacteria containing both anthrax and other organisms, only the anthrax was destroyed in a matter of minutes. He observed no issues with resistance against the lysins.

On the more common and problematic issue of antibiotic-resistant bacteria, Fischetti and his colleagues identified and purified a lysin enzyme, Cpl-1, that can successfully treat mice infected with the Streptococcus pneumoniae organism responsible for bacterial meningitis. This bacterial strain is highly resistant, deadly, and difficult to treat, especially when antibiotic resistance is becoming more widespread.

Fischetti and his colleagues from the Institute for Infectious Diseases in Bern, Switzerland discovered that treatment with Cpl-1 eighteen hours after infection with S. pneumoniae eradicated all the bacteria within four hours without harming the mice. Lysin was 100 percent effective in curing the mice if it was given within 24 hours of exposure, compared to traditional antibiotic therapy. Treatment was less effective after 48 hours, however. If this research finds its way into clinical treatments, it will be possible to treat life-threatening, resistant infections, as well as treat and prevent simple infections such as earaches in children.

The Future of Phage Enzymes in Therapeutics

Despite its efficacy in animal experiments, lysins have yet to become implemented as a clinical treatment for human diseases. Since the phage enzymes are considered "foreign" to the human body, the immune system and cilia hairs of the respiratory system rapidly clear them before they get a chance to produce a clinically significant effect.

Fischetti discussed several possible methods of delivering lysins to the human body in his 2005 lecture at Rockefeller University. One is to cover the enzymes in small fat globules, or micelles, so that when introduced into the system, the micelles slowly erode to release the enzymes. They can then be used in spray form, either nasally or orally, to prevent infection. This would be especially helpful to healthcare workers and daycare staff who are constantly exposed to bacteria.

Another hurdle is developing enzymes that could enter gram-negative bacterial cells. So far, the Fischetti group has identified enzymes that could attack gram-positive bacteria, which have a different cell wall structure than gram-negative bacteria. They now possess some clues that could help them identify these enzymes, but the complex outer membrane of the gram-negative bacteria presents a challenge.

Fischetti admits that society may have a difficult time parting with their antibiotics, but the advent of antibiotic-resistant bacteria signals new approaches to tackling pathogens. "We need to keep an open mind when dealing with infectious diseases. There's a whole generation of people who have grown up with antibiotics, as the only way to control infection. But there are other ways to control bacteria, we just need to find them..." said Fischetti about the implications of his phage research. "We have nothing at this point to control these diseases. Zero...this could finally give us something."

the brainiacs

Elizabeth Lindhardt Robinson

The woman next to me on the subway doesn't know this, but the white plastic bucket at my feet is full of sheep brains.

I'm headed uptown with several other Columbia University students to teach an afterschool neuroscience program at Community Health Academy of the Heights—a run-down public middle school in a Dominican neighborhood in upper Manhattan. Today is a lesson our students have long been looking forward to: brain dissections.

Science in middle school is fun. You get to play outside and watch explosions and touch slimy things, like the rubbery grey brains floating around in our bucket. As an undergraduate finishing up Columbia's notoriously difficult introductory biology course, I'm jealous.

After an awkward subway ride hoping other passengers weren't reading the label on our bucket, we arrive at 181st street and walk two blocks past empanada carts and street vendors to the school. Nearly all of us are White or Asian and wearing glasses, and on these streets, 67 blocks uptown from Columbia, we stand out.

School is still in session when we arrive. Behind the closed classroom doors we hear students chattering and the raised voices of teachers saying: "Hey, sit down!" and "class isn't over yet!" It's Friday afternoon, and the weather outside is lovely. Great.

While we wait for the bell to ring, we consider the walls we're leaning against. Every week, more and more brown particleboard is nailed to them with no apparent purpose. Puzzled, we asked a group of students loitering in the hallway.

Apparently, when boys fight in the hallways, they shove each other against the walls, leaving craters in the ancient, pea-green sheetrock. The particleboard is there to keep the walls from caving in.

Finally the bell rings, and the hallway is chaos as we push our blue wheelie-cooler full of supplies into the classroom for set-up.

Akyl, a skinny Dominican sixth-grader and one of our best students, sees the white bucket we're carrying and asks, "What's in there?"

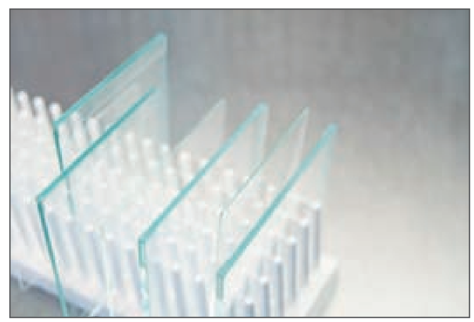
"Brains!" I say, and his eyes grow to double their normal size.

"Real brains? Do we get to cut them up?!" No trace of science-phobia here.

"Yeah! They're pretty slimy though so we're going to need to set up first."

We are the Brainiacs, and every week we see the crisis of public science education played out in inner-city schools. The ten of us, mostly pre-medical neuroscience majors, team-teach an afterschool program once a week at both Community Health Academy of the Heights and a Harlem charter school called Thurgood Marshall Academy.

Though we teach neuroscience exclusively, our primary goal is to alter the idea that students have, even as early as the sixth grade, that science is



boring and difficult. We are all passionate about science, and we believe that by sharing our enthusiasm and showing students that science is important and creative, we can start to correct their misconceptions.

These are inner city kids: tough, street-smart, and difficult to convince. Still, they are curious and extremely bright, and they're dreaming big. Each semester, we start our first lesson by asking them what they want to be when they grow up, and they still give wonderful answers like, "poet-fashion designer," and "doctor-firefighter." This gives us hope that we are catching them early enough to make a difference.

Unfortunately, our program is not well funded. We bought the brains online and borrowed dissection kits from another program for scalpels and scissors. We pilfered clear plastic trash bags from the Columbia dorms and cut holes in them for the kids to wear as aprons. Surprisingly not a single one of these very fashion-conscious seventh graders hesitated to don one. Kids love dissections.

Community Health Academy of the Heights recently won a $2 million grant from GE, a portion of which was allotted for after-school programs. We were excited, initially, thinking that the school might help us pay for supplies, but it seems the new money has only made matters worse.

Now, in the middle of class each week, a student interrupts our lesson to hand out some variation on crackers and juice for a snack. We already give the kids snacks, and the interruption throws our lesson off track.

One day, all but two of the girls in our class were absent. We asked one of the remaining girls where they were, and she said "they're at dance practice." Apparently, an afterschool dance program had just been launched, and rehearsals were at the same time as our class. We never had more than two girls in class for the rest of the semester.

Though all of the Brainiacs love teaching, none of us want to be teachers. "When we pay so much for our education we want to get into a career where there's prestige or money," says Ying Li, the straight-talking international student who founded the program three years ago, "There's neither, I think, in teaching." Ying was recently accepted into the M.D./Ph.D. program at University of Texas Southwestern.

"Teaching in public school isn't something that somebody from Columbia does," says senior Brainiac Eric, adjusting his black-rimmed glasses. "If a Columbia student goes into education it's at the administrative level where you can make six figures." Eric (he asked me to change his name—med school admission committees are always watching), plans to earn both an M.D. and an M.P.H. before looking for work in public health administration.

I'm interested in science journalism, a career where I certainly don't expect to make six figures, but as Ying points out, I'm an anomaly.

"I don't want to be just another drone teaching some state's curriculum," says Eric.

"But isn't a doctor also a drone? Providing a service?" I asked.

"Yes, but teaching is not fun when you've been doing it for 25 years and you're stressed out."

"So being a doctor is fun after 25 years when you're stressed out?"

"Well no, but you get to go golfing once in a while. You have the money to do that. It's the balance of the compensation and the stress level. I know I'd be an awesome teacher and if someone told me I could make six figures doing it, I would do it."

For others, the problem is prestige. "I think there is definitely a stigma against science education," says Ying. "There's a reputation that the bottom of the barrel goes into education, and usually because they can't do anything else." For successful science students, public school teaching is a step back in both compensation and esteem. Furthermore, being a science teacher forces you to the fringes of the science community. Nobody who is passionate about science wants to go there.

But even at Columbia, a powerful research university, teaching is despised. For many scientists, teaching undergraduates is a chore, a burden, a hateful obstacle on the road to tenure. They make it clear through their begrudgingly delivered PowerPoint lectures and their skimpy office hours that teaching undergraduates is not something they do willingly.

Worse yet, more and more undergraduate teaching is forced upon over-worked graduate students with zero experience teaching, and in many cases, limited English language skills.

For Melanie Cooper, a chemistry professor at Clemson University in South Carolina, undergraduate courses such as these are largely to blame for science illiteracy in the United States. In a presentation at the annual AAAS conference in San Diego this year entitled "Introductory Courses are the Root of all Evil," Melanie illustrated with numbers and anecdotes that even students with high scores on standardized tests come away from introductory science courses with "bizarro ideas about what a bond is."

Melanie points out that this situation is not so bad for students headed to graduate or med school, where their misconceptions will be corrected in labs and small-scale courses, but for public school teachers, these giant, boring, lecture-only undergraduate classes are where they learn most of the content they will teach.

From public elementary schools all the way up through Ivy League Universities, science education in the United States is broken. According to the Programme for International Student Assessment, which evaluates student learning in developed countries, students in the United States rank 17th in science and 24th in math among developed countries. We're below the countries you'd expect: Finland, Japan, and Germany among others, but we're also behind "developing" countries like Croatia, Latvia, and Estonia.

The National Science Foundation published a report showing that in 2006, only 54 percent of Ph.D. s awarded in the U.S. went to U.S. citizens. And the rate of growth for international students was triple that of U.S. citizens, suggesting that the number of Ph.D.s we award to international students, many of whom return to their home countries, will soon surpass the number that go to citizens. High-level science education is increasingly a commodity for profit rather than a service for American citizens. We are selling the best higher education around to the brightest students of other nations,

Our public education system is bureaucratic, political, and undervalued, and the consequence is a society of ignorance and apathy toward scientific issues, and fewer and fewer students pursuing careers in science.

The Obama Administration says it is working on it. There is more money in public education now than ever before, much of it concentrated in science through the Educate to Innovate program, which is intended to promote American competitiveness in science through increased funding and new programs for public school science. Still, the roots of our education problem run deep, and it remains to be seen whether or not Obama's new education plans will make a difference.

According to Evelyn Roman, who has worked with the New York City public school system as a curriculum adviser and program developer for 24 years, "once again with this new reform, they are missing the boat."

I met with Evelyn to in the Columbia student center where

> "...students in the United States ranked 17th in science and 24th in math among developed countries..."

we talked over a small wobbly aluminum table outside the cafeteria while her daughter, a precocious nine-year-old with purple glasses, skipped and danced around, enjoying the open space and the attention of passing college students.

Evelyn works closely with both teachers and school administrators to develop science and math programs for urban schools. She sees how schools spend their money, and she watches as students start falling behind.

Her first complaint is the disconnect between teachers and school administrators. "There are schools that don't even have enough money for paper. That's basic. But yet the administrators make six figure salaries," she says, "when schools get more money, it doesn't trickle down to the teachers."

At Thurgood Marshall Academy, where we teach a group of seventh and eighth graders, each student has a notebook where, at the end of each lesson, we ask them to write about what they learned. We were surprised to discover that not a single one of these 12 and 13 year-olds can write in complete sentences.

"Cells, we saw the frogs brain, which is the dendrite. And the axon—send messages," wrote one. "I learned about axon send messages and a dendrites that that receive the messages," wrote another.

It is clear that they are learning (the axon is the part of a brain cell that sends messages and the dendrites receive them) but they do not understand how to structure their thoughts. I asked Evelyn, who has worked with Thurgood Marshall Academy for years, why they never learned.

"Basically the kids learn how to read on their own, and there's not a lot of phonetics being taught." She explained that in many classrooms in Washington Heights, students learn to read from different books at different paces, rather than working together to learn sentence structure. "A lot of kids don't have the opportunity to learn to write, to express their voices through words," says Evelyn.

Poorly trained and inexperienced teachers allow their classrooms to fragment, with a few students progressing while the majority lose interest and fall behind. "A lot of the teachers that I train come from the best schools of education in the country, and they don't feel adequate about teaching. They don't feel prepared to teach," says Evelyn.

"I think the schools of education are the problem," She says. "They feel that because they are in academia, they have to continue to invent and renovate, when some of the old traditional ways of teaching should really be left alone...They keep reinventing the wheel when the real problem is implementation."

"At Teachers College," says Evelyn, referring to the Columbia school of education, "they tell me, 'Well you teach the science and we'll teach the pedagogy.' But I don't understand how the pedagogy could be divorced from the science or the content. Right there it's telling you they're just teaching theory but no methodology or implementation. And the teachers come out ill-equipped."

One of the biggest problems Evelyn sees is testing. "They test the kids to death, but yet they have no stride and no academic gain. We know that doesn't work." She laments the sad truth that testing will continue, and perhaps even intensify, with the Obama administration's new education reform.

For Evelyn, we don't need anything new to fix science education. "If you cut classroom sizes, if you increase the preparation of teachers and also if you increase the hours that the teachers have peer mentoring from veteran teachers that are really good, it would improve teaching automatically," she says.

"What about Obama's "Race to the Top" program?" I asked.

"I read his education plan. I was not impressed. I've been around for twenty-something years and it's basically a time capsule. The same problems I've seen over and over in education reform. The system is too politicized."

We see this politicization expressed in the biographies of many of the people appointed to leadership positions in education. They aren't teachers. "These people are career politicians," says Evelyn. U.S. secretary of education Arne Duncan, for example, has never taught in a classroom. "They need to open up the dialogue with teachers, with people who are in the trenches and who are doing it. There aren't enough practitioners at the table," says Evelyn.

I got a chance to see the other side of the education decider-practitioner divide in February when I attended the annual conference of the American Association for the Advancement of Science in San Diego.

As I listened to panelists present their ideas and research on science education issues ranging from teaching evolution to the politics of funding, I thought about CHAH and the teachers I met there. The disconnect Evelyn talked about was clear. These people were academics, and as such they were looking for a new, scientific, evidence-based solution to the education problem.

After a session on informal learning in science museums, I approached Martin Storksdieck, the director of the board of education of the Nation Academy of Science, for an interview.

We met on a rainy morning at a generic-looking coffee shop next to his hotel. I suspect he was still in bed when I called him at 7:30 AM, but he arrived 20 minutes later, more awake than I was.

In his position with the National Academy of Science, Martin has a lot of influence. He leads a group of education experts who are currently working to develop a new, innovative framework for science education standards. He taught science for several years at a U.S. community college, and it is clear that he bases a lot of his thinking on that experience. Still, his complaints were largely societal and philosophical—the opposite of Evelyn's practicality.

Martin is from Germany, a place where teachers are treated very differently. "[teaching] is a highly respected profession in Germany. It's extraordinarily competitive to get in," he says. "In order to become a teacher in Germany you have to have two equivalent masters in the subject fields." Still, he says that the education system in Germany is faulty just like ours, and grappling with many of the same problems.

For Martin, the problem is that education is an art rather than a science. "In my mind," he says, "its not the problem that we learn, but that we have so little research on turning [science teaching] into a truly science and evidence based profession." I imagined Evelyn's fury had she been at that table with me. "The problem is that we don't teach people what it means to learn, the metacognitive aspect," says Martin.

"One of the reasons why it's difficult to [reform education] is that we have such gaps in our knowledge base. It's very different from physics where it's been built slowly and we just fill in the gaps more and more. Teaching has always been this big problem." He theorizes that turning science education into a lively, connected research community would make it more like physics or engineering, and in turn attract a higher-caliber of student and societal respect. I'm sure it would, but the path to this future is unclear.

I asked both Evelyn and Martin if they were optimistic about the future of science education. "No," replied Evelyn, even before I'd finished the sentence. "I've been around long enough to know that the educational stuff is not changing." The system is too political and education is not valued as the societal cure-all that it can be, she says.

"Yes, I'm optimistic," says Martin, "as long as people are struggling to find answers."

"One thing that people don't realize is that the United States is actually not a first world country. It's a mix...and if you have that level of diversity you cannot expect to perform on a first-world level," says Martin.

Evelyn, talking about our student's sentence troubles, says: "The vocabulary use at home is not that that you would find with parents that are educated. And also the environment that they are exposed to, they don't necessarily find that scholastic engagement or discourse."

And because the best higher-level education in the world is in the U.S., learning science has a much greater value for top students in other countries. Ying, who came to Columbia from Hong Kong, says "Science is seen as a way out because it's something structured that you can go to school for. You can learn a skill, and then you can try to move to the states. It's something tangible."

But for our students in Harlem and Washington Heights, the story is different. As Eric points out, "Who has come out of those neighborhoods? Socioeconomically, you're going to get rappers and you're going to get basketball stars. Those are the success stories that these kids see." The public education system should show them that they don't have to be famous to be successful. Science education should be a way out.

The United States' low international rank in science and math education has many causes, but it is largely socioeconomic. The home environment is an important component of education, and in social situations where education is undervalued and learning is not encouraged, there is only so much that schools can do. Ignorance and apathy toward education are self-perpetuating, with few exceptions.

The problem of the low esteem of education, on the other hand, defies all socioeconomic boundaries. Teaching is a challenging and rewarding profession that is integral to any productive, educated society, yet it is maligned from public elementary schools to Ivy League universities. Changing it will require leadership from public education boards and university administrators to make teaching undergraduates an honor rather than a punishment, and to give school teachers a voice in the issues that they grapple with every day.

The Brainiacs program will continue, as each group of seniors head to medical school and pass their responsibilities and teaching advice down to underclassmen. Our program is only three years old, so our success is hard to measure. We feel that if we inspire even one student each semester to change their mind about science, we are making a difference.

Still, at the end of the semester our students go on to the eighth grade, to other science classes with other teachers, and it is hard to know what lies ahead for them. We may have sparked their interest, but it could easily be snuffed out in high school physics or chemistry, or when parents or peers don't understand.

If nothing else, the kids see us, with our glasses and our giddy excitement over brains, and by the end they don't think it's so strange that we love science.

Steven Yoon

geoengineering

The resignation of Yvo de Boer, the Dutch bureaucrat who has led the United Nations towards an international framework on climate change, has led many to seriously question the feasibility of a global regulation of carbon emissions. Mr. Boer's resignation epitomizes the frustration of the diplomatic world after a largely unsuccessful Copenhagen conference. The resulting three-page Copenhagen Accord has not been ratified nor acknowledged by all United Nations members. More importantly, Mr. de Boer's resignation suggests a general lack of confidence on delivering results with future climate talks. Has the search for a political answer to climate change outlived its usefulness? In this climate, a scientific solution to global warming must be seriously considered.

James R. Fleming, a technology historian, narrates a nightmare scenario where he attends a NASA-sponsored high security clearance meeting available to a select few scientists and engineers. The theme is geoengineering, plans to solve global warming with direct human intervention. The star of the show is also one of Pentagon's chief weapon designers, who takes pride in the Dr. Evil moniker given to him by his detractors. He declares that geoengineering provides "instant climatic gratification," achieved for a tiny fraction of the cost of existing "bureaucratic methods" to quench CO2. Ideas are bountiful; atmospheric scientists, an astronomer, and an acclaimed science fiction writer each share the stage with their schemes to fix the earth. Fleming is concerned for the future; each speaker is "largely silent on the possible unintended consequences of his plan." He takes a walk on the grounds of an old experimental Navy airfield hangar and wonders: when is the design fundamentally flawed?

The scene brings to mind the world of Dr. Strangelove, where science is in bed with Cold War politics and void of moral consequence. Historical precedence indicates that science sometimes shirked controversy by having discussions behind closed doors. This includes atmospheric science: during the Vietnam War, the United States induced artificial rainfall over hotly contested areas with a series of secret operations termed OPERATION POPEYE. After a 1971 expose by the Washington Post, the Pentagon faced significant international outrage over the military use of weather modification. The Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques (ENMOD) was held and signed by eighty-five countries in 1977, cementing Nixon's sole contribution to climate science. Since then, suspicion towards artificial climate change has only grown, with the recent Climategate scandal fueling the fire.

With this background, it is surprising that voices are getting stronger to search for a technological solution to climate change. Paul Crutzen, Nobel Prize laureate and atmospheric chemist, became the biggest name to endorse geoengineering in 2006. He caused a stir in the scientific community with his editorial, Albedo Enhancement by Stratospheric Sulfur Injections, where he claimed injecting 1 to 2 billion tons per year of sulfur into the stratosphere would compensate for a temperature rise caused by a doubling of pre-industrial levels of CO2. His endorsement rests on a well-supported assumption: the light scattering effects of sulfate particles in the atmosphere significantly counters greenhouse warming caused by CO2. Wild et al. found that the decline of global SO2 emissions at the rate of 2.7 percent per year from 1983 to 2001 has a correlation to an increase in solar radiation by 0.10 percent per year. The 1991 Mount Pinatubo volcanic eruption confirmed the positive relationship between sulfate particles in the atmosphere and their effects on global cooling. The estimated 6 billion tons of sulfur released into the stratosphere was found to have a high climate cooling efficiency. Hansen et al. calculated a cooling effect of 0.75 Watts per square meter per sulfur teragram across the globe. Crutzen makes clear the need for further research, but with caution: in order to reap the benefits of this "fortunate coincidence," its risks must be studied carefully.

Proponents for geoengineering argue that sulfate aerosols are a natural component of the Earth's stratosphere, and geoengineering aims only to amplify its effects. Sulfate aerosols are concentrated sulfuric acid (H2SO4) particles suspended in a fluid medium, commonly varying in diameter from 0.1 to 1.0 microns. The size of the particle is determined by the source and the amount of sulfate precursors. The precursors make their way to the stratosphere in roughly two ways: oxidation of free-floating carbonyl (COS) molecules and volcanic eruptions. A large volcanic eruption was shown to spike sulfate aerosol levels and increase the amount of bigger particles. However, the exact reactions causing sulfate aerosol formation is unknown. Pinto et al. found there is a non-linear relationship between the mass of anthropogenic injection of precursor elements and resulting sulfate aerosol particle size.

What role does sulfate aerosols play on Earth's climate? Many studies have been conducted with a simplified model of the Earth climate (AOGCM), which does not take into consideration the effects of the ecosystem, ocean circulation and Arctic climates. The cause of global warming is divided into two sources, based on their source. "Incoming solar energy," is the shortwave radiation from the sun entering Earth, and "outgoing longwave radiation" is the reflected radiation from the Earth entering the atmosphere. Sulfate aerosols scatter incoming solar energy, and absorb outgoing longwave radiation. Rasch et al. found that the effectiveness of light scattering of sulfate aerosols is affected by the size of the particles. Smaller particles were found to be more effective at scattering incoming solar energy while not absorbing outgoing longwave radiation. However, smaller particles also provide more area for surface chemistry, which studies suggest may harm the ozone layer.

The Mount Pinatubo eruption of 1991 was a rare opportunity for geoengineers to corroborate their claims in the real world. The eruption was the second largest volcanic eruption recorded in the 20th century, and covered the Earth's stratosphere with large sulfate aerosol particles. The eruption confirmed that an increased amount of sulfate aerosols in the atmosphere does reduce global temperature. However, it also produced side effects that were not adequately anticipated by simplified climate models. Trenberth et al. found the eruption caused major disturbances in the hydrological cycle during the 1992 water year. Precipitation levels were 3.12 standard deviations below normal projections and river discharge levels were 3.67 standard deviations below normal projections. Dai et al. found the year 1992 had "a peak percentage of global land areas under drought conditions." Effects were more pronounced in heavily populated tropical regions, especially parts of South Asia and Latin America. Barring unlikely coincidence, the Mount Pinatubo explosion was the major cause of disrupted hydrological cycles.

"The fascination with fluctuations in global average temperatures, although understandable, cannot serve as a proxy alone."

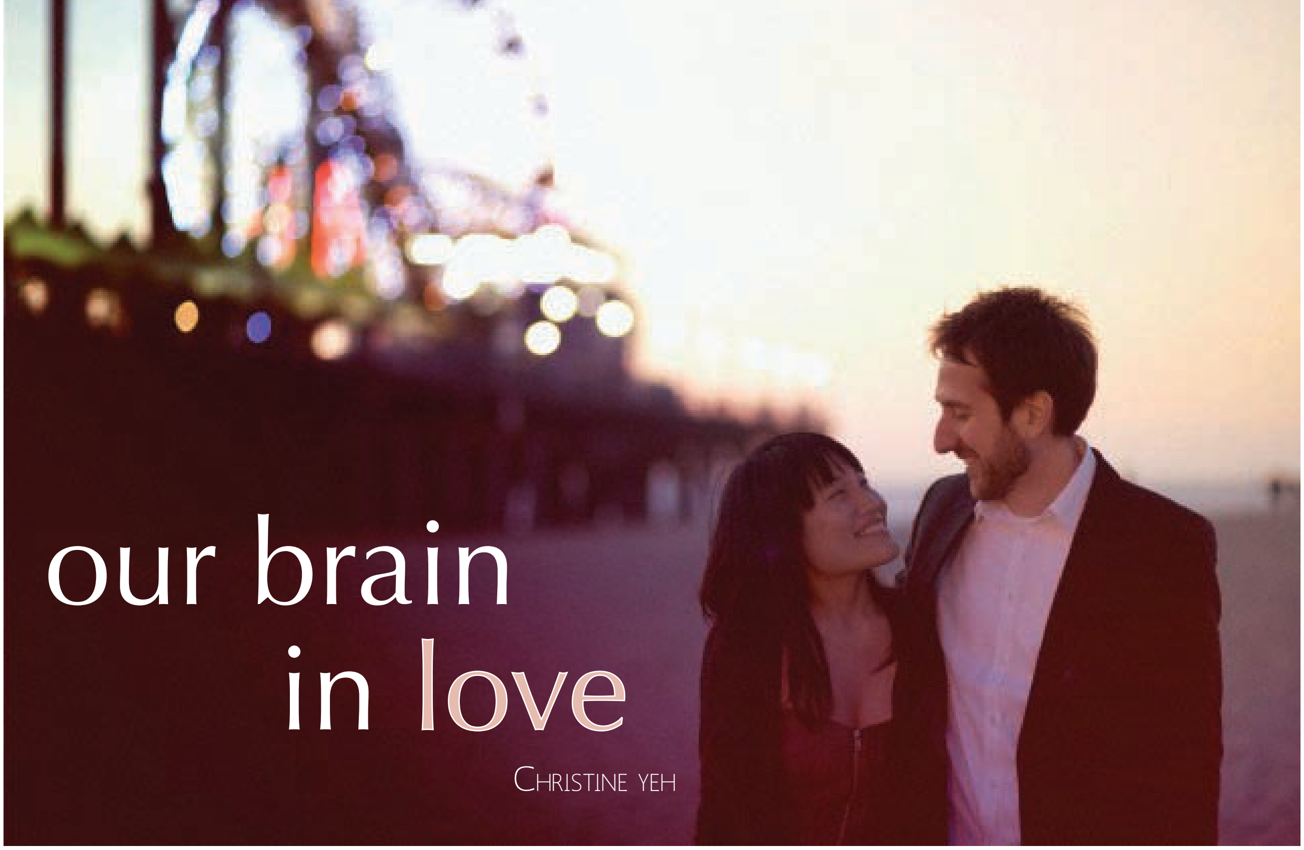
Although Mount Pinatubo's cooling effect on global temperatures was confirmed, the effect on regional temperatures had mostly been overlooked. This may have come with scientists using preliminary models that did not adequately address the complexities of Earth's climate. The fascination with fluctuations in global average temperatures, although understandable, cannot serve as a proxy alone. Robock et al. found that under a simulated increase of sulfate aerosols in the stratosphere, traditional summer monsoons weakened over Asian and African countries and created higher regional temperatures. The study concludes that an inefficient hydrological cycle has a negative effect on regional surface temperatures. There are two major explanations for this phenomenon. First, an inefficient hydrological cycle would cause less monsoon clouds to be present in the atmosphere. This would cause incoming solar energy to directly heat the Earth's surface. Second, an inefficient hydrological cycle would disrupt surface heat reflection by evaporation, known as "latent heat". As latent heat is the main source of outgoing longwave radiation from the Earth, its disruption would contribute to higher regional temperatures on Earth's surface.

Likewise, increased amounts of sulfate aerosols in the stratosphere have been connected to the reduced efficiency of hydrological cycles and uneven regional temperature distributions. The global climate was found to be more interconnected previously assumed, and simplified planetary models such as AOGCM cannot adequately address the complexities of Earth's climate. Part of the reason is moral concerns; if one country initiated geoengineering efforts, increased sulfate aerosols levels would spread throughout Earth's stratosphere, and the entire world would be affected. It also must be noted that regions with the most risk would be the world's most highly populated tropical regions. Therefore, who will control the planetary thermostat?

To borrow Fleming's words, is the sulfate aerosol approach fundamentally flawed? Faced with ever-increasing CO_2 levels in the atmosphere, the search for man-made solutions to quell global temperatures seems like placing a band-aid over a mortal wound. High CO_2 levels contribute to far more complex environmental problems than increased global temperatures. Caldeira and Wickett have found absorption of CO_2 in the ocean has already caused the pH of surface ocean water to drop by a value of 0.1 units, and will fall an additional 0.3 units by the end of this century. This would be the lowest value in 300 million years, and would have devastating effects on the marine ecosystem. Moreover, CO_2 has a very long half-life in the atmosphere; Matthews et al. found near-zero emissions will be needed in the future for the goal of attaining a stable global temperature. If future emissions of CO_2 will irreversibly tax the climate, would we have to pump in exponentially increasing amounts of sulfate aerosols into the atmosphere to maintain the status quo?

With such serious potential consequences of increasing sulfate aerosols, we must demand Crutzen to give us the facts: why would a scheme with such serious flaws gain traction in the scientific community? According to Crutzen, if a "low probability, high consequence" scenario of rapid global warming is realized, we must have a solution that is readily deployable. Crutzen believes the sulfate aerosol method to be the most economical, as continuous deployment of sulfate would not exceed his estimates of $25 to 50 per affluent capita per year. Feasibility studies using existing technologies, such as rockets and cannons, indicate that rapid deployment is a possibility if deemed necessary.

The calls for geoengineering research also serves as a wake-up call: the climate change debate has been endlessly politicized, while the indications of large-scale climate changes have long been scientifically established. The best justification for further geoengineering research is research itself; to increase knowledge, and to leave humanity with options for the future.



our brain in love

Christine yeh

"There is always some madness in love. But there is also always some reason in madness."
- Friedrich Nietzsche

What is it, really, to love? For centuries, philosophers, poets, and writers have spent endless hours attempting to make sense of the myriad emotions and complex behaviors associated with romantic love. When two people are deeply in love, it seems as if the world is spinning solely for them. Senses become heightened in this blissful state: a word, touch, or gesture can trigger bouts of ecstasy, and rejection can trigger enormous despair. In addition to being overwhelming, love can also be irrational, dangerous, and petty. As Nietzsche and almost everyone who has experienced love can attest, love's varied personalities can seem capricious and incomprehensible. However, recent neurological research on the brain in love has revealed some fascinating findings on the biological mechanisms behind the madness.

Helen Fisher of Rutgers University has been a pioneer in the study of the neural underpinnings of romantic love. Determined to find regions of the brain associated with the intense feelings of being in love, Fisher and her colleagues performed functional magnetic resonance imaging (fMRI) scans of twenty men and women who reported to be head over heels in love. The experiment involved showing a photo of the subject's significant other, followed by distraction tasks to rid the brain of residual emotion, and then a final neutral photo. The fMRI scans of the brain when viewing the photo of the significant other demonstrated significant increased activity in the caudate nucleus, a primitive brain region that is associated with reward-seeking behaviors. Another significant brain region with increased activity was the ventral tegmental area (VTA), which houses cells that generate dopamine, a neurotransmitter that produces focused attention, motivation, and exhilaration: common symptoms of the lovestruck.

In addition to the fires that rage in our brains when we are in love, low serotonin levels in the blood have also been implicated as a culprit in the obsessive nature of romantic love. When Italian scientists in 1999 compared the serotonin levels in individuals with untreated obsessive-compulsive disorder with those who were newly in love, both groups demonstrated decreased levels of serotonin in the bloodstream. Furthermore, patients with obsessive-compulsive disorder are often prescribed antidepressants that fall under the category of selective serotonin reuptake inhibitors (SSRIs). Thus, the constant, obsessive daydreaming, replaying of conversations, and memory of small details associated with one's beloved may be attributed to the brain's decreased production of serotonin in the early whirlwind stages of a romantic relationship.

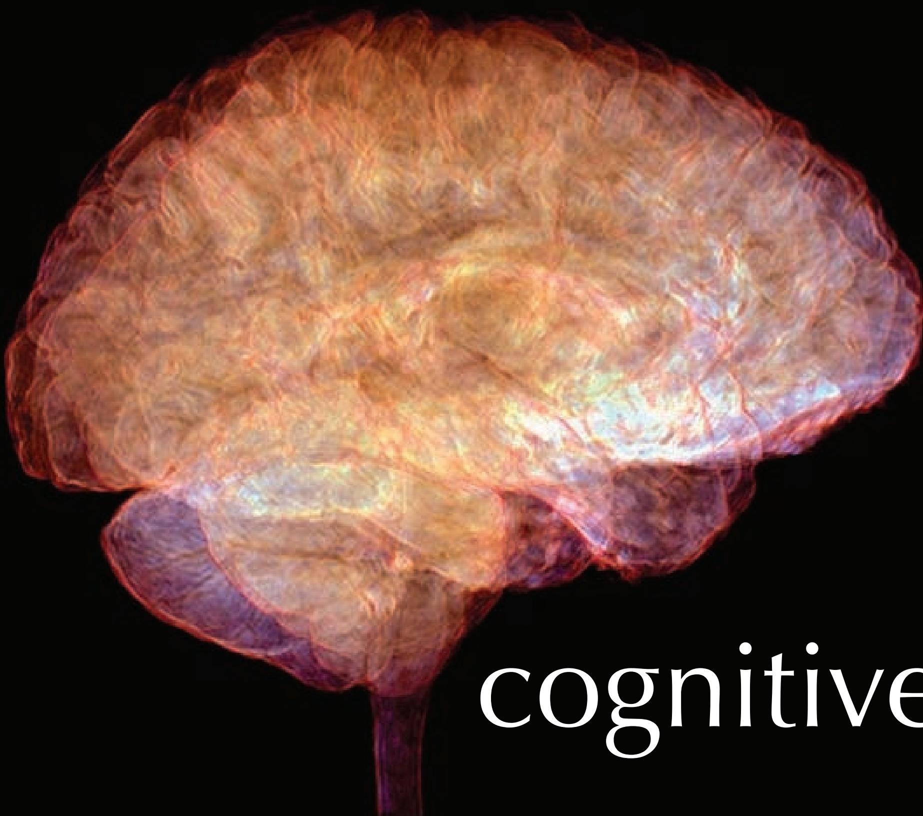
Yet romantic love rarely acts alone: almost always it is accompanied by its sidekick, sexual desire. Lust is closely intertwined with romantic love, although the networks for love and lust are physically separate. Strong sexual arousal activates the limbic and paralimbic brain structures: the right amygdala, right anterior temporal pole, and hypothalamus. Hormones are also responsible for the human urge to procreate. Both males and females with higher circulating testosterone levels than average have been shown to participate in more sexual activity, and declining testosterone levels in men in middle and old age have shown to produce decreased libido. For two-thirds of middle-aged women, however, declining estrogen levels unmask testosterone, contributing to piqued sexual desire.

The networks for sex and romance frequently communicate with each other: romantic feelings can trigger lust, and physical desire can morph into deep emotional attachment. In one experiment performed by researchers at the Mississippi Neuropsychiatric Clinic, scientists studied 364 patients with recurrent major depression and sexual dysfunction: one group was given Sertraline (Zoloft, Pfizer), an SSRI, and another group was given bupropion (SR) (Wellbutrin SR, Glaxo Wellcome), which is believed to enhance dopamine production. After follow-ups over the course of eight weeks, significantly more individuals who took bupropion reported improved sexual performance. Thus, the correlation between these two pathways may explain why some people report falling in love with their best friend, and why casual sexual liaisons can seldom remain casual under the force of our complex brain architecture.

Larger questions emerge from these scientific observations: why have humans evolved these particular neural networks that allow them to fall in love with only one individual at once? Why is there such an intense craving to be united emotionally and sexually? Why do some lovers become possessive and jealous, and why does the passion and desire wane with time? Why, in the words of Ambrose Pierce, is love "a temporary insanity"?

The answers, Fisher proposes, are probably evolutionary. She theorizes that, when the ancestors of humans made the transition from trees to the grasslands, the development of bipedalism meant that females could not easily carry their young on their backs, and more energy had to be expended to rear children and search for food. The increased hassle meant that men were probably recruited to help raise and protect the young; monogamy became the sensible option. As women sought out partners who would be loyal and responsible fathers, the brain developed mechanisms that would allow them to focus and become romantically and sexually attached to qualified candidates. The neural network involved in producing the dopamine that produces such elation, craving, and preference for a particular individual likely evolved to unite two lovers long enough to procreate. After the rearing stage was complete, neural networks for attachment would become active, replacing the madness of love with the deep bond found in collaborative parenting.

What, then, does it mean to be in love? Are we mere puppets of evolution, and love the puppet master? Scientists have mapped out our inner worlds for us to see and decide.



cognitive reserve

Abbey Elizabeth Vandersall

Cognitive reserve is a concept used to describe why some individuals cope better than others with the same degree of brain damage. It provides an explanation for the disparity in clinical manifestations of individuals with the same degree of brain pathology. Cognitive reserve can be broken down into two categories: neural reserve and neural compensation. Neural reserve looks at the variations in the efficacy, capacity, or plasticity of brain networks to explain this discrepancy. For instance, an individual whose brain networks are more efficacious could cope better with brain pathology than another individual with a less efficacious network. Neural compensation suggests that some individuals are simply able to compensate for brain detriments better than others.

FIGURE 1

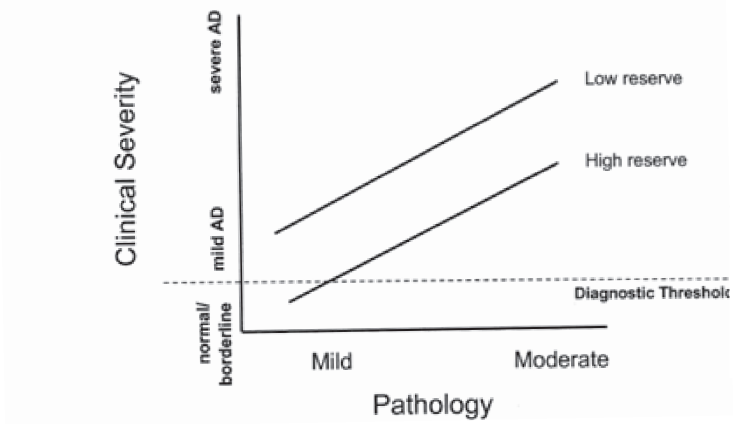
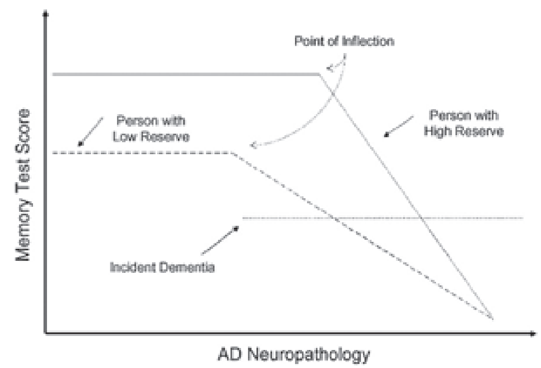


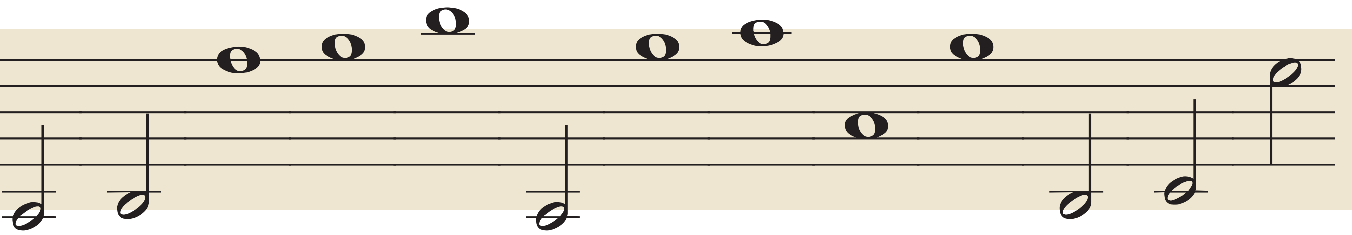
FIGURE 2



Cognitive reserve can be applied to many situations where an individual sustains a brain injury. It is interesting to look at brain damage associated with Alzheimer's as brain pathology; the disease is typically located in similar neural locations across individuals, in contrast to the widely variable neural damage associated with a stroke. Furthermore, dementia associated with aging does not demonstrate a clear correlation between degree of brain pathology and clinical symptoms. The concept of cognitive reserve can be clearly understood when used to compare two individuals with the same degree of brain pathology, one with high reserve and one with low reserve. Figure 1 demonstrates that at any degree of brain pathology, individuals with a lower cognitive reserve present more clinical manifestations than individuals with a higher cognitive reserve. This idea is supported by the observation that up to 25 percent of elders meet the pathological requirements for Alzheimer's disease at the time of their death, despite not presenting as impaired in neuropsychological testing. Figure 2 is an illustration that suggests how cognitive reserve could impact the correlation between brain deterioration and the execution of cognitive tasks, in this case a memory task. It implies that for an individual with high reserve, their memory will remain unaffected at higher degrees of brain pathology than for an individual with low reserve. Therefore, the two individuals will have different levels of neuropathology associated with Alzheimer's disease when diagnosed with clinical dementia.

While it is clear that cognitive reserve is looking to individual variation in cognitive processing and neural circuitry to explain this disjunction, there is evidence to suggest that cognitive reserve is not simply a result of genes but rather gene-environment interactions. Studies have shown that cognitively stimulating environments and exercise can promote neurogenesis, the process where new neurons are generated, in the dentate gyrus, located in the hippocampus. Additionally, there are studies that suggest that stimulation directly affects pathological disorders. Cognitively stimulating environments could slow or perhaps stop the brain deterioration associated with Alzheimer's disease. For healthy elderly individuals, studies suggest a correlation between intellectual and social leisure activities and a slower cognitive decline.

Despite the prominent epidemiological evidence supporting cognitive reserve, there are still many questions. The concept of cognitive reserve was proposed to explain macro-observations, but many researchers are working to further understand cognitive reserve on a neural level. In addition to the research discussed, there are also many fMRI studies that have been and are being carried out to further understand how the brain changes with aging, how the environment can affect the brain, and how these changes in the brain relate to cognitive tasks. Ultimately, many are hopeful that cognitive reserve and the research performed around it will be a successful starting point for finding ways to slow or hinder the onset of dementia associated with aging.



a musical solution

David Rhee

"Every disease is a musical problem; every cure is a musical solution."

Georg Philipp Friedrich Freiherr von Hardenberg

Parkinson's disease (PD) is a degenerative disorder that affects one's normal motor functions. As the disease progresses, Parkinsonian patients might exhibit a shuffling gait, a rigid posture, an expressionless face, and uncontrollable tremors. PD results from the death of specific neurons in the region of the brain stem called the substantia nigra - a region important to the production of the neurotransmitter dopamine. In normal patients, these neurons provide the primary pathway for dopamine to another region called the caudate nucleus. Therefore, the subsequent degeneration of these neurons in the onset of PD results in improper caudate nucleus function.

The caudate nucleus region of the basal ganglia system is believed to be responsible for the initiation of movement. Its dysfunction accounts for the inability of patients with Parkinson's to begin simple movements, such as getting out of bed. In addition, other motor functions, such as gait and speech, are negatively effected. Parkinson's patients are not paralyzed in the traditional sense because they are able to respond to stimuli, like catching a tossed ball. Instead, they are "trapped" by their inability to spontaneously will movement. Many times, the patients move in a discontinuous stop-and-go manner described as "kinetic stutter."

The ability of music to overcome this kinetic stutter in these subjects has been well documented. Frances D., a Parkinsonian patient, would sit rigidly with periodic bursts of ticcing and jerks. When exposed to music, she is completely freed from her twitches. She stands up and dances to the rhythm of the song. With an exuberant expression and a conducting hand, she swings her body in a seamless flow.

In early medical literature, there was a vague consensus on music's therapeutic value and there was a general belief that it could do nothing but good. It was only in the late 1940's that the idea of formal music therapy became defined. In the Second World War, some soldiers returned from the front lines with cases of head trauma, Post-Traumatic Stress Disorder (PTSD), and other general maladies. As physicians discovered that many psychological and even physiological symptoms were noticeably alleviated by merely listening to music, they began to hire musicians on a regular basis to perform for their patients. The soldiers not only reported experiencing less pain but also showed improvements in their blood pressures and heart rates.

And in a similarly "magical" manner, music therapy also improves the quality of life in PD patients. Research has shown that patients who undergo music therapy exhibit a significant improvement in their motor functions and in their motivational and emotional well-being when compared to patients who do not undergo music therapy. It has even been shown that simply imagining music is enough to produce this liberation; however, it is often extremely difficult for PD patients to initiate this internal music. Furthermore, the beneficial effects of music therapy (internal or external) seem to decline after the conclusion of each session. Only two months after the conclusion of the music therapy course, there was no significant difference in motor function or emotion between the Parkinsonian patients who received musical therapy and those who did not.

It has been suggested that the rhythm in music provides a template for movement - a motor "clock" - that is critically lacking in PD patients. Neurologist at Columbia and best-selling author of Musicophilia, Oliver Sacks writes, "Music, indeed, resists all attempts at hurrying or slowing, and imposes its own tempo." Dr. Sacks encountered one patient whose movements were too fast on his right side and too slow on his left. Physical treatment was tricky because alleviation of one side usually led to exacerbation of the other. But this patient loved to play his organ and when he did, both hands played in unison.

It has also been suggested that the sensory stimulation and social interaction in music therapy may initially provide psychological and emotional benefits in PD patients; however, these effects are temporary. Seeing as it has been documented that one's emotional stress strongly influences abnormalities in motor performances such as gait, the psychosocial benefits of music may be the "key player," pun intended, in the facilitation of movement. This is in accordance with the inability of traditional physical therapy, which has negligible effect on emotional states, to produce significant results in PD patients.

The power of music on the mind remains a relatively untapped goldmine. It has been shown that music also has therapeutic value for patients with amnesia, Attention-Deficit Disorder (ADD), Tourette's, and aphasia. Compared to some physical therapy and medical treatment, music therapy does not require bulky, expensive equipment. It also is noninvasive and relatively less demanding on patients. For the past four decades, the versatility, efficacy, and simple elegance of music therapy has galvanized the scientific community to systematically and critically research the actual mechanics behind the melodies, but much still remains unsolved in this dynamic field. Even after the neurobiological pathways of music are established, there may still remain a sense of wonder that will forever elude science.

a gift of life

Helena (Hao) Wu

In 1954, the first successful organ transplant was performed by Joseph Murray, a plastic surgeon who transferred a kidney from a twin donor. Since then, almost every organ in the body—ovary, pancreas, liver, kidney, heart, bladder, lung and bone, and even testes—have been transplanted. The prospect of receiving a completely new organ provides hope for patients with end-stage organ failure or infertility. Organs obtained from deceased or live donors are practical, cost efficient, and offer a long-term solution to individuals who otherwise have a life expectancy of only a few years.

The benefits of organ transplants have caused the demand for organs to skyrocket, especially when finding a suitable match is a tedious and difficult process. It starts from the United Network for Organ Sharing (UNOS), the official database for facilitating organ transplants in the United States. The database contains recipient and donor information from transplant centers across the nation. The organ must be transplanted within several hours after removal from the donor, so the decision to find a recipient must be made quickly. In many cases, the retrieval team travels via helicopter to obtain the organs from deceased donors while the surgical team prepares the recipient in a neighboring hospital. Procuring organs is a complex and time sensitive procedure. The transplant team must perform extraction immediately after the donor is deemed dead, inject preservative into the organ, and then perform the surgery within hours.

The scientific community is trying to improve the technology so that organ-patient compatibility can be optimized and post-transplant complications can be reduced. The donor and recipient must be matched for

MHC antigens and HLA proteins, which are surface markers on cell membranes. They identify foreign substances and alert the immune system to attack. Even if the match is nearly perfect, the recipient must take immunosuppressant drugs for a lifetime. These drugs suppress the immune system so that the transplanted organ will not be destroyed by the neutrophils, a type of white blood cell that combats foreign microbes or cells. At the same time, the drugs compromise the body's ability to fight infections and tumors. To address this issue, Kawai and Cosimi, leaders from the Massachusetts General Hospital research group, have proposed an innovative approach of partially destroying the patient's bone marrow with radiation. Since the T-cells, another type of white blood cells that is central to the immune system, are killed, they will interfere less with the foreign organ. To regenerate the immune cells, bone marrow from the donor is given to the patient so that the new T-cells will be accustomed to the new organ. The treatment has been tested on five subjects and four of them have been drug free for at least five years. Kawai and Cosimi's methodology reduces the negative consequences of transplantation.

Due to the recent success in technology, the one-year survival rate for organ transplant patients is as high as 98% for kidney transplant with the lowest being 75% for heart-lung procedures. Five-year success rates range from 49.7% for heart-lung transplants to 90.3% for kidney transplants. What worries the public is how replaceable humans parts are. New organs can prolong life, but how much of a person's body is still his or her own after many of the organs have been replaced?

There are also ethical issues related to which patients will receive the organs since live donations are usually from family members and close friends. Less privileged individuals without a social network may not be able to receive organs as quickly as those whose family and friends are willing to donate. Also, the recipients may feel indebted to the donor or the donor's family, and carry a psychological burden.

Donated organs are "precious gifts of life," but the growing desperation of patients has led them to become commodities that fuel the black market economy. Organs are scarce, and around the world, nineteen people die every day waiting for a transplant. Organ theft is highly common in countries with poor regulations. Patients waiting for organs in the U.S. can elect to buy a new organ from Asia and have the surgical procedure completed in a timelier manner. For example, in 2008, a clinic outside New Delhi sold about five hundred organs illegally pilfered from unsuspecting victims.

The future of organ transplant may lead toward customized organs. Instead of relying on organs from human donors, researchers are trying to grow organs in a laboratory or in the patient's own body. Given proper chemical stimuli, stem cells may form into a functional organ. Organ engineering can create custom organs that are not rejected by the body. The compatible MHC and HLA do not provoke an immune response and thus patients are less likely to rely on immunosuppressant drugs. Although the idea of growing organs in petri dishes sounds farfetched, progress has already been made. In 2008, Finnish scientists successfully grew part of a jaw in a patient's abdomen. At the Wake Forest Institute for Regenerative Medicine, a bladder grown on a biodegradable scaffold and kept in an incubator has been transplanted in a patient.

Hopefully with the innovations of the new decade, organs will become more available to those in need of a fresh start. As with any scientific advancement, ethical issues are inevitable. It is important for the scientific and public community to navigate the potential problems so that organ transplants will continue to improve.

forensic accessibility

Tina Wexler

John Floyd is not getting a new trial. His judge took no more than fifteen minutes to make a decision, though his lawyers spent five hours trying to prove that there was evidence of a cover-up in his past trials. John Floyd, who has been imprisoned for the past 28 years in the Louisiana State penitentiary, tried to prove that the bulk of forensic evidence for the murder he was convicted of was hidden and destroyed. Under the Supreme Court precedent set in Brady vs. Maryland, adequate proof that evidence wasn't disclosed would be grounds for a new trial, had the judge been satisfied that such evidence existed and might have been exculpatory.

The use of forensic science in our courtrooms, particularly in the last 20 years with the advent and development of DNA testing, has resulted in very compelling consequences pertaining to the issue of "contextual contamination" or the misapplication or misrepresentation, of scientific evidence for the sake of proving a specific point. In the field of criminal justice, how this issue is navigated and interpreted has very real and dramatic results both for convicts and victims of crime. The confluence of institutions and voices in the field of criminal justice - District Attorney's offices, courts, forensic crime labs, and of course defense lawyers - sometimes creates an adversarial process that extends way past the trial itself, especially in regards to the litigation and investigation of post-conviction relief cases. The use of forensic evidence involves the scientific method in an adversarial conflict is quite unlike the use of science in any other social context.

In the past 20 years, DNA and forensic testing have uncovered truths about cases and led to the exonerations of over 500 people in the United States. They have contributed to the convictions of many more. In many cases, forensic retesting has uncovered evidence of malpractice and misrepresentation of evidence in the initial trials of the wrongfully convicted. It has led to an unprecedented movement to increase the accessibility of post-conviction DNA testing and forensics testing to ensure that felony convictions hold fast in light of new data. There has been a call by forensic

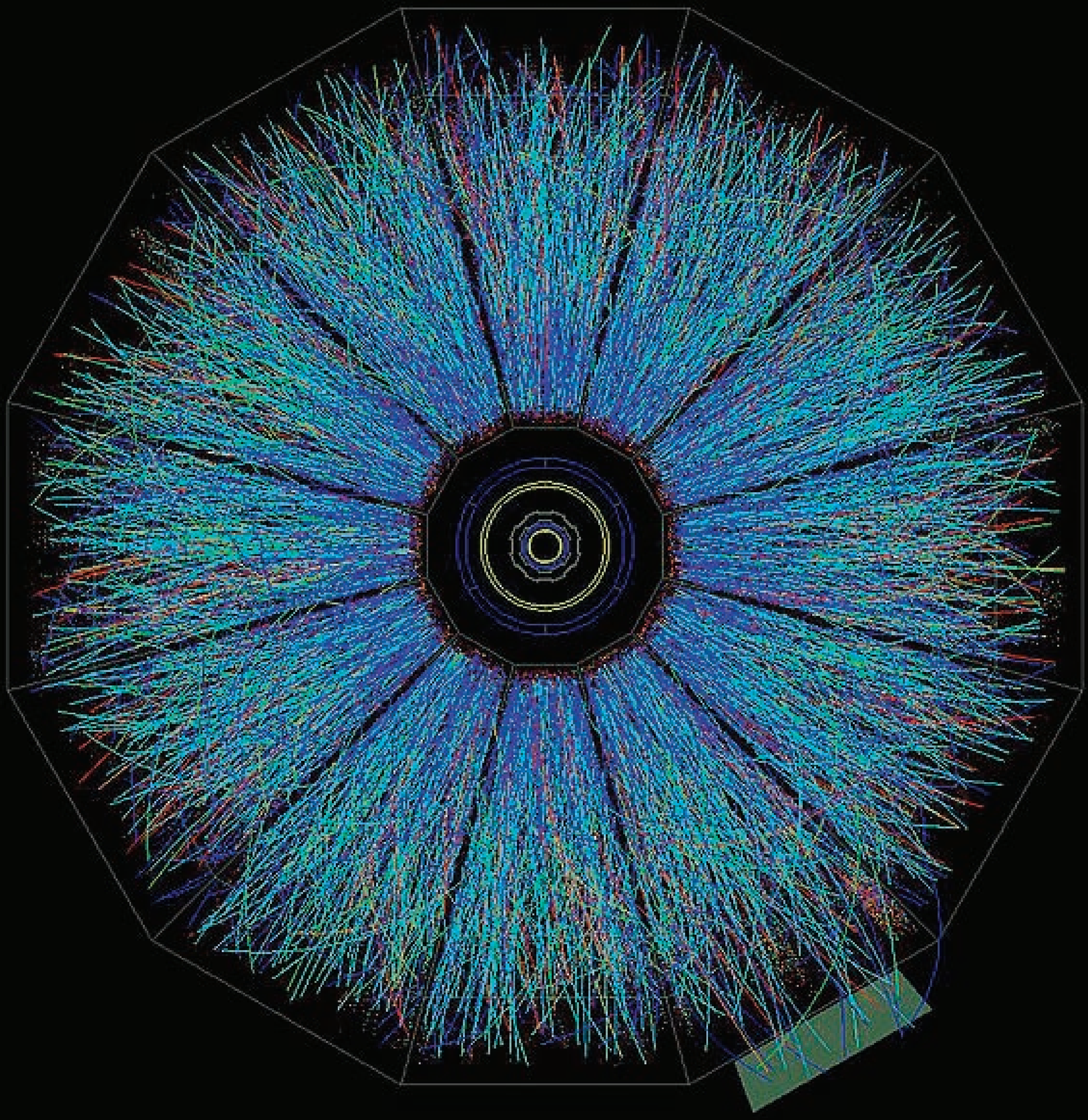
> "We need to find affordable procedures that increase accessibility to testing of biological evidence."

scientists, the National Academy of the Sciences, and "innocence activists" to increase funding and the body of research on forensic techniques, to ensure that the science being used in courtrooms is based on adequate methodology.

Some have responded to this movement negatively, seeing activists and lawyers as attacking the entire institution of forensic science as unprofessional and faulty. In an article published recently in the journal of the International Association of Criminal Justice, John Collins and Jay Jarvis, two specialists in the field of forensic science, write that "innocence activists" indiscriminately and inappropriately "disparage the forensic sciences to the extent that reasonable people might be persuaded to distrust the work being performed in America's crime laboratories."

This fear of ruining the finality of scientific and judicial decisions is echoed in a recent Supreme Court decision, District Attorney's Office vs. Osborne. The issue being decided was whether a defendant should be able to access biological evidence following a conviction under the Due Process Clause of the Fourteenth Amendment. The result was a decision that stated there should not be a federal precedent for such access following a conviction and that access should instead be regulated by the state. The decision was made in part because that evidence would not necessarily be favorable to the defendant and such a determination must be made prior to granting of access. The court decided that providing across-the-board access to biological evidence would increase "perpetual disrespect for the finality of convictions [which] disparages the entire criminal justice system."

True "scientific" decision making, which we expect of our forensics labs and, in a way, our courts, must be open to retesting and reinterpretation. Rarely do scientists disparage the work of their peers who question results of previous research and testing. Rarely is a conclusion in any research experiment held as final or complete truth. How then can we deny retesting and uphold all convictions without reasonable doubt, based on the test results made and analyzed by a few people? Cost is an important consideration. We need to find affordable procedures that increase accessibility to testing of biological evidence. We need to do this also to ensure that both rich and poor convicts claiming innocence have this access, by not forcing them to pay for testing themselves. Testing and retesting should be just as standard a protocol as conducting certain blood analyses and other tests each time a person visits a doctor or hospital, for fear of serious health consequences. There also must be recognition that most post-conviction litigators share the goals of forensic scientists—they wish to uncover the truth, not seek innocence where innocence does not exist. Retesting of evidence must be able to be present in the dialogue of post-conviction appeals, to ensure greater faith that justice is being done.



the theology of science

Kathleen V. Tatem

As I browsed through the bookstore at the Massachusetts Institute of Technology, I came across a shirt with the phrase "God said $\int E \cdot dA = q/E_0$ $\int B \cdot dA = 0$ $\int E \cdot dS = -d(phi)_B/dt$ $\int B \cdot dS = -\mu_0 i + \mu_0 E_0 (phi)_E/dt$ and there was light" printed on it. I bought it because I was excited that I recognized the equation, and I thought the phrase was clever. I didn't really think much about what the phrase implied until later. A biblical passage about the creation of the Universe that states, "God said, 'Let there be light, and there was light,'" had been altered to include Maxwell's equations of electromagnetism. The idea that God's word controlled the Universe, an idea that had persisted for centuries, had been replaced by an equation. If God really did say, "Let there be light," we now know that the language He spoke was mathematics.

As math and physics enable us to probe deeper into the most fundamental features of nature, we sometimes encounter an opposite situation where the language of math and science fail to convey true profundity. An example is the term used to describe a theorized fundamental particle that physicists are currently hunting for: the God particle. Its technical name is the Higgs boson, named after the man who first theorized its existence, but journalists have coined the term "God particle." The particle provides an explanation for why mass exists and therefore why we exist. It is the elementary constituent of the Higgs field, a hypothesized field that permeates the Universe and is responsible for the existence of mass. It provides a theoretical framework to explain why matter particles outnumbered antimatter particles after the Big Bang.

The European Center for Particle Physics (CERN) has spent billions of dollars on the construction of the largest particle accelerator ever built to search for this elusive particle. So why spend all this money? Why exert all this effort to find a particle that might not actually exist? Why do scientists spend their time looking for answers to questions for which religion has already provided answers? Science provides us with a means to study the Universe based on observation, mathematical hypotheses, and experimental data. Religion also provides a means for understanding the Universe, but it is not quantitative or derived from experimental observation. In the case of Christianity and especially Catholicism, religion has been in opposition with science for a long time. But perhaps science is not just an opponent to religion devoid of doctrine and feeling; perhaps it is more than just an analytical approach to understanding the Universe. The term "God particle" and my shirt from MIT imply that there is a religious aspect to modern science.

Religions around the world are extremely varied, yet, in almost all cases, religions evolve from an initial revelation or insight that is passed on to future generations. Examples of such revelations can range from the Buddha's enlightenment to the aboriginal Australians' belief in an ancient period they call the Dreamtime. Regardless of what the initial revelation was or how it has been transmitted through future generations, the acceptance of the validity of the initial insight established the authority of religious ideas. In the past, religion was considered a source of knowledge and authority, but today, science is our ultimate authority on knowledge. For example, if religion could satisfy our questions about the Universe, the huge investments needed to build the particle accelerator at CERN would never have been supplied. The shift in authority occurred during the Scientific Revolution, when progressive individuals such as Isaac Newton and Rene Descartes sought for ideas to be accepted based on proof, rather than blindly trusting ideas handed down from the past. This, of course, was in direct conflict with religion, since religion is based heavily on faith in old thoughts and trust in ancient revelations. Science was often in conflict with the Church during the Scientific Revolution, but religious feelings were not obliterated from the hearts of scientists. Religious sentiments, while they are far from the forefront of scientific thought, are still evident today.

Isaac Newton is famous for discovering laws of mechanics, optics, and gravitation. But was Newton a man who was only curious about why apples fall to the ground, as the myth stipulates? Were his experiments motivated simply by a desire for a framework to define how and why objects move the way they do? Newton was really on a quest to answer something deeper. He and many scientists of the Scientific Revolution believed that their work was revealing the thoughts of their Creator. Newton wanted to describe space, time, and the features of the Universe in scientific, rather than religious, terms. While his equations on gravity were incredibly accurate, Newton did not understand the reason for them. He presented a revolutionary theory of gravity, but he could not answer the question of why the planets had the particular orbits they possessed. He could not pose a definition for space and time. These compelling questions were left out of his theory. Newton wrote, "This most beautiful system [the Universe] could only proceed from the dominion of an intelligent and powerful Being." He thus attributed the particular orbits of the planets to the work of God, an all-knowing entity who had created the planets and their orbits just as they are, enabling life to exist. As for space and time, he spoke of them as an arena in which life takes place: infinite, eternal, and unchanging, a clockwork universe governed by the hand of God. Without sure scientific explanation, Newton left his questions about gravity, space, and time in religious terms.

Often the term "God" or the idea of some kind of transient entity is employed when we encounter the unknown, as Newton did. The case of the Higgs field shows that religious terms are still used even when we are pushing the boundaries of the unknown. Albert Einstein, who lived long after the Scientific Revolution, de-mystified some of the mystery left unsolved by Newton in his theories of relativity, yet there is still great ambiguity when we consider the questions of "What is space?" and "What is time?" The fundamental answers are still unknown; thus the questions still invoke the idea of a transient power or entity. Religion embraces the feelings of awe and humility when considering such an idea. Science embraces these feelings and the belief that with time humanity is capable of understanding what is now in the realm of the unknown.

After Einstein completed his theories of relativity and contributed to the study of quantum mechanics, the study of subatomic interactions, he began to search for something else. Relativity and quantum mechanics could not be combined together because no one had found a way to incorporate gravity into quantum equations. Einstein had the feeling that there must be a theoretical framework for the entire Universe, not separate frameworks. Einstein spent the last five years of his life searching for what is called the Theory of Everything. In the Theory of Everything, all events in the Universe could be predicted and explained, including the Big Bang, cosmic expansion, and what happens inside black holes. It involves the unification of the fundamental forces and constituents of nature into a single model that can explain all fundamental interactions. However, this theory has yet to be developed.

The search for a complete understanding of our Universe can be traced back to the founding fathers of science. Rene Descartes was a mathematician and philosopher who lived during the Scientific Revolution, a time when much that had been thought to be true was proved wrong. He wanted to create a method of discovery, so that humanity could never again go down the same road. Like Einstein's all-encompassing theory, this goal has yet to be achieved and might not actually be possible. However, just as Einstein explained what was an insurmountable mystery to Newton, the orbits of planets, scientists might one day find answers to Einstein's and Descartes' puzzles.

These are very ambitious goals, and they stem from curiosity and passionate desires for understanding. Like religion, these goals also require an element of faith. Science is founded on the belief that there is one set of universal laws. Science is also founded on the belief that human beings have the capacity to understand the laws of the Universe, the belief that things that are not currently understood will come to be known in time. For Isaac Newton, science was a spiritual matter; he and many of his contemporaries believed they were unveiling the truth of God through scientific observation. Some early scientists actually set out to find evidence to verify biblical stories. The intentions of modern science are less prejudiced, but scientists still rely on faith in all-encompassing laws. The religious undertones of science did not disappear after the Scientific Revolution; Einstein once said, "I want to know God's thoughts; the rest are details." The search for the Theory of Everything still hints at this desire, in that it would enable us to predict the outcome of any experiment.

"It might be full of mathematics and data, but science is not devoid of feeling: it is a poetic story of human passion, curiosity, and intellect."

The search for an understanding of the Universe can be humbling and awesome, whether it is through science or religion. Professor J. R. Seeley, quoted in William James' Varieties of Religious Experience, believes that "any habitual and regulated admiration is worthy to be called religion" and, consequently science, music, and government, since they are "organized and admirably believed in, are the more genuine religions of our time." Religion provides many people with a sense of meaning and purpose in their lives; for scientists on a quest to unravel some of the Universe's greatest mysteries, a sense of meaning in their lives is probably apparent to them from the work they do. Science itself can provide people what religion normally provides: a supportive community, a sense of purpose, as well as inspiring feelings of awe and satisfying fundamental human curiosity. Science provides a path to knowledge, but it is also a community of researchers. Similarly, religion provides community and a way for people to feel connected to the divine.

It might be full of mathematics and data, but science is not devoid of feeling; it is a poetic story of human passion, curiosity, and intellect. Science is a human endeavor to gain understanding; like religion it is a human creation to understand something greater than ourselves. Since the Scientific Revolution, the authority of science has replaced the authority of the church. Science isn't recognized as a new religion, yet it has religious undertones that exist in the background of society. As my shirt from MIT managed to illustrate so cleverly, science and religion are fused.As I browsed through the bookstore at the Massachusetts Institute of Technology, I came across a shirt with the phrase "God said = and there was light" printed on it. I bought it because I was excited that I recognized the equation, and I thought the phrase was clever. I didn't really think much about what the phrase implied until later. A biblical passage about the creation of the Universe that states, "God said, 'Let there be light, and there was light,'" had been altered to include Maxwell's equations of electromagnetism. The idea that God's word controlled the Universe, an idea that had persisted for centuries, had been replaced by an equation. If God really did say, "Let there be light," we now know that the language He spoke was mathematics.

Saranya Purushothaman

stem cell science

what we can expect this decade

Human embryonic stem (ES) cells are the point of origin for all cells in our body. These primitive units of life were successfully isolated in 1998 by Dr. James Thomson and colleagues at the University of Wisconsin, sparking world-wide interest. Scientists and physicians were intrigued by the immortal nature of ES cells and their unlimited developmental potential to produce cells ranging from blood to nerve to muscle. Yet, their controversial derivation from human embryos created an upheaval of opposition, stunting the promise of regenerative medicine in their early years.

Last year, more than a decade after their isolation, the first embryonic stem cell trial was approved for treatment of spinal cord injuries by the U.S. Food and Drug Administration (FDA). Recent political support from the Obama administration and an increased interest by both the scientific and non-scientific communities has given momentum to this promising field in the new decade.

Before delving into the possibilities of stem cell research, it is important to understand the basic properties of stem cells and explore the tangible progress already made by scientists. Based on the method and source of derivation, stem cells can be categorized into three types: embryonic, adult, and induced pluripotent.

Embryonic stem (ES) cells, the most controversial of the three types, are grown from the inner cell mass of the blastocyst, a structure that forms five days after fertilization of the egg. At this stage, the cell has not yet begun to make any specific tissue but has the potential to form every tissue type, a characteristic referred to as pluripotency.

Adult stem cells, also known as tissue-specific stem cells, are found in tissues that have already developed, such as the bone marrow and the heart. Unlike ES cells, adult stem cells are believed to be limited to differentiating only into cell types of their tissue of origin. Despite their limited potential, adult cardiac stem cells have been implicated in regenerating injured heart tissue by producing functional cardiac muscle cells known as cardiomyocytes, as shown by Dr. Georgina Ellison and colleagues at the Liverpool John Moores Institute in England.

In 2006, Professor Shinya Yamanaka and colleagues at Kyoto University in Japan made a remarkable breakthrough by reprogramming adult skin cells into stem cells termed induced-pluripotent stem (iPS) cells. This finding introduced a stem cell line that bypassed the ethical issues associated with human ES cells. Current methods to generate iPS cells have an associated risk from the cancer-causing viruses that are used in the process. Hence, while iPS cells hold great promise for creating patient- and disease-specific cell lines, their carcinogenic tendencies impede clinical application until a better approach arises to circumvent viral delivery of the reprogramming factors.

The functional comparison of human ES cells, adult stem cells, and iPS cells is an active area of research. Yet, it is important not to lose sight of the long-term goal: generating cells for human transplantation. For that, Professor Douglas Melton, co-director of the Harvard Stem Cell Institute, says the human ES cell is still vital because it is the only one that has not been genetically modified and thus poses the least risk to the transplant recipient.

In the past decade, the pursuit of embryonic stem cell research has not been easy for scientists due to political hurdles. In 1996, the Dickey-Wicker amendment was passed, which is considered the most important legislation relating to stem cell research. It specifically banned the use of tax dollars for research in which embryos are destroyed, thereby limiting federal funding for stem cell research. In 2001, the Bush administration announced that funding from National Institutes of Health (NIH) could not be used to establish new ES cell lines. Although federal funding was permitted for a small number of existing human ES cell lines, many of these lines failed to expand in cell culture. Since 2001, researchers developed over 700 ES cell lines using private money, yet none of these lines were eligible for federal funding until last year. In March 2009, President Obama issued executive order 13505 rescinding the Bush administration's ban on embryonic stem cell research. This act provided federal funds to many of the stem-cell lines established by private sectors. Although the Dickey-Wicker amendment still remains an obstacle for federally funded researchers seeking to create their own ES cell line, the recent government support for stem-cell research is a positive step forward.

Beyond the political realm, scientists are still working to solve the problem of how to direct the process of differentiation in ES cells to make specific cell types. Recreating cell specialization in a petri dish has proven challenging, but not impossible. Last year, Shuibing Chen and colleagues from the Melton laboratory at Harvard discovered a small molecule, (-)-indolactam V, which directs differentiation of human ES cells into the pancreatic lineage. This finding brings us one step closer to generating ES cell-derived insulin producing pancreatic beta-cells for treating patients with type 1 diabetes. In the next ten years, the functional derivation of specific cell types, such as the beta-cell, from ES and iPS cells is plausible.

In the face of hard statistics, many wonder if stem-cell science is overshadowed by the hype surrounding it or if its promise could actually be reality. According to Christopher Thomas Scott, head of Stanford University's Program on Stem Cell and Society, in 2001, nearly 80 thousand people needed organ transplants, fewer than 24 thousand received them, and 6 thousand died waiting. In his book, Stem Cell Now, Scott states that in 2002, the prevalence of diabetes in the United States exceeded 18 million people, which is over 6.3 percent of the population. That year, total healthcare costs of diabetes surpassed $130 billion.

Everyday we are informed of our increased risk for obesity, diabetes, heart disease, a variety of cancers, and an early death. Some scientists claim that stem cell therapy for use in clinics could be FDA-approved by the end of this decade. Yet, for neurodegenertive diseases like Alzheimer's or Parkinson's, scientists must spend more time on basic research to better understand patient-specific neural connectivity before considering clinical application.

A continued symbiotic relationship between stem-cell scientists and the government is essential to advance the science into the clinics. Nevertheless, progress in the ever-evolving field of embryonic stem cell research is inevitable and unprecedented discoveries in modern medicine are in our near future.

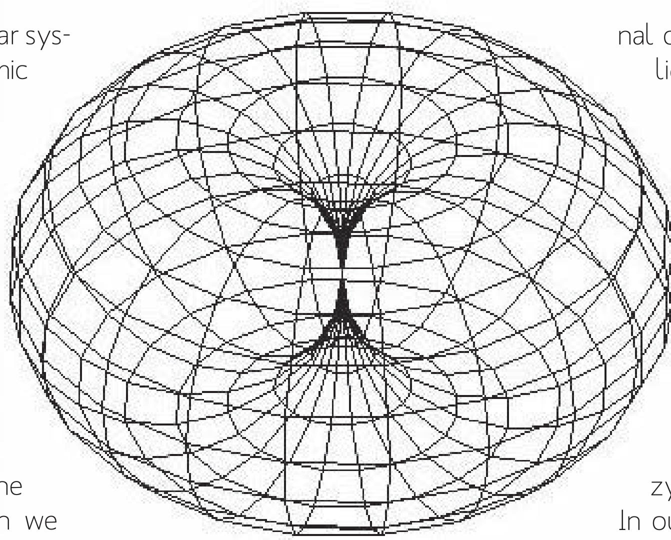
Tri-Space Races

Achieving Superluminal Speeds

Daniel Sims

"This Stuff is Far!" was written by George Hrab to serve as the theme song from the International Year of Astronomy. The song celebrates the distances involved with space. As the song states "This stuff is far... (like über far) you can't get there by car in a day| It's super duper crazy far but not just pulsars quasars and stars|I mean it's far, far, far...".

This distance has "explosions going off inside [the] brain[s]" of physics and engineers. For example, Proxima Centauri, our closest star, is 4.22 light-years away. So, it would take 4.22 years to get there at the speed of light. Despite this, the fastest craft ever launched is the New Horizons probe which had a top speed of over 50,000 miles per hour which is .00007508 times the speed of light or about 56,206 years cramped in a probe. Thus, conventional space travel won't lead to humans visiting our nearest star. Even traveling the speed of light is an inconvenience; a nine year round trip will cause space colonies in other solar systems to have little to no economic impact on Earth and creates a huge barrier to space exploration outside our system.



But why are we stuck at such mind numbingly slow speeds? $E=mc^2$ looks like the equation for the energy associated with speed (kinetic energy = mass* acceleration squared). So, in theory, if anything hits the craft at this speed, even the smallest particle, all the mass changes into energy. Then we have the Lorentz factor, which predicts that it will require more and more energy to get a spaceship's speed closer and closer to the speed of light. It also predicts that it will require infinite energy to get a spaceship to go at the speed of light.

This problem seemed to be overcome by the Alcubierre warp drive. Better know for its use in the popular series Star Trek, the warp drive expands the fabric of space and time behind it, and contracts it in front of it. It is like walking on a moving walkway. You can move at a running speed by walking. The physics works if you are going under the speed of light, but problems start if you are going faster than the speed limit of the universe. At these speeds, massive amounts of Hawking radiation is produced, and any crew on a spaceship would be killed. Even if we could avoid this, the energy required to bend space is massive. Furthermore, the observers on earth would be perplexed as they would see a faster-than-light spaceship having an infinite mass and an infinitely small length. Also, spacecraft cannot go faster than the speed of light because that would make the craft go back in time. They can go forward, but going back in time causes a lot of paradoxes.

This is where Tri-Space Theory comes in. This theory proposes that there is another realm on the other side of the space-time fabric. This realm allows faster than light (superluminal) speed. However, it is hard to hop through the fabric since the fabric is a realm where things travel exactly at the speed of light . So, in order to move through the fabric, you would need to become light, and then transfer to the superluminal realm.

Once a spacecraft is in the superluminal realm, all the problems disappear. A craft would need to go slower than the speed of light to reverse time, which, just like it is impossible to go faster than the speed of light, the superluminal can't go slower than the speed of light. Continuing with this reversed world, the more energy you take from a system, the faster it goes. This allows for infinite speeds since we could just shut down the engines. This will make the ship go faster. Radiation would only be produced if the craft was going slower then the speed of light.

So, why did this seemingly crazy idea get published? Anti-gravity. In our realm, gravity can be imagined as a sheet with large bowling balls on it. If a marble were placed on the sheet, it would roll toward the bowling balls because of the "crater" caused by the weight. But if we freeze the sheet and then flip it over, the marbles would roll away from the bowling balls. What we see as anti-gravity is "exactly what astronomers seek when searching for dark matter. Furthermore, r[ecent discoveries have also concluded that enormous dark matter 'halos' surround[ing most galaxies. Quantum tunneling is also explained because the particle can switch to the superluminal state and transfer its information at what we see as a violation of the laws of physics."

If this theory is right, then even the laws of physics cannot limit what humans can do. This will unlock a new age of space exploration where we can get data from the edge of the universe in seconds.

Columbia Science Review

www.columbia.edu/cu/csr