BREAKTHROUGH

Tufts' Undergraduate Science Magazine

Sulfur Injection Geo-Engineering: A Fight Against Climate Change

Debunking Hydrogen Myths

Faculty Profile: Dr. Trimmer

Volume I, Issue 1
Winter 2009-10

FROM THE EDITOR

Welcome to the first issue of *Breakthrough: Tufts' Undergraduate Science Magazine*. *Breakthrough* is Tufts' first undergraduate publication focused on the natural and physical sciences. The magazine will serve as a one-stop source for information on some of the most interesting and relevant research currently going on all across Tufts University, as well as the world at large, in a style of writing that everyone, science background or not, will enjoy.

This magazine was founded to address the need for science communication and awareness amongst the Tufts community. As a highly research-oriented university, Tufts is on the cutting edge of scientific discoveries and innovation. However, without a cohesive and accessible outlet for this information, it is difficult, if not impossible, for the Tufts community to stay up-to-date on the research endeavors and successes of our multiple science departments. *Breakthrough* will serve as that outlet. The *Breakthrough* team has been in close contact with Tufts science departments to create a publication highlighting some of the most exciting scientific research at our university. In addition to reporting up-and-coming Tufts research, *Breakthrough* includes a *Historical Perspective* article in each issue describing past scientific discoveries at Tufts or by a Tufts professor or alum. The magazine also contains a *World Science News* section and articles about present-day scientific research from around the globe. *Breakthrough* seeks to not only increase scientific awareness on our campus, but to foster inter-departmental debate and discussion among the science and non-science communities at Tufts.

With articles running the scientific gamut, from biology to psychology to engineering and technology, *Breakthrough* has something for everyone. Most importantly, *Breakthrough* is designed and written to be accessible to all readers, regardless of background knowledge. As such, *Breakthrough* has the potential to increase both scientific literacy and pride in the Tufts community. I hope that you enjoy reading this magazine as much as I, and the rest of the team, enjoyed creating it.

All my best,

Sophia Cedola
Editor-in-Chief

OUR STAFF

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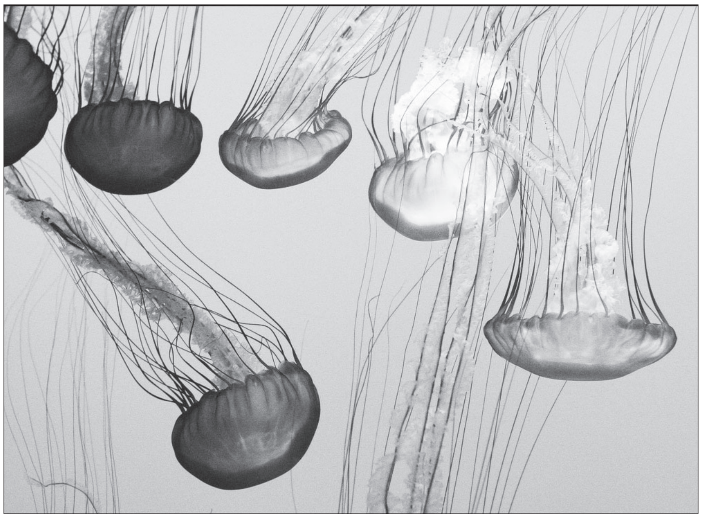
Want to submit an article or join our staff? Come to one of our meetings (Tuesday nights, 9 p.m., Eaton 209) or e-mail us at tuftsresearch@gmail.com.

The Spread of an ‘Immortal ‘ Jellyfish

BY AMANDA WEST



CDC.gov

The jellyfish Turritopsis nutricul has been found to be able to literally reverse its aging process. After becoming sexually mature, this jelly is capable of returning back to its juvenile polyp form, while most species of jellyfish die after reproduction. This is done through a process called transdifferentiation, which allows the jelly to turn one cell type into another, such as a muscle cell into a nerve cell.[1] It is capable of regenerating every cell in its body, with no known limits on the number of times it may make the transition from juvenile to adult and back again. Recently, two scientists, Maria Pia Miglietti of Pennsylvania State University and Harilaos Lessios of the Smithsonian Tropical Research Institute, have been studying the DNA of these jellyfish.[2] These researchers have realized that although the jellyfish originated in the Caribbean, it has now spread to parts of Europe, Panama, Japan and Florida, among other places. The spread of this jellyfish has been attributed to its ability to live indefinitely, as well as its ability to reproduce asexually by essentially making copies of itself. Until now, this jellyfish’s invasion of the world’s oceans went unnoticed, presumably due to its small size of only 5mm. Although these creatures seem to have mastered the art of immortality for themselves, it is unlikely that any anti-aging drugs will be produced using their genes. Miglietti says, “Nobody is looking into that and I don't think you're going to find any secrets in these creatures.”[2]

1 “The Curious Case of the Immortal Jellyfish”. Discover Magazine. January 29 2009. <http://blogs.discovermagazine.com/discoblog/2009/01/29/the-curious-case-of-the-immortal-jellyfish/>.

2 Than, Ker. “‘Immortal ‘Jellyfish Swarms World’s Oceans”. National Geographic News. January 29 2009. <http://news.nationalgeographic.com/news/2009/01/090130-immortal-jellyfish-swarm.html>.

Artificial Life

BY MATTHEW FERREIRA

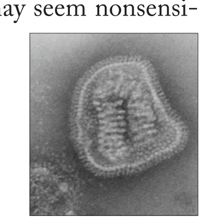
Dr. Craig Venter, the man famous for his privately funded sequencing project of the human genome, has declared that his lab is very close to creating artificial life (August 2009). A recent breakthrough by a member of his laboratory has led to this confidence from Venter. Ultimately, Venter’s lab hopes to produce man-made strains of bacteria that can change coal into a more environment-friendly gas and algae that absorb CO_2 and subsequently create hydrocarbon fuels. According to Venter, artificial life can also have a profound impact on vaccines and various other medicines. As of now, Venter’s team has assembled a completely synthetic genome; experiments are underway to transplant the genome into cytoplasm to create an organism with the synthetic DNA. If you’d like to read more about this research, visit http://www.jcvi.org.

Schrodinger’s Virus

BY LAUREN WIELGUS

A group of researchers from Germany and Spain have proposed a way to perform a real-life experiment similar to Schrodinger’s famous cat thought experiment, proposed in 1935. In the original thought experiment, a cat is in a box containing a vial of poison. A tiny hammer sits above the vial, and will smash it to release the poison if an atom of radioactive material decays. As one cannot know whether the atom has decayed until they look in the box, is the cat dead or alive?

The answer, according to quantum mechanics, is that the cat is in a superposition of both states. This effect may seem nonsensical when applied to macroscopic objects, such as cats, but can be seen in particles. A team of German and Spanish scientists, led by Oriol Romero-Isart, Mathieu L. Juan, and J. Ignacio Cirac, hopes to probe the gap between the macroscopic real world and the quantum world by using a virus to stand in for the cat.



phil.CDC.gov

In the proposed experimental setup, a single virus will be cooled to its lowest energy state in a vacuum chamber. Then, a single photon will be beamed into the chamber. Until someone looks, the virus will be in both at rest and in motion, as it may or may not have been hit by the photon.

There is some debate over whether this experiment is truly similar to Schrodinger’s cat, as some do not consider viruses to be “alive.” Still, an attempt to place a macroscopic object in a superposition of two states should yield interesting results regardless of whether the object can be considered animate, and may help define where the boundary between the macroscopic and quantum worlds lies.

To learn more, check out the source paper:

Romero-Isart, O. et al. preprint at http://arxiv.org/abs/0909.1469 (2009)

Nanoparticle Transport Within Soil

BY AMANDA WEST

pagedooley / Flickr.com

Dr. Kurt Pennell, chair of the Civil and Environmental Engineering department at Tufts, is a key investigator in the Integrated Multiphase Environmental Systems Laboratory (IMPES) at Tufts. The research done at the IMPES lab works by combining laboratory experiments with computer and mathematical models to examine the persistence of certain compounds within soil and explore the effectiveness of various treatments on contaminated soils. Dr. Pennell and other investigators within the IMPES lab hope to be able to develop innovative soil remediation technologies that can be used to reduce environmental contamination. In June 2009, the IMPES lab received a $350,000 grant from the National Science Foundation to research nanoparticle transport within soils. Dr. Pennel states that this research may be used to enhance the performance of "filtration technologies for treatment of drinking or waste water", among other things. Dr. Pennell and colleagues wish to recruit female and minority students into this research as well as include interested undergraduates. For more information, visit http://engineering.tufts.edu/cee/impes/index.html.

Trace Fossils

BY MARY BETH GRIGGS

Senior Lecturer Jake Brenner, an Ichnologist in Tufts' Geology Department, is studying trace fossils in rocks. Trace fossils are impressions or features made by animals in sediments (worm burrows, dinosaur footprints, etc).

Currently Brenner is studying fossils found in glacial sediments, looking into how quickly ancient species of fish returned to the eastern US after the last glacial period. There are no fossilized remains, so the pattern must be pieced together using only the impressions made by fish as they swam along the ancient lakebed.

If you want to learn more, visit his website at http://ase.tufts.edu/geology/jbenner.asp.

Did You Know?

BY LAUREN WIELGUS

Thanks to Alex Vilenkin, the director of the Tufts Institute of Cosmology, Tufts may soon have a descendant of Newton's apple tree growing on campus. After learning that MIT has an apple tree descended from the famous tree at Newton's farm, Vilenkin asked his friend Alan Guth, a physicist at MIT, for a cutting to celebrate the 20th anniversary of the Tufts Institute for Cosmology. The cuttings are currently being grafted onto orchard rootstock in Harvard, Massachusetts. Though the first attempt at grafting the tree proved unsuccessful, another attempt will be made in the spring of 2010. However, since apple trees can take from two to ten years to bear fruit, it will be some time before Tufts' students can sit under Newton's tree waiting for inspiration to strike.

More World Science News

Mice Created from iPS Cells

BY SAURABH SINHA

In an important proof of principle for stem cell research, two groups of scientists in China have created mice entirely from induced pluripotent stem cells (iPS). iPS cells are normal body cells that have been genetically reprogrammed to express the necessary genes for pluripotency, the ability to divide into any cell of the body. First developed in 2006, iPS cells present an avenue for obtaining stem cells without having to derive them from embryos.

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Scientists at the Institute of Zoology in Beijing and Shanghai Jiao Tong University reprogrammed mouse fibroblasts to become pluripotent and these cells eventually gave rise to new mice with the same genotype as the iPS cells. Mice have been similarly made from embryonic stem (ES) cells, showing that iPS cells are comparable in their developmental capacity to embryonic stem cells. Though the process still needs to be streamlined, the potential of iPS cells as an alternative to ES cells underlines countless breakthroughs that could be made if the field is funded and pursued.

bobhall106 / Flickr.com

A Prescription for Disaster

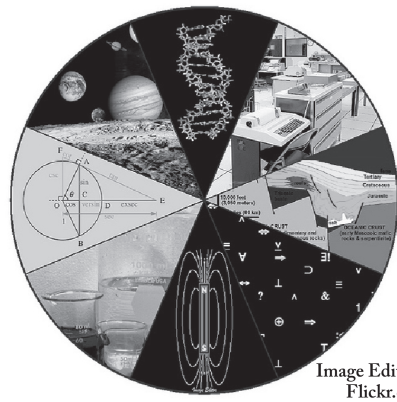
Modern society must act decisively to head off the crisis of scientific illiteracy.

By Michael Shusterman

Carl Sagan called science a candle in the dark, a force to drive back the superstitions and mythologies that pervade society. And for much of human history, science has been a shining example of the power of rational inquiry to probe the mysteries of the natural world. Modern scientific methods have rescued medicine from the days of bloodletting and miasma's, they have allowed society to harness the power of atoms and to travel into the depths of outer space. Science has changed our fundamental understanding of time, biology, politics, and warfare – indeed even of the very nature of reality itself.

Yet a gnawing problem exists deep within our society. For a culture so deeply dependent upon science and its principles, we are largely ignorant of these same concepts. Many Americans are effectively scientifically illiterate. In a recent survey by the California Academy of Sciences, only 53% of Americans knew how long it took the earth to travel around the Sun and as many as 41% believed that humans and dinosaurs had once coexisted in the past (an intriguing plotline for a science fiction story).

The argument could be made that these are trivial facts. Does the average person really need to know about paleontology or what the definition of a year is? Such information is often seen as irrelevant to daily life. For many students at Tufts University, this is the case. Science courses and the information they provide have become chores to deal with on the way to graduation. In truth, such a perspective, whether at Tufts or within society is a dangerous one. Today's world requires a scientifically literate citizenry. The spread of information technologies, the rise of developing nations, and the accompanying complexities associated with a global civilization have pushed issues like environmental policy, genetics, and even particle physics into the mainstream. While fifty years ago most Americans did not need to know about DNA or CO2 emissions, today, these are topics that are unavoidable in newspapers and in the media.



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When that newspaper is opened, how can we expect an individual to understand the basic premise of the article or research being described without a firm grasp of the elementary concepts, much less some rudimentary understanding of the scientific method? More importantly, can we trust our political leadership to understand the topics? Today there are few scientists in Congress (the most notable exception being recently elected Illinois Representative Bill Foster, a former particle physicist). Yet Congress is routinely asked to deliberate and decide on questions on topics as diverse as climate change, genetics, space research, medical studies, and defense spending. Unfortunately, many in Congress are also scientifically illiterate. The result is dependence by members of Congress on 'experts' to explain issues to them. This is understandable as no single individual can know everything regarding a given field. However, without a foundation for discerning which information and sources are credible, the temptation to succumb to tailored tall tales by special interests groups with clever public relations tactics and lobbyists is high.

Our society's scientific illiteracy has allowed those with special agendas to manipulate public opinion on topics ranging from vaccinations and evolution to climate change and pharmaceuticals. The pervasive apathy towards science present in today's culture is a recipe for disaster. However, some are fighting back.

Journalist Chris Mooney and marine biologist Sheril Kirshenbaum (a Tufts alumna), coauthors of Unscientific America, have recently argued that scientists should become actively engaged in informing and driving public opinions and perceptions of their research. At Tufts University, some faculty members have already begun to do so, particularly within the Chemistry Department. Professor Charles Sykes and his laboratory have collaborated with a Boston area school to provide hands on demonstrations of advanced topics in microscopy to interest students in careers in science and to expose graduate students to science education. Meanwhile, closer to the campus, Professor David Walt used funding acquired from the Howard Hughes Medical Institute to create a unique multi-professor course for non-science majors called "From the Big Bang to Humankind." In this course, a broad spectrum of basic concepts are presented to non-science majors to create a cohesive narrative linking chemistry, biology, astrophysics, geology, evolution, and other fields.

These efforts are all steps in the right direction, but much more remains to be done. It is imperative that both the federal and state governments take steps to increase funding for science education, that scientists actively promote public education measures, that universities create courses to inform non-science majors, and that more public oriented events are designed to expose society to the fascinating discoveries and important conclusions coming out of laboratories and research centers.

In a prescient note, Carl Sagan noted that: "We've arranged a global civilization in which most critical elements profoundly depend on science and technology. We have also arranged things so that almost no one understands science and technology." It is not too late to change the direction of our cultures and societies perspective on science and science education. Now is the time to take decisive action.

Michael Shusterman is a senior majoring in biology and history.

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Plants As Vaccine Factories

A paradigm shift in vaccine production.

By Amanda West

mckaysavage / Flickr.com

Research to develop vaccines within plants has been underway for the last two decades. These vaccines involve the use of plants, such as bananas, tomatoes or peanuts, which have been genetically altered using biotechnology to produce a vaccine that can be orally administered. Most of the vaccines that researchers are hoping to develop, such as those for cholera, polio, hepatitis B and measles, are to help the developing world, which bears the greatest burden of these diseases.

The vast majority of current vaccines require administration through injection. There are many problems with the use of needles, particularly in the developing world where up to 45% of deaths are a result of infectious disease.[1] Most injectable vaccines require "cold-chain" management, meaning they must be kept refrigerated. This increases transportation and storage costs significantly and in many areas of the developing world, electricity is either unreliable or nonexistent, making the logistics of vaccination much more difficult. The use of needles is also problematic because it requires highly trained personnel to administer the injections, and if proper procedures are not followed, there is an added risk of infection due to reused needles or unsterilized injection sites.[2] Additionally, injectable vaccines typically only initiate systemic immunity against a disease, and not mucosal immunity. Mucosal immunity should be the first line of defense against any pathogen that enters through the respiratory, gastrointestinal or reproductive tracts because it helps to fight infection before it gets past the mucus membranes and into the circulatory system. Both systemic and mucosal immunity are important to generate full protection against a particular pathogen.[3]

Plant vaccines may be able to solve these problems by allowing for the production of orally administered vaccines. These vaccines will be created by making a plant produce the antigens that are associated with a particular pathogen. To force plants to produce these antigens, the genes that code for the antigen are extracted from the pathogen of interest. By using transgenic technology, scientists can make plant cells take up the pathogen's DNA and incorporate this DNA into its own genome. When grown, the plant will then produce the antigens that are associated with the pathogen, which will in turn create an immune response in humans when administered.

The human body generates immunity through the use of B and T cells which together are capable of recognizing a foreign antigen and creating antibodies against it. The antibodies effectively flag the invader for destruction by other cells. After the perceived threat is gone, some B and T cells remain in the body and serve as memory cells. In the event that the actual pathogen should appear in the body in the future, its antigens will be recognized very quickly by the memory cells and an immune response will be staged against it, hopefully before it has the chance to do any harm.[1]

Plant vaccines also represent a significant improvement over current vaccine technologies that are in use because they will not require the use of needles. This means no need for refrigeration and no risk of infection. They are also much cheaper to produce than vaccines created using animal or microbial cells and will not require as much training to administer.

However, there have been some setbacks. Originally scientists were envisioning an edible vaccine that could be grown in a fruit, and eaten directly from the plant. It turns out that researchers were a bit naïve in this vision; you won't be able to vaccinate yourself against measles by grabbing a tomato off the vine. There are many reasons for the change from an "edible vaccine" to the new description of a "plant-derived vaccine". Most significantly, it is very hard to control dosage unless the plant is processed due to the differing sizes and protein contents of the fruit. Since it is very important that a person receive the right level of antigen in order to produce the correct immune response, plants will likely need to be dehydrated and processed into powders, pills or

see Plants, page 22

Molecular Neurobiology at Tufts

A look into Professor Michele Jacob's lab.

By Saurabh Sinha

The human brain is a testament to the power of evolution. It is the vehicle of higher consciousness, a concept that has motivated centuries of metaphysics and epistemology. With this level of existential import, the question of how the brain works is one that is inherently captivating and fascinating. The field of neuroscience has been making tremendous strides in disentangling the intricacies of human brain functionality. The fusion of molecular biology with neuroscience in recent years has supported an increased understanding of key underlying aspects of cognitive processes.

The human brain, part of the central nervous system, is composed of neurons and glial cells, which interact at miniscule junctions known as synapses. The synapse is one of the integral underlying mediators of cognitive function. It is the main communication modality of the central nervous system and, as such, mediates the entire spectrum of brain functionality, including learning and memory.

The standard picture of the synapse considers the interaction between neurons in the brain. Pre-synaptic and post-synaptic neurons can communicate with one another by modulating electrical transmission over the synapse in a process referred to as neurotransmission. Neurotransmitters are released from the pre-synaptic neuron and stimulate a post-synaptic current change. This is the basis of neuronal communication, and the nature of these interactions changes with the type of neuron and neurotransmitter. This high degree of variation accounts for the vast differences in functionality from region to region in the brain. Not surprisingly, the synapse is a complex system that involves numerous proteins and messaging systems within neurons.

Over the past few years, the laboratory of Michele Jacob at the Sackler School of Graduate Biomedical Sciences has been interested in defining those proteins and messaging systems; that is, identifying mechanisms at the molecular level that mediate synaptic strengthening. Specifically, they have studied cholinergic synapses, which are synapses that utilize the neurotransmitter acetylcholine for neuronal communication. These synapses are vital for learning and memory, attention and are also present at the neuromuscular junction, a chief component of muscle contraction.

Researchers in the Jacob lab made an important discovery in a 2008 paper that identified a specific protein as a key synaptic organizer. The adenomatous polyposis coli protein (APC) had previously been defined as a tumor suppressor protein implicated in colorectal cancer; however, many colorectal cancer patients with APC gene mutations also presented cognitive deficits, which suggested a possible role for APC in the nervous system. Furthermore, APC mutations have been associated with autistic spectrum disorder. To explore the possibility of a cognitive role of APC, the Jacob lab analyzed the chick ciliary ganglion, an important group of cells with cholinergic synapses involved in control of eye movement. Though these synapses are not of the brain, they are still valuable for understanding normal synaptic function. Being cholinergic synapses, they also play an important role in cognitive functions.

The researchers used an array of molecular biology techniques to elucidate the role of APC in organizing the chick ciliary ganglion synapse. The most telling of these was the use of a dominant-negative construct of the APC gene. This construct was a version of the gene, modified so that it would produce a defective APC protein fused to a green fluorescent marker. After introducing the construct into ciliary ganglion neurons through a process known as transfection, the researchers incubated the neurons, allowing them to form synapses. Using this method, they were able to compare defective neuronal synapses against normal synapses and observe differences in APC positioning by analyzing differences in fluorescence. The most important observation was that the formation of cholinergic synapses between neurons was significantly inhibited in neurons transfected with the defective APC gene. These synapses were disorganized and immature compared to normal synapses, indicating a key role for APC in the organization of cholinergic synapses.

APC duly fits the bill for this role because the protein has multiple binding domains, allowing it to feasibly interact with the complex system of proteins present at the synapse. The Jacob lab has used information in further studies to develop a working model for APC's binding partners. These include cytoskeletal proteins that help anchor the synapse, neurotransmitter receptors, and adapter proteins.

These results are not an end. Rather, they are the point of departure in a long series of experiments and studies. The next steps include extending this picture of APC function to the brain. The Jacob lab is currently working with APC knockout mice, focusing on its role in the hippocampus (the major memory center of the brain). These studies will make it possible to understand the molecular basis of cognitive deficits such as Alzheimer's disease and autistic spectrum disorder. Gaining this perspective could radically redefine the medical approach to these disorders.

While these findings concentrate on a seemingly insignificant level (a single protein involved at the synapse), it is very important to keep the implications of this research in mind. Understanding synaptic organization sheds light on the basis of information transmission in the brain and indeed provides us with powerful ammunition to attack the age-old question of how the brain works.

Saurabh Sinha is a senior majoring in biology and minoring in cognitive and brain sciences.

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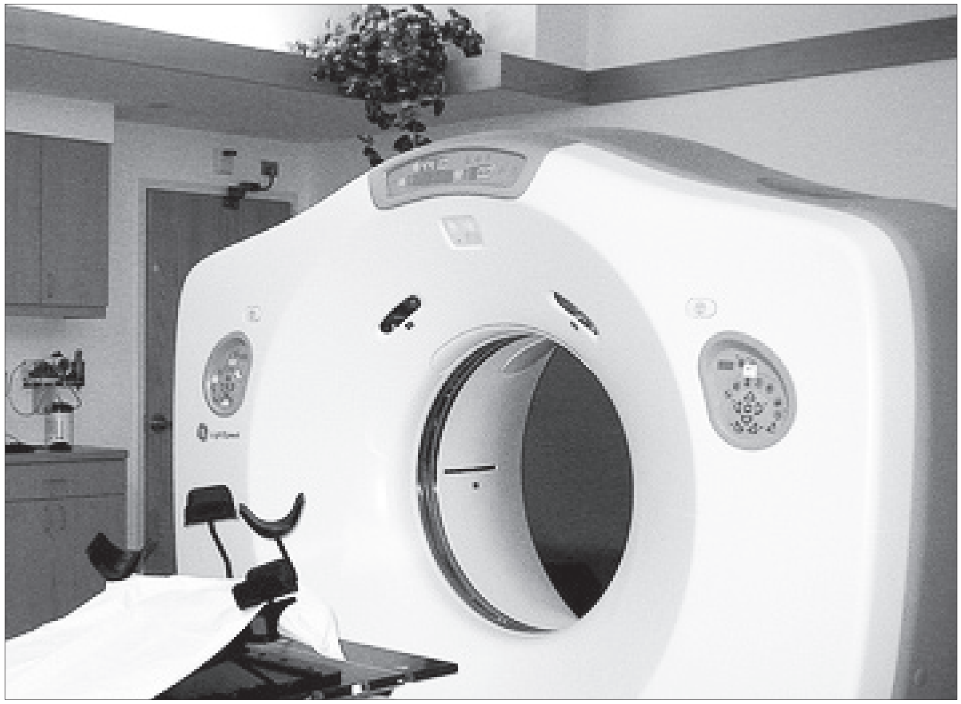
The Development of the CAT Scan

And one Tufts professor's amazing contribution.

By Ryan Pandya



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In centuries past, a tumor—especially one in the brain—meant death. A tumor couldn't even be properly diagnosed, let alone properly treated. Even with the advent of X-ray technology in the late nineteenth century, finding the proper dose of radiation took a rough estimate, a guessing game: hardly the sort of precision warranted by serious medicine.[1]

This imprecision is now a thing of the past. Today, powerful computers can integrate the raw information from hundreds of X-ray images into a full, three-dimensional model of one's body cavities, within minutes.

CAT or CT scans—Computed Axial Tomography, or just Computed Tomography—are responsible for this achievement. Today, there are about 6,000 CT scanners installed in the U.S. and about 30,000 worldwide.[2] But not many people know the history of this incredible technology.

The 1979 Nobel Prize in Physiology/Medicine was awarded jointly to the two men who developed CAT scanning: Godfrey Newbold Hounsfield, the British engineer who built the first medically practicable machine, and Allan Cormack, then professor of physics at Tufts, who devised the ingenious mathematical formula which is the basis of computed tomography.

So how exactly do CAT scans work? When a patient lies inside a CAT scan machine—essentially a retractable table inside of a donut-shaped apparatus—the donut-shaped part on the outside begins to emit X-rays. These X-rays are a form of electromagnetic radiation, like visible light or radio waves, but have higher energy: this means they can pass through some of the matter of the human body, but are impeded by denser matter, like bones. X-rays alone produce a silhouette of the inside of the human body, much like holding a flashlight behind an object and looking at its shadow on the wall. But X-rays have inherent drawbacks: as a two-dimensional image, a silhouette cannot possibly display information about depth or show a small object (such as a developing tumor) behind a larger mass. To fix this, a CAT scanner takes hundreds of X-ray snapshots at different angles, moving in a circle around the patient (hence *axial* tomography—"axial" means "rotating around an axis," and the term tomography comes from the Greek *tomos,* a cut, and *graph,* written). All of these images are then combined to make a 3-D model, through a complicated mathematical function.[3] It was for the development of this function that Allan Cormack received the Nobel Prize in 1979.

In 1955, Cormack was a Lecturer in Physics at the University of Cape Town. When the attending Physicist at the local hospital resigned, Cormack, the only qualified nuclear physicist in Cape Town, offered to take over supervising the use of radioactive isotopes at the hospital. At the time, radioisotope doses for cancer treatment were determined with a trial-and-error approach:

> [A nurse] would superpose isodose charts and come up with isodose contours which the physician would then examine and adjust, and the process would be repeated until a satisfactory dose-distribution was found. The isodose charts were for homogeneous materials, and it occurred to me that since the human body is quite inhomogeneous these results would be quite distorted by the inhomogeneities - a fact that physicians were, of course, well aware of.[4] *Alan Cormack, Nobel Lecture*

Not content to leave this process in its imperfect state, Cormack tried to think of an elegant solution. He realized that what was needed was a distribution of "attenuation coefficients" of tissues in the body (essentially, the distribution of which parts of the body were more or less resistant to X-rays passing through). Cormack saw that this distribution could be measured with an apparatus external to the body, and that this information would be useful for diagnostic purposes—perhaps far more useful than he realized at the time.[3]

His 1979 Nobel Prize citation recognized Cormack as, in a sense, the first to develop a method of displaying a "correct radiographic cross-section in a biological system." In both 1963 and 1964, he published his analysis of the problem at hand, which he understood "was basically a mathematical one."[5]

Any given X-ray image could be seen as a "slice" or cross-section of the body, and if a two-dimensional function could be devised which expressed "how X-rays attenuate in each individual part within a slice," the problem would, ostensibly, be solved.

Former Tufts Professor Allan Cormack received the Nobel Prize in 1979 for developing a mathematical function that allows for CAT scans to render a 3-D model.

Interestingly, this problem had already been solved by Johann Radon in 1917, but Cormack did not find this out until fourteen years after he first began working on it.[iii] By then, he had already solved the problem himself, through extensive experiments using gamma rays (chosen because of their shorter wavelengths). Amazingly, Cormack was able to figure out the same solution as Radon had, and lay the groundwork for CAT scans to be medically practicable.[4]

It would be remiss to suggest that CAT scans were only developed by Cormack. In 1977, Godfrey Hounsfield published his own paper on what he called the E.M.I. Scanner, the first version of a CAT scanning machine. The EMI Scanner was named after the parent company of the laboratory at which it was developed, Electric and Musical Industries—which, at the time, was also The Beatles' record company. Hounsfield was able to develop the CAT scanner from prototype to finished product almost "as a direct result of the Beatles' success" and EMI's immense profit.[6]

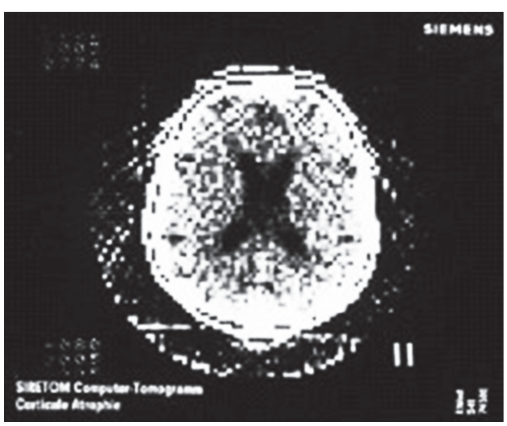
Hounsfield's paper identified three main limitations of X-rays, which the EMI Scanner was designed to overcome.

As Cormack had noted, all the information of a 3-D object cannot possibly be expressed "within the framework of a two-dimensional X-ray picture." This was the first limitation of X-rays. Second, Hounsfield said that X-rays could not distinguish between different soft tissues—they could only show bones and air (fat and certain organs could be made visible only with "contrast media," special radio-opaque dyes). The third limitation of X-rays was that the different densities of the substances in the body could not be measured "in a quantitative way." (This limitation was the specific reason Cormack began researching computed tomography.) Conventional X-rays only showed the average density—relatively useless information, especially compared to what the EMI scanner would output. Hounsfield went on to give his definition of Computerized Tomography:

> While conventional X-ray technique starts off by asking the question, "What does the body look like inside?", computerized tomography, on the other hand, starts off by asking the question, "What substances are inside the body?" It measures the attenuation of [hundreds of] X-ray beams … and then, from the evidence of these measurements, is able to create a picture of the body's interior … we virtually obtain total three-dimensional information about it.[7] *Godfrey Hounsfield, Royal Society of London*

The result of Cormack's formula and Hounsfield's design is the CAT scanning machine we know today. Thanks to these pioneering scientists, radiology and medicine have fundamentally changed.

Ryan Pandya is a freshman who has not yet declared a major.



Above, a 1975 CT image. At right, a state-of-the-art modern CT image.

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Fermilab

On the cutting edge of particle physics.

By Lauren Wielgus

It is not very often that physics at Tufts requires safety training courses, a hard hat, and the ability to drive a small cherry picker. However, this summer, my Summer Scholars research project led me over 100 meters below ground at the Fermi National Accelerator Laboratory (Fermilab), helping students and scientists disassemble the prototype MINERνA neutrino detector. I took a three-day trip out to Fermilab, a national particle physics lab, to see firsthand where all the data I had been poring over actually came from.

Fermilab, established in Batavia, Illinois in 1967, contains the nation's largest particle accelerator, the Tevatron. The Tevatron accelerates protons and antiprotons to 1 TeV (1 trillion electron volts), the highest energy in the world, at least until the Large Hadron Collider at CERN starts running at an expected 7 TeV. A variety of experiments are located around the 3.9 mile accelerator ring. Fermilab's 1900 employees include 900 physicists, engineers, and computer experts. Another 2300 visiting scientists and students from around the world take part in research at Fermilab. The MINERνA collaboration includes researchers from eighteen institutions.

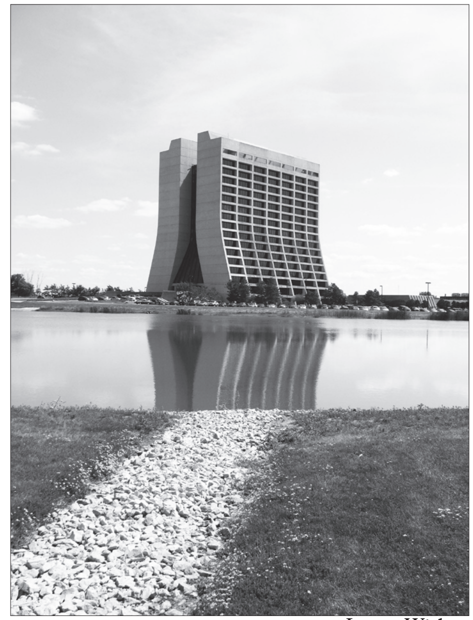
With its many visiting students and scientists, Fermilab has an active social community. Some researchers live on site in the Fermilab Village. While visiting, I took part in the MINERνA decathlon, a 10-week series of alternating sporting events and physics lectures. After a game of soccer with a mix of undergraduates, graduate students, professors, and researchers, we returned to the community center, hung out in the lounge by the bar, and nursed our injuries. I talked to researchers and students from around the world, and later attended a lecture with many of the soccer players from earlier in the week.

I came to Fermilab expecting a cold, industrial style group of buildings laid out on asphalt. The natural beauty of the landscape took me completely by surprise. Volunteers at Fermilab have worked hard since 1975 to restore the native prairie ecosystem on its campus. Over 1200 acres are devoted to growing native grasses, and a herd of buffalo even grazes above the center of the Tevatron ring, which is located underground. Other native plant and animal species are now seen around Fermilab's prairies and wetlands. Fermilab is not only devoted to advancing the particle physics frontier, but to restoring the America's frontier ecosystems as well.

The Tevatron accelerates protons and antiprotons to 1 TeV (1 trillion electron volts), the highest energy in the world.

A small group at Tufts is currently taking part in MINERνA, the Main Injector Experiment for ν (neutrino) –A. The Tufts group, led by Professors Gallagher, Kafka, Mann and Oliver, includes a mix of undergraduate and graduate students, and works with 21 other institutions around the world. This experiment searches for low energy neutrino interactions. Neutrinos are neutral, nearly mass-less particles that come in three known flavors: muon, electron and tau. They are created in radioactive and nuclear reactions, such as those in the Sun and in nuclear reactors. Over 50 trillion solar neutrinos pass through the human body every second.[1]

Current models of how neutrinos interact with matter have high error rates. MINERνA aims to study how muon and electron neutrinos interact with a variety of nuclear targets including helium, carbon, hydrogen, oxygen, iron, and lead. By studying how neutrinos interact with different targets, we will be able to test our current models of neutrino interactions.



Lauren Wielgus

The MINERνA detector sits right in front of the near detector for MINOS, a neutrino oscillation experiment. MINOS, MINERνA, and other neutrino experiments at Fermilab use the high intensity neutrino beam created from the Tevatron's proton beam. The high intensity of the beam allows MINERνA to collect information about thousands of neutrino interactions with a relatively small detector. In the spring of 2009, MINERνA collected data on over 20,000 neutrino interactions with a tracking prototype, a detector one fifth the size of the planned 5-ton detector. After taking apart the prototype this summer, and assembling the full size detector this fall, MINERνA is on schedule to begin collecting data in January 2010. The information learned from MINERνA about neutrinos will help neutrino researchers around the world to better model neutrino interactions.

Lauren Wielgus is a junior majoring in physics.

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Does The Earth Need A Shot?

A look at sulfur injection geo-engineering.

By Mary Beth Griggs

Talk about climate change is dominating debates from the schoolhouse to the House of Representatives, and a central question to these debates is 'what can we do about it?'. While the answer may be 'Nothing at all', there are many in the scientific community who aren't willing to accept that. They believe that global warming can be reversed using technology- an idea known as geo-engineering or intentional climate change.

There are many different methods of geo-engineering. Some are innocuous, and fairly widespread, such as the replanting of trees on previously deforested land. Others can get quite radical, such as building cloud machines on floating platforms in the ocean, or building trillions of mirrored sunshades in orbit to reflect solar radiation away from the Earth and thereby reduce global warming. Some studies decades ago even suggested that the Earth's oceans be seeded with reflective material to bounce the solar energy back into space, at the cost of polluting the oceans.

While the recent cool summers have led us away from "global warming" to "climate change" as the trendy phrase to use, it is in fact global warming that these scientists wish to prevent. In a nutshell, global warming is the increase in the global temperature. Its primary threat to the human species is that higher temperatures cause melting of the polar ice caps, which raises sea level. Scientists wish to use geo-engineering to halt the temperature rise. This would enable the ice caps to build up once again, and stop the flooding of coastal and island areas. Areas along the world's coasts are home to significant population centers, including cities like New York, Washington DC, London, and Sydney.

One highly publicized method of geo-engineering involves the injection of sulfur dioxide into the upper atmosphere (the stratosphere) in order to block some of the sun's radiation. It has received coverage from a variety of media outlets, from the New York Times,[1] to Scientific American Magazine,[2] to The Daily Show.[3]

Humanity has never attempted anything as far-reaching as this.

This type of geo-engineering was pushed to the forefront of the debate over intentional climate change in 2006 by Paul Crutzen. A winner of the Nobel Prize in chemistry and a respected atmospheric chemist, he published an editorial essay proposing that sulfur particles be placed in the stratosphere as a way to cool the earth.[4] He notes in the article that this is a method of last resort, writing that "the very best would be if emissions of the greenhouse gases could be reduced so much that the stratospheric sulfur release experiment would not need to take place. Currently, this looks like a pious wish."[4] His use of the word "experiment" is important- humans have never gone so far in attempting to change our world. We may have made it snow in ski resorts during the winter, or made it sunny for days in China ahead of the Olympic games[5]- but humanity has never attempted anything as far-reaching as this.

How'd they get the idea?

While humans may not have tried to change the earth's climate in such a dramatic way before, the Earth itself certainly has. The people that came up with this method did so based on a natural phenomenon known as volcanic winter. When a volcano erupts explosively, it throws sulfur dioxide into the air, and if the eruption is large enough, and contains the right gases, the volcanic aerosols that are produced can block the Sun's rays. With the solar radiation blocked, the earth below the aerosol cloud cools.

The idea behind this particular method of geo-engineering is, if we put enough sulfur dioxide (mimicking a volcanic explosion) into the atmosphere, it could halt global warming to buy us enough time to reduce carbon dioxide emissions. The volcanic aerosols can be easily developed from sulfur dioxide produced as a byproduct of industry every day. The equation itself is a simple one: SO_2 + Atmosphere + Heat --> 75% H_2SO_4 + 25% H_2O.

Getting the aerosol itself might not be a problem, but one area of debate is how to inject it into the stratosphere. There are differing delivery methods, ranging from the reasonable to the bizarre. Some involve pumping sulfur dioxide up through a large hose elevated by helium balloons; others involve distributing it through coordinated releases from airplanes, or from large dispersal guns mounted on airplanes, or simply releasing it from balloons.[1]

Close Encounters of Humankind (with Sulfur Dioxide)

Observations of climatic change due to volcanism and the associated volcanic aerosols began as far back as ancient times, and can be found in some of the earliest known written documents. From the ancient civilizations of Samaria and Greece to the Mayan culture in America, all document periods of darkness that were followed by crops dying. What these societies also have in common is that they are all societies that have a written historical record, and lived in proximity to volcanic regions.

More recently, in 1783, Ben Franklin observed cooler temperatures in Europe and North America, and attributed it to the Laki eruption in Iceland that happened at around the same time.[6] His observations were of a "dry fog" that blocked out the sun's light, and made for a harsh winter.[6] A little over 30 years later, in 1816 people all across the Northern Hemisphere observed a year without a summer, just after the explosion of Tambora in 1815. Poor harvests were recorded all across Europe and North America, with New England losing much livestock and Ireland entering a period of famine.[6]

A little closer to the present, we have evidence of cooling due to volcanic areosols from the El Chichon eruption in 1982 and the eruption of Mt. Pinatubo in 1991. When El Chichon erupted it caused a regionally far cooler summer in 1982 and when Mt. Pinatubo erupted in 1991 it lowered the earth's temperature by nearly one degree Fahrenheit, a direct correlation to the twenty million tons of sulfates that it released.[2] One degree doesn't seem like a lot, but should it have been a steady and far longer eruption the cooling would have been magnified.

All of these events have been noted in the incredibly short span of geologic time that humans have been on this earth and recording information about their surroundings. Even if the people writing about the events thought that the poor crops and hard winters that came after the eruption were punishment from the gods, we know better. Their gods, Ben Franklin's "dry fog" and what we now know to be a chemical compound are all the same thing. History tells us one thing, and it is that we should take the lessons of the past in full and apply them towards the future.

After the engineers go home

What goes up must come down. The same is true with sulfur dioxide aerosols. Once the sulfur dioxide has done its work and acted as a cooling blanket of sorts it will fall out of the stratosphere within a few years[7] and back into the lower troposphere- what then? The dry fog might cause lovely sunsets for painters and gloomy days for writers, but as history has shown us, the widespread cooling can affect crops. Modern science also presents us with the grim reality that Sulfur dioxide particles in the lower part of the atmosphere have been known to cause acid rain, which could affect previously unspoiled areas of vegetation, and they've also been known to cause premature deaths- up to 500,000 a year according to Crutzen.[5]

The injection of sulfurous material into

kevindooley / Flickr.com

the stratosphere could prevent the ozone hole from recovering. Volcanic aerosols can react with ozone in the stratosphere. Injecting these materials into the stratosphere could have the effect of potentially setting back the recovery of the ozone hole by as much as 30 to 70 years.[5] This is a worst-case scenario conclusion, but still a potential and very serious consequence that would need to be looked at more in depth before initiating the program.

Unless we have a plan in place to make the world close to emission-free during this period of intentional climate change, then geo-engineering for the sake of geo-engineering is pointless.

Then comes the question of the monetary burden of the project. Crutzen suggested that the US and other industrialized nations pay the $25-50 billion that he estimated it would cost for the program.[2] He pointed out that the amount that the United States spends on military operations annually far exceeds this. While that may be true, it still begs the question; is it the *right* thing to do?

Global warming affects the whole world, and so does any solution to it that might be developed. And while the island nations might be very pleased to have a few more years left in a cooler world, the more populous countries that are already enmeshed in famines and food shortages would not.

Food might seem irrelevant to geo-engineering, but the fact is, anything we do to block the sun is going to in some way effect the crops that rely on the sun to grow. While industrialized nations might be able to pull a system together to save the crops in their countries, others will not be so fortunate. Many of the "third world" nations have an agrarian-based economy whose crops would be drastically affected by any blockage, no matter how small, of the sun's radiation. Even the so-called first world countries with their technological prowess might not be spared. Ireland's famine in 1815 was not an isolated incident. It was caused by the last massive eruption of Tambora in the Phllipines and during the year that followed, the western world, from New England to Germany, [6] was seriously affected by the lack of food. Should the United States or any nation decide unilaterally to go through with a plan for sulfur injection, the international outcry could be catastrophic should something go wrong.

Most importantly, sulfur injections are only half of the story. As stated earlier, there must be a drastic reduction in carbon dioxide emissions during the artificial cooling period. When faced with a similar crisis in the 1960's over Chlorofluorocarbons, the International community was able to come together and ban them outright because there were alternatives available that the manufacturers could easily switch to. In the face of this crisis there is no such quick fix. There are many options for alternatives to combustion, in the form of wind energy, solar power, tidal generators, etc., but none that are yet ready to take the reins from combustion on a global scale.

All of the scientists that have endorsed this idea of geo-engineering, as

see Sulfur, page 22

AFTER YOUR

Preparing Now For

Become a Dentist

Are you interested in dentistry? Does a career that combines the arts and the sciences appeal to you? If you are enticed by a career in science that is very hands on, then dentistry may be for you!

What training will I go through after I leave Tufts?

- 3-4 years of dental school
- Residency
    - Residency is only necessary when specializing in oral and maxillofacial surgery, in which one would train as a general surgeon for 2 years before 2 years of specializing.

What do I have to do now to get there?

1. Start early and meet with your pre-health advisor and/or Dean

2. Take and do well in the pre-dental requirements, do not hesitate to use tutoring resources from the get-go.

- Biology I and II (and lab)
- Chemistry I and II (and lab)
- Organic Chemistry I (and lab)
- Physics I and II (and lab)
- Most dental schools may require:
    - Biochemistry
    - Organic Chemistry II (and lab)
    - 2 semesters of English and 1-2 of calculus

3. Take the DAT

This is the dental entrance exam that students aim to take during their junior to senior year after fulfilling the 3 core sciences (biology, chemistry, and organic chemistry).

4. Volunteer! Even if you are unsure whether or not it is the career path for you, the best way to know is to immerse yourself in the dental atmosphere.

- Shadow a dentist in the area; asking the pre-health advisor to help find you a local dentist is one of the easiest ways to gain exposure!
- Join the Tufts Pre-dental Society! This club is the best way to meet students, find volunteering opportunities, and get advice from upperclassmen that are going through the application process.

5. Make sure you show up! This is the best advice I can offer to any student interested in a career in dentistry or any of the health related fields. Attend class, get involved in volunteer opportunities, show up at the dental school, and meet your health advisor. It is a lot to take in, but if you're dedicated the time put in is definitely worth it! Visit http://www.adea.org for more.

- Katharina Fung

Become a Veterinarian

Are you passionate about animals? Do you like science? Are you interested in a career that combines both of these fields? If so, you might want to be a veterinarian!

What is veterinary school like?

- Tufts Vet accepts a class of about 80-100 students per year
- You should apply the summer before senior year (or to early acceptance program during sophomore year)
- Supplemental applications are due in the fall and interviews are held in winter/spring

What do I have to do now to get there?

1. The required courses are similar to medical and dental schools, but there are a few differences. Here are some courses you should look into:

- Biology I and II (and lab)
- Chemistry I and II (and lab)
- Organic Chemistry I and II (and lab)
- Physics I and II (and lab)
- Biochemistry
- Microbiology
- Public Speaking

2. Work and Volunteer with Animals!

Whether it be at a shelter, animal hospital, or around your neighborhood, the importance of animal experience cannot be stressed enough! It might also be a good idea to diversify your experiences. For example, try working with large, small, and even exotic animals.

3. Perform Research at Tufts or Elsewhere!

Veterinary researchers play an important role in public health and epidemic control (remember swine flu?). Doing research as an undergraduate will surely add to your resume.

4. Plan Out Your Standardized Tests!

Look at the testing requirements for the veterinary schools that you are interested in. Most schools in the USA require only the GRE, while the VCAT or MCAT is optional. Many foreign schools, however, require the MCAT. Also check out if any GRE subject tests are required for your schools of interest.

Visit AAVMC website for further information on applications and school requirements: http://www.aavmc.org.

- Matthew Ferreira

BACHELOR'S
Your Future in Science

Get a Ph.D.

Do you want to not only learn scientific knowledge but help further this knowledge? Do you have an insatiable curiosity and the ability to form creative solutions to problems? Then a life of research might be the life for you. There are a plethora of masters and Ph.D. programs in the sciences in the United States and beyond. These programs are very competitive and time consuming, requiring dedication, time-management skills, and perseverance for successful completion.

What can I do with a Master's or Ph.D. in a science field?
Most careers in which you will use your Master's or Ph.D. training will involve research (i.e. becoming a professor or working as a scientist for a private research company); however, you could also work as an administrator in a science or technology company.

What are graduate programs like?
Graduate programs tend to be small and competitive. Unlike the college application process, when applying to graduate school you will not be applying to the school in general, but to a specific professor under whom you wish to work.

- Master's programs normally take 2 years to complete
- Ph.D. programs take between 5 and 7 years to complete

What do I have to do now to get there?
1. Major in an area of interest and do well in your classes.

2. Get involved with science research at Tufts! Department websites are a great resource to find a professor who's doing research in a field of interest to you.

3. If you wish to be a competitive applicant to some of the top graduate programs in the country, then you should not only aid Tufts professors in their research, but complete a research project of your own, whether it be an independent research class or a senior honors thesis. Don't fear, you will have a mentor and much guidance along the way! You may want to:

- Check out the Summer Scholars website to look for open research opportunities (http://summerscholars.programs.tufts.edu).
- Design an original research project and approach a professor for mentorship
- Apply for a grant to support your research from the Tufts Undergraduate Research Fund

- Sophia Cedola

Become a Doctor

Are you passionate about medicine? There are many different careers in the healthcare industry! If you are prepared to put in a lot of time in school and at your job, becoming a Doctor or a Pharmacist might be the way to go. How about a little less schooling? Becoming a Physician Assistant, Nurse, Nurse Practitioner, Surgery Technician, or Physical Therapist are all good (but not exhaustive!) options. We will discuss the career choice of doctor here.

What can I do with an M.D.?
An M.D. opens the doors to many career options such as becoming a practicing physician, a researcher, a professor at a Medical School, or an administrator in a healthcare organization.

What training will I go through after I leave Tufts?
- Four years of medical school, which breaks down into 2 years of classes and 2 years of rotations
- Residency
  - In residency you are a paid doctor; however you will be continuing your medical training and will be under the supervision of attending doctors. Residencies usually last about 3-5 years.
- Fellowship
  - You may choose to complete a fellowship after your residency to further your expertise in a subspecialty of medicine. Fellowships can last up to three years.

What do I have to do now to get there?
1. Set up a meeting with your Dean and the Tufts Pre-Health Advisors

2. Take and do well in the pre-med requirements. (Don't be afraid to get a tutor!)
   - Biology I and II (and lab)
   - Chemistry I and II (and lab)
   - Organic Chemistry I and II (and lab)
   - Physics I and II (and lab)
   - Some medical schools also require:
     - 2 semester of English and 1-2 of Calculus
     - 1-2 semesters of upper-level biology

3. Volunteer! At a hospital, a clinic, anywhere in the health industry. Even better: "shadow" a doctor. You can set this up yourself by contacting doctors at local hospitals/clinics.

4. Take the MCAT and be sure to do your best. Definitely buy a preparation book to study with; you may also want to take an MCAT course. Visit http://www.aamc.org for more information.

- Sophia Cedola

Dr. Barry Trimmer

He's pioneered a new field of robotics, drawing inspiration from biology.

By Dan Slate

Dr. Barry A. Trimmer, Henry Bromfield Pearson Professor of Natural Science and Tufts Professor of Biology, has one simple piece of advice for undergraduates interested in scientific research: "It's really important to be excited by what you're doing. You should come out of [your research] with a little tickle into your intellect that says, 'that was interesting, I think that's really cool.' The bottom line is, it should be fun."

It's this passion that has driven Trimmer throughout his career, whether it be creating fireworks from household chemicals in his younger years, or discovering novel biomimetic technologies through his work with the tobacco hornworm in more recent times. "I always identified myself as a scientist," explains Trimmer as he recounts instances when he would invite friends over to dissect a dead animal found in his backyard, or when he would disassemble a household appliance to figure out how it worked. Trimmer, who grew up in England, attended Cambridge University and pursued an undergraduate degree in the Natural Sciences with a focus on Neurophysiology, Insect Biology, and Cell Physiology. During his time at Cambridge, Trimmer crossed paths with Dr. Andrew Huxley who taught one of his Biology courses and, along with Dr. Alan Hodgkin, won the Nobel Prize in Physiology and Medicine for his work on characterizing action potentials in nerves.

After completion of his undergraduate degree, Trimmer decided to attend graduate school and was presented with a few options: "One was to study ant social organization in Brazil and live in the Amazon for two years […] but I ended up staying at Cambridge to study under Dr. Michael Berridge, whose research focused on intracellular signaling systems." Though perhaps less exotic, Trimmer's description of his Ph.D. advisor demonstrates that his experience at Cambridge was no less influential. Dr. Berridge was one of Trimmer's former professors whose intellect stunned the

Courtesy Dr. Trimmer

young scientist and drove him to sign on as a graduate student under a Professor who typically didn't accept advisees. Trimmer describes Dr. Berridge as a reserved, yet brilliant researcher who was ultimately knighted for his groundbreaking work that lead to the discovery of the Inositol Triphosphate (IP3) signaling pathway, a critical second messenger pathway present in all cells. Dr. Berridge reluctantly accepted Trimmer as a graduate student after Trimmer explained he would not require much supervision. He fondly recounts working in a small, single room lab alongside Berridge, who did all of his own research, unlike larger labs in which the Principle Investigator is typically more removed from daily research activities. While he worked independently much of the time, there were instances when Trimmer explains that he would become stuck and approach Dr. Berridge for assistance. "He would look over my data, lay it all out, and then go, 'There!' and would put his finger right over it within two minutes. It was just great to be around somebody that smart."

After completing his Ph.D. work in 1983, Trimmer decided he wanted to pursue work in neuroscience and neurobiology. At the time, there was a significant amount of turmoil in Britain and jobs, especially in academia, were virtually non-existent. Further, neuroscience had not yet been recognized in the U.K. as a discipline in and of itself and was often spread across academic research departments. Trimmer, therefore, decided to continue his research in the United States where Neuroscience was recognized as a distinct field. Through a connection in his lab at Cambridge and with funding from a Harkness Fellowship grant, he took a position as a postdoctoral researcher in Dr. Edwin Kravitz's lab at Harvard Medical School, examining peptide expression in the lobster nervous system. Trimmer recounts, "it was supposed to be a 21-month appointment, and I've been here for 26 years."

After his time at Harvard, Trimmer took a postdoctoral research position in a newly created lab at the University of California, Berkeley, run by Dr. Janis Weeks. It was at this lab that Trimmer first encountered the model system he still works with today, the tobacco hornworn, scientifically termed, Manduca sexta. Dr. Weeks's lab focused on the central nervous system and its modulation of behavior at the mechanistic level. While Dr. Weeks was a developmental neurobiologist, Trimmer explains that his interest focused more on the "moment to moment modulation of neurons and how information transfer occurred." Fortunately, because the lab was new, Trimmer was given leeway to pursue much of his own research and very quickly realized the benefits of the Tobacco Hornworm model system. Working under Weeks also proved fundamental to Trimmer's understanding of running a lab and managing personnel. Weekly lab meetings were so effective that Trimmer continues the practice in his own lab to this day. Most importantly, his experiences at Harvard and at Berkeley were, as Trimmer explains, "training experiences and formative for my own lab at Tufts."

Just as Trimmer and his wife settled into the San Francisco Bay area, Janis Weeks accepted an offer to move her lab to the University of Oregon, leaving Trimmer to decide between a lengthy commute or a new position elsewhere. Once again, Trimmer's passion for his research becomes apparent as he explains his decision to make the 600-mile commute in two-week intervals on his motorcycle. "I would work for two weeks, intensely, basically I slept on someone's floor. I worked 18-hour days collecting data. I just did experiments. I didn't do analysis, I just collected as much data as I could. Back in the day, the data was all stored on digital tapes and the digital tape reader would be strapped to the back of my motorcycle as I would drive back to Berkeley to spend two weeks analyzing my data on the computer at home. It wasn't the best, but it worked." By this time, Trimmer had a good idea of what his own lab might pursue and began to apply for tenure track positions at a variety of Universities. Shortly thereafter, in 1990, he was offered a position in Tufts' Department of Biology.

Trimmer explains his decision to accept the position at Tufts: "At the time, Tufts seemed a little bit small. I had come from large universities at Cambridge, Harvard, and Berkeley and I didn't know much about Tufts. But when I visited, it was a good match. It seemed like a place where I could get a lot of good work done and invent my own way of doing science. The Boston area was definitely a plus too." A true collaborationist, Trimmer was also excited by the access to other academic departments that working on an undergraduate campus provided. His initial work at Tufts focused on examining information transfer at the synapse and its impact on animal behavior. Trimmer's lab was one of the first groups to study muscarinic receptors in invertebrates, ultimately determining that they played an important role in adjusting the gain of the synapse via the IP3 pathway inside the cell, the very pathway Trimmer's Ph.D. advisor helped discover.

While examining intracellular signals was interesting to Trimmer, digging deeper into intracellular mechanisms would have meant losing focus on his true interest: the effect of neural activity on behavior. Further, Trimmer realized that while many scientists were engaged in the study of intracellular signaling pathways, few had attempted to examine these pathways in the larger context of animal behavior. Thus, the focus of Trimmer's research began to shift towards examining how the tobacco hornworm moved, ultimately leading to his current focus on understanding soft-bodied locomotion. Trimmer explains the shift as one of personal preference: "My interest was in neurobiology and behavior. How does an animal move? How does an animal do what it does in the wild? These interests took the lab on a new trajectory."

Trimmer is perhaps most recognized on campus for his work on the development of soft, biomimetic robots, modeled after the tobacco hornworm. "I was heavily influenced by the field of neuroethology, the study of how cells translate stimuli into natural behavior. The people who pioneered that field were also interested in emulating biological processes. The basic idea is, if we understand something well enough, we should be able to build a model that behaves the same way." Testing these models would help validate or invalidate scientific theory and could serve as a foundation for asking more informed questions about a particular model system. This idea led to the development of the Biomimetic Devices Laboratory (BDL), a collaborative endeavor by the various science and engineering departments on campus.

Trimmer explains the benefits the lab provides to his work with the tobacco hornworm: "Looking at the caterpillar from an engineering perspective, we suddenly realized we understood less about its motion than we thought we did." At the time, the BDL was a novel, yet risky, proposition. Trimmer admits that, as with any new venture, it took patience to get the idea off the ground. Yet, with money from a seed grant from the Provost's Office, the BDL came to fruition and now is home to a vibrant community of researchers from a wide range of disciplines. The collaborative effort between biologists, physicists, chemists, engineers, and mathematicians allows for a very unique approach to answering scientific questions. Trimmer's lab now focuses on modeling and characterizing the locomotion of the tobacco hornworm with an eye toward developing a new type of soft-bodied robot. This ultimate goal came one step closer to fruition in October 2009 when Trimmer's group and other Tufts researchers presented their soft robotic designs at the Defense Advanced Research Projects Agency (DARPA) conference as part of an existing grant from the military agency. The Tufts team successfully met all the project metrics, the only team to accomplish this feat, despite competing with numerous other universities and robotics companies.

While the research in Trimmer's lab grinds on, he provided some insight into exactly what allows such research to occur. "The most stressful thing for any researcher or professor, is trying to fund their research." A competitive grant proposal process combined with a multitude of other demands on a university professor's time make procuring funding an arduous, if not downright unpleasant, process. Trimmer recounts his initial arrival at Tufts as being one of humble beginnings: "When I arrived at Tufts, my lab was empty. It didn't even have tables. My office didn't even have a chair or a filing cabinet." This situation is common throughout academia. While most professors do negotiate a startup funding package with their university, they must become self-sufficient very quickly. When considering the demands of teaching on a professor's time, this goal of running a well funded research lab becomes much more complicated. Yet Trimmer believes that, though many in academia may consider good research and good teaching mutually exclusive, finding the perfect balance between the two has been the secret to Tufts success. "Tufts makes it very clear that Professors have to teach, teach well, and enjoy it. And because of this, Tufts attracts professors who have an interest in doing both. I actually find that teaching keeps me sharp, it keeps me current, and I learn things I may not have known before."

Despite these time demands, Trimmer still manages to run an extremely successful and vibrant research lab with an emphasis on the interdisciplinary study of science that is truly visionary: "We want to try to break down the boundaries between the math, science, and engineering disciplines. We want them to be completely transparent to one another. That's got to happen because the sciences do not fit into the silos of departments that we have arranged them in at universities."

Dan Slate is a junior majoring in biology and entrepreneurial leadership.

The Overlooked Fuel

Hydrogen is cleaner than gasoline. Why aren't we using it?

By Jackson Dolan

In a renewable energy focused world, hydrogen is being lost amidst the constant media coverage of other sources. Wind, solar, tidal, and nuclear are easily the most discussed sources of renewable energy, but none can truly replace fossil fuels as the dominant energy resource for the United States. Hydrogen however, can do everything gasoline can and is 100% clean. The only byproduct of hydrogen combustion is water. There is no carbon dioxide, or any other toxic chemicals, produced.

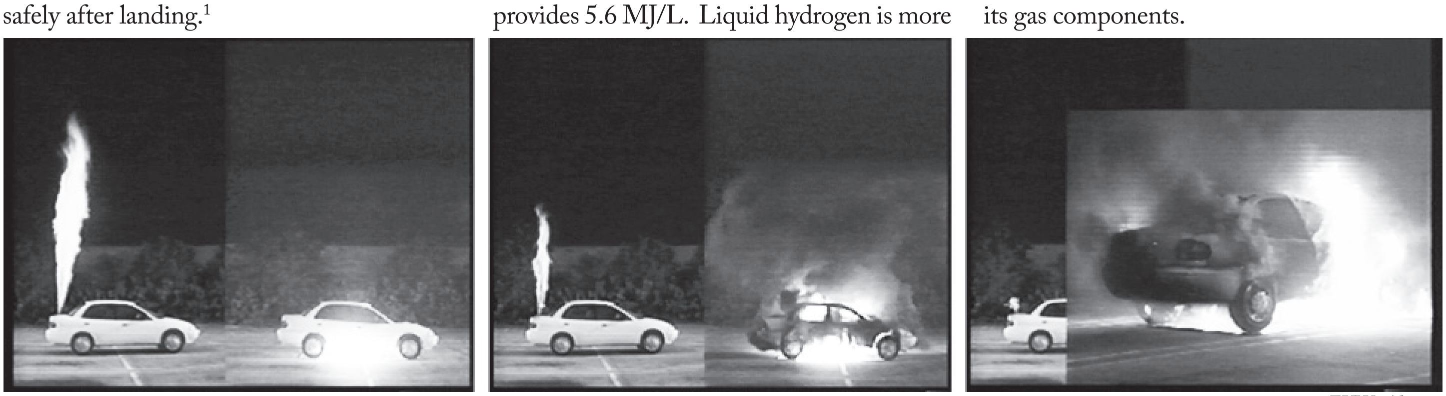
Hydrogen is also safer than gasoline. There was a demonstration at a high school in Connecticut, and while there were strict fire codes regarding hydrogen on the property, the school absolutely forbid bringing an equivalent amount of gasoline to the demonstration. The Hindenburg disaster, a popular example of the dangers of the element, was not caused by hydrogen. The entire zeppelin was covered in an aluminum based paint which is strongly similar to modern day rocket fuel. There was a spark, and the paint ignited. The hydrogen accelerated the burning, but it burned upwards, away from the ship and passengers. Out of the 37 deaths that occurred in the crash, 35 of them resulted in people jumping out of the ship. The remaining two deaths were due to diesel burns, and were not hydrogen related. Everyone that stayed aboard the ship evacuated quickly and safely after landing.[1]

The Hindenburg highlights an important fact of hydrogen safety: substantially lighter than air, hydrogen burns up and away extremely quickly. The much heavier gasoline explodes and burns, and does so for a long time. Think about every explosive car crash scene in the movies; the gasoline pools onto the ground, spreading the fire while it continues to burn. The University of Miami conducted an experiment in which 3000 cubic feet (almost 8,500 Liters) of hydrogen was leaked from a gas tank and ignited, while a similar leak was sprung in an identical vehicle but with gasoline instead. The hydrogen car's temperature only changed by about 1 or 2 degrees Celsius throughout the entire burn, which lasted about a minute and a half. A car will get hotter if it is left to sit in the sun all day than if it had a burning hydrogen leak. The comparable gasoline leak continued to burn, spreading to the entire car and eventually leaving it a charred shell.[2] (See photos, below.)

The biggest problem with hydrogen is storage space. It has, hands down, the highest energy to weight ratio (Specific Energy) of any non-nuclear source, with a staggering 143 MJ/kg. Gasoline yields about a third of that, 46.4 MJ/kg. But the advantage of gasoline and other fuels is that they can be compacted easily while hydrogen cannot. The energy density of gasoline is 34.2 MJ/L, yet hydrogen, even compressed at a massive 700 times atmospheric pressure, still only provides 5.6 MJ/L. Liquid hydrogen is more difficult to attain, requiring more intense pressures and an incredibly low temperatures, still only provides 10.1 MJ/L.[3,4] To simplify a bit, if a 20 gallon gasoline tank was filled with liquid hydrogen, it would provide about 764 MJ of energy, ignoring losses. The equivalent volume of gasoline would release over three times that, at nearly 2,600 MJ. Putting this in perspective, one gallon of gasoline contains about 130 MJ of energy. This will allow an average vehicle to drive 19.8 miles.[5] Unfortunately, the same volume of hydrogen will only yield 3.24 miles.

Hydrogen has enormous potential, but it is being crippled by myths and misinformation.

This provides obvious difficulties for trying to integrate cars and hydrogen. The relatively small size of cars increases the storage difficulties, and would therefore increase costs, making cars that simply use hydrogen as a fuel source rather than gasoline economically unviable for most of the world. Fuel cell cars, which recycle the water produced from combustion back into hydrogen and oxygen, would be even more expensive than their pure hydrogen counterparts as they require electrolyzers to turn revert water into its gas components.



EVWorld.com

The results of fuel leaks from two cars. The one on the left burns hydrogen; the other burns gasoline. First photo is after 3 seconds; second photo is after 60 seconds; third photo is after 90 seconds.

Even if the mass production of hydrogen powered cars suddenly becomes viable, they would hardly fly off the shelves because hydrogen is publicly available in only a handful of places. There are only 112 hydrogen fueling stations throughout the United States. California has over 50 stations, but most states don't have any. To put that number in perspective, a simple white pages search yields nearly 600 gas stations just in Los Angeles. This should come as no surprise though, given the fact that gasoline and diesel cars compose almost all of the cars in the United States at this time. It is a self serving cycle – there is no market for hydrogen cars because people would not have a place to refuel them, and there aren't any filling stations because no one has a hydrogen car. An abrupt change from gasoline to hydrogen would be incredibly expensive technologically and would also require training the hundreds of thousands gas station attendants and mechanics. Yet the solution to starting a hydrogen economy is simple: stop focusing on cars.

The biggest problem with hydrogen is storage space.

Hydrogen can be used in a myriad of other ways, all of which would help lower our dependence on fossil fuels. It can replace acetylene for welding, run generators and space heaters. People can even buy hydrogen powered grills capable of cooking what some affectionately call Hindenburgers. Lawnmowers are easily modified to run off of hydrogen instead of gas, and Mowgreen, a Connecticut based clean lawncare company, uses one regularly.

If we insist upon transportation, look at trains. An extra car or two could easily hold a large reserve of hydrogen, and if these were implemented on frequented routes or even subways, it would go a long way to ease public apprehension towards the gas. It could also be used as a marketing ploy. Amtrak might actually be able to create worthwhile business if it suddenly had the country's first ever train with electricity provided by hydrogen and not coal.

Transportation is not the biggest energy drain though. Buildings, both residential and commercial, combine to use over 40% of the country's energy.[3] Architects and HVAC engineers are already acting on a variety of ways to improve efficiency, and renewable technology sources are being implemented to help make the buildings more self sufficient. Solar panels line the rooftops of Google, and the Bahrain Tower has three wind turbines built within the structure. Hydrogen can integrate wonderfully with setups like this, solar in particular. Solar energy taken in during non-business hours can be used to convert water into hydrogen and oxygen, instead of pouring the excess electrical energy back into the grid to save for later. The hydrogen can be stored for future rainy days to be combusted for power, or used for other applications that electricity is not suited for, such as combustion processes. The separated oxygen can be used or sold for extra money, as it is plentiful enough in the atmosphere that there is no need to keep it for the future hydrogen combustion. Such a set up would also work well with gated communities, where there is an enormous amount of surface area for solar cells and extra space to store hydrogen.

Jackson Dolan

Hydrogen has enormous potential, but it is being crippled by myths and misinformation. It is widely regarded as only being applicable to cars, and people are frightened by the sensationalized explosions of the Hindenburg. The technology for large scale application is here and will only improve until hydrogen can be used easily and affordably in cars, planes, and other smaller devices. How fast this happens largely depends on public involvement and demand, and it requires people to open their eyes to the world outside of fuel cells and science fiction. Hydrogen has the numbers, and with the support it deserves, it can begin to take its place among the heralded clean energy options.

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The Serendipitous Nature of Astronomical Discovery

Professor Kenneth Lang's influential lecture.

By Catherine Hoar

This past fall the International Astronomical Union (IAU) and the National Institute for Astrophysics Astronomical Observatory of Padova celebrated the 400th anniversary of Galileo's first viewing of the sky through a telescope with "Astronomy and its Instruments Before and After Galileo," an international conference in Venice, San Servolo Isle. Kenneth R. Lang, Professor of Astronomy at Tufts, was invited by the Scientific Organizing Committee of the symposium to present a lecture entitled "The Serendipitous Nature of Astronomical Discovery."

The conference, an event of the International Year of Astronomy 2009 (IYA2009), was a joint symposium under the patronage of the United Nations Educational, Scientific and Cultural Organization (UNESCO).[1]

Lasting from September 28 to October 3, the symposium included exhibitions, discussions, and oral presentations. It's main goal was "to highlight mankind's path towards an improved knowledge of the sky using mathematical and mechanical tools as well as monuments and buildings, giving rise, in so doing, to scientific astronomy," according to the conference's website.[1]

The sessions put together to achieve this aim addressed many aspects of astronomy, including its history, instruments, development, and relationship to society. Lang's lecture, presented on October 1, explored unexpected discoveries made by astronomers throughout history.[1]

Galileo Galilei and his telescope were introduced in the opening example of Lang's lecture. Lang explained that Galileo was originally observing the full moon and Jupiter in January 1610 when he unexpectedly found the four largest moons of Jupiter. His groundbreaking discovery implied that, contrary to the standing geocentric model of the solar system, "there is more than one center of motion in the Universe."[2]


Courtesy Professor Lang

The significant consequences of the discoveries Lang discussed, including many additional discoveries, make the notion of serendipity even more surprising. William Herschel, for example, discovered Uranus, "the first planet to be discovered since the dawn of history." Lang explained how this finding not only "doubled the size of the known planetary system" but also allowed for the prediction of Neptune's location.[2]

Our knowledge of asteroids and the asteroid belt between Mars and Jupiter also stems from serendipity, according to the lecture. While gathering information about stellar positions for a star catalogue, Giuseppe Piazzi observed Ceres, the first known asteroid, in 1801.[2] The significant results of this discovery are perhaps best illustrated by the information about asteroids available today. Ceres, originally thought to be a star or a comet,[2] is now known to be the largest asteroid. Over 750,000 asteroids with diameters greater than one kilometer are estimated to be in the asteroid belt, and estimates of the number of smaller asteroids are in the millions.[3]

Astronomical discoveries continued to unfold in the twentieth century, leading to the further developments. Lang continued by describing how Vesto Melvin Slipher's discovery of the large recession velocities of spiral nebulae was used, in combination with Edwin Hubble's data, to discover the expansion of the Universe.[2]

From 1933 to 1935, Karl Guth Jansky observed radio emission from the Milky Way, with the most intense signal emitted from the galaxy's center, according to the lecture. This discovery, made while Jansky measured possible radio communication interference, was extended by Sir Martin Ryle's Nobel Prize winning work with synthesis arrays of radio telescopes.[2]

A number of Nobel Prizes have resulted from unexpected discoveries, a fact explored in the lecture. Riccardo Giacconi shared the prize in 2002 for his work with X-ray detectors and telescopes and for his role in the discovery of cosmic X-ray sources. For the discovery of three-degree cosmic microwave background radiation in 1965, Arno A. Penzias and Robert W. Wilson were awarded the Nobel Prize in Physics in 1978.[2]

Yet another Nobel Prize for an unanticipated discovery was awarded to Anthony Hewish. Hewish, graduate student Jocelyn Bell, and colleagues discovered radio pulsars after noticing radio pulses within a repeated period during a survey of radio sources. Hewish shared the prize with Sir Martin Ryle in 1974. Finally, in 1993, Russell A. Hulse and Joseph H. Taylor Jr. received the Nobel Prize in Physics in recognition of their discovery of the binary radio pulsar in 1975.[2]

The lecture maintained a strong connection to historical context throughout. This was particularly clear in the example of the discovery of gamma ray bursts, announced in 1973 by Ray W. Klebesadel, Ian B. Strong and Roy A. Olson. The discovery took place while gamma ray detectors monitored the banned testing of nuclear weapons in the Earth's atmosphere, on the moon, and in outer space.[2]

Following this chronology of important discoveries, Lang discussed how astronomy in general is "an instrument-driven science" based on new technologies and resulting glimpses into the otherwise "invisible" Universe.[2]

The presentation extended the principle of serendipity beyond historical events and breakthroughs of the past. "Astronomy is," Lang said, "governed by unexpected findings…" And this unpredictable nature may apply to potential possibilities. He stated, "The main ingredients of our observable Universe, its material content and dominant energy source, await future serendipitous discoveries."[2]

Lang, author and a past Visiting Senior Scientist in Solar Physics at NASA Headquarters, is a member of IAU, the Royal Astronomical Society and the American Astronomical Society.[4] Throughout his career, particularly during his work on Source Book in Astronomy and Astrophysics, 1900-1975, one of Harvard University Press's Source Books in the History of the Sciences, Lang has noted several important historical discoveries which provided inspiration for his lecture. He said of these discoveries that "It struck me that so many of them were unexpected, accidental, serendipitous."[5]

Others have also recognized the presence of serendipity in astronomy, including Russell A. Hulse. Lang referenced Hulse's 1993 Nobel Lecture, in which Hulse observed, "pulsars yielded two exciting scientific stories which began with serendipity and ended with a Nobel Prize."[6]

Appreciation of these important discoveries and of astronomy in general was encouraged by IYA2009, a global program started by IAU in celebration of astronomy and the 400th anniversary of Galileo's use of a telescope. Opening ceremonies for IYA2009 took place in 16 countries during the early months of 2009.[7]

Throughout the year events were carried out in an effort to "help the citizens of the world rediscover their place in the Universe through the day- and night-time sky," which was hoped to "engage a personal sense of wonder and discovery." Global meetings and various special projects have allowed IYA2009 to reach the public on global, national, and local levels.[7]

The proposition for IYA2009, passed by IAU in 2003, was endorsed by UNESCO in 2005. The year 2009 was announced as the International Year of Astronomy by the United Nations in 2007.[7]

"Astronomy Beyond 2009," the closing ceremony of IYA2009, also took place in Italy. From January 9 to January 10 2010 in Padova, a meeting of astronomers, science historians, and participants discussed the past year as well as the future of astrophysics.[8]

Resources, news, and more information about IYA2009 can be found at http://wwww.astronomy2009.org/. To follow IYA 2009, the year 2010 has been declared the International Year of Biodiversity.[9]

Catherine Hoar is a freshman who has not yet declared a major.

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Further Reading

Resources, news, and more information about IYA2009 can be found at:

http://www.astronomy2009.org/

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Additionally, Lang has an article in the January 2010 issue of Science magazine. The article is entitled "Serendipitous Astronomy."

Sulfur

continued from page 13

well as those that have opposed it make the same point: unless we have a plan in place to make the world close to emission-free during this period of intentional climate change, then geo-engineering for the sake of geo-engineering is pointless. It would create a cooling lull with global effects that even the scientists studying it do not have a grasp of.

In a paper published on October 22, 2009, Dale Jamieson makes the observation that, "unless a duty of respect for nature is widely recognized and acknowledged, there will be little hope of successfully addressing the problem of climate change."[8] While we as a human race may have inadvertently changed the world's climate during the industrial revolution and after, intentionally attempting to "change back" a process we do not fully understand could have more dire consequences than the effects we have now.

Mary Beth Griggs is a senior majoring in geology and archaeology.

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Plants

continued from page 7

purees before they can be used as vaccines. These vaccines will also need to be eaten raw; cooking a vaccine-containing potato can degrade the antigens within it, making it ineffective.[3] However, powders and pills may help to increase the vaccine's shelf life and will also help in part to ensure that pharmaceutical plants don't get mixed up with food crop. Oral vaccines have also been shown to produce both mucosal and systemic immunity.[1]

The first clinical trials on humans began in 1997 on harmful strains of *E. coli*, which cause millions of deaths each year due to diarrhea. Volunteers were fed between 50 to 100 grams of raw potato containing vaccine against *E. coli* three times over the course of three weeks, and both mucosal and systemic immune responses were observed. The majority of the volunteers had 4-fold increases in the levels of antibodies specific to a mucosal immune response, which was significant since *E. coli* enters through the mouth and a mucosal immune response would be the first line of protection.[4] Other testing on both mice and humans has shown success in developing vaccines for cholera, hepatitis B, influenza B, measles and many more diseases, although there are still many more phase I and II trials to be completed before the U.S. Food and Drug Administration determines plant vaccines to be safe and effective.[1]

If these plant vaccines are commercialized, it has been estimated that they may cost between 10 to 100 times less than the vaccines that are currently produced using animal or microbial technologies. Lower costs means that more countries can afford to vaccinate their people, and the 30 million children who currently don't have access to vaccines, may have a better chance of getting protection against the diseases that claim so many of their lives.[5] However, before these vaccines are commercialized, many issues still need to be worked out, particularly how the production and distribution of these vaccines will be regulated. Since this is genetic modification technology, researchers have to ensure that the genes being produced in these plants will not be able to spread to related plants in the wild, and must also account for other possible environmental impact concerns such as other species eating the modified plant tissue containing a vaccine. Hopefully regulations will be set in the next 2 to 5 years so that some of these vaccines can be put onto the market and begin saving the lives of the world's most disadvantaged citizens.

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it is only by standing on the shoulders of giants."
- Sir Isaac Newton

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