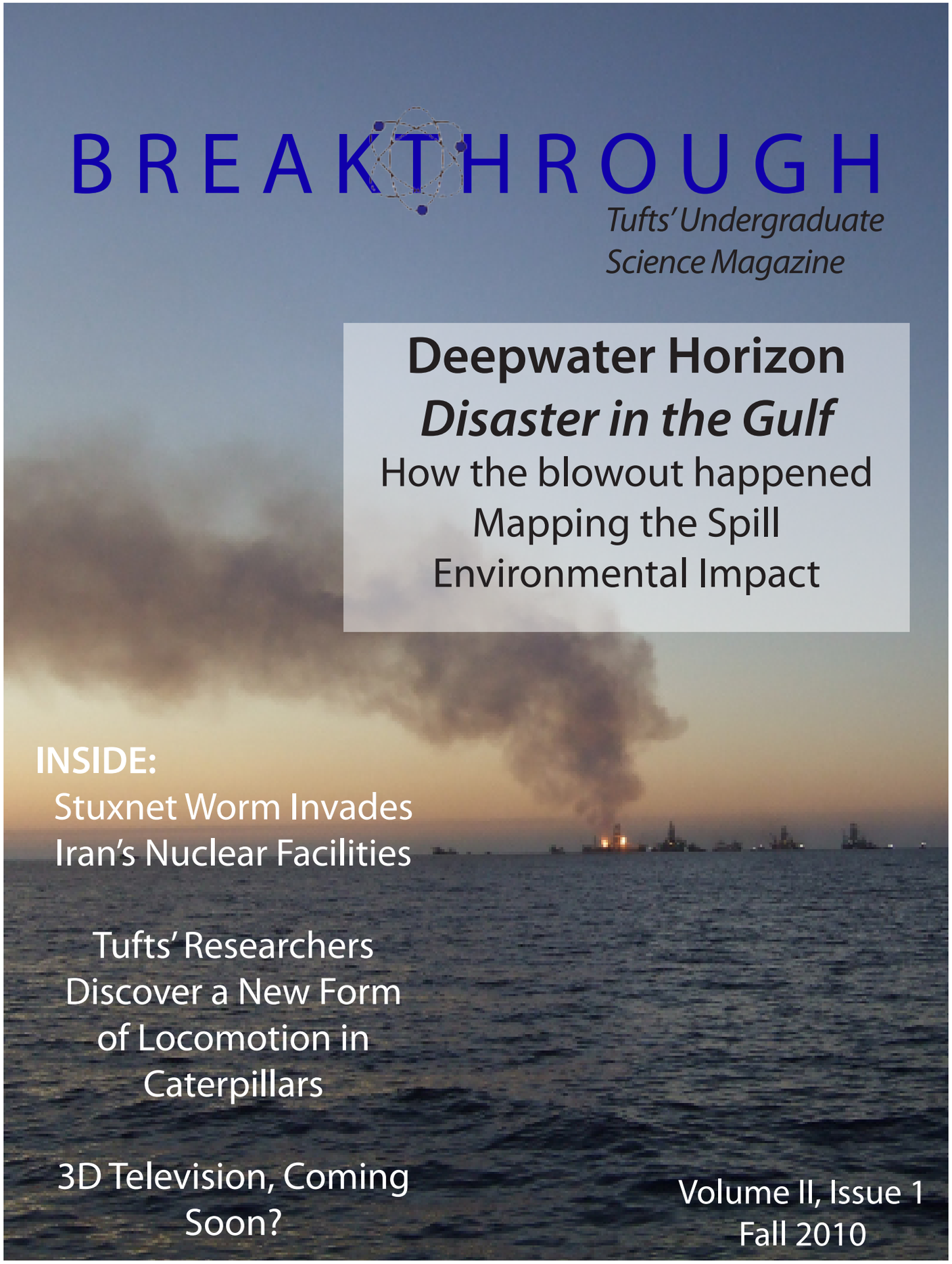

BREAKTHROUGH

Tufts' Undergraduate Science Magazine

Deepwater Horizon
Disaster in the Gulf

How the blowout happened
Mapping the Spill
Environmental Impact

INSIDE:

Stuxnet Worm Invades Iran's Nuclear Facilities

Tufts' Researchers Discover a New Form of Locomotion in Caterpillars

3D Television, Coming Soon?

Volume II, Issue 1
Fall 2010

FROM THE EDITORS

Dear Readers,

Since our issue last Spring, much has transpired in the world of science and technology: Craig Venter created the world's first synthetic genome, the oil spill in the Gulf of Mexico captivated our nation for months, and the Large Hadron Collider was fired up for the first time. This issue seeks to cover these developments and more.

From the start, Breakthrough has been devoted to the mission of breaking open the scientific disciplines for all to see. Our goal is to produce a publication focused on science and technology that is informative, yet easy to read. We like to think of ourselves as the "Popular Science" for Tufts and will continue to make changes and improvements over the next few months to realize that vision.

As always, this latest issue splits its focus between research at Tufts and science developments in the world at large. If you are looking to follow us in between publications, head over to trcommons.org and check out our blog or follow us on Twitter: @tuftsscience.

Finally, we are always looking for additional writers, individuals with layout experience, brand managers, and anyone passionate about science and technology. If you're interested in joining us, drop us a line at tuftsresearch@gmail.com.

Thanks for picking up our latest issue. We hope you find it informative and enjoyable to read!

All the best,

Dan Slate and Lauren Wielgus
Co-Editors-in-Chief

Cover image courtesy of Dr. Dana Yoerger, Woods Hole Oceanographic Institution.

OUR STAFF

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Join Us!

Want to submit an article or join our staff? Come to one of our meetings (Wednesday nights, 9 p.m., Campus Center Large Conference Room) or e-mail us at tuftsresearch@gmail.com.

A Second Earth?

BY MAHA MIAN

It is hard to imagine the existence of life on other planets besides our own. Then again, given that over 500 planets have been discovered in the past ten years alone, the possibility of a second Earth becomes so much greater. And now, with the discovery of Gliese 581g, that possibility might just become reality.

Gliese 581 is a red dwarf star located 20 light years away from Earth. It and its surrounding entities make up the 581 system that has been studied for the past 11 years by both the University of California, Santa Cruz, and the Carnegie Institute of Washington (funded by both NASA and the National Science Foundation). The team was led by Steven Vogt and Paul Butler of NASA. The star was tracked using a particular spectrometer attached to W. M. Keck Observatory's optical telescope in Hawaii, which allowed astronomers to record orbiting planets in the 581 system.[1] The combination of data from 2 independent sources led to a confirmation of the discovery of six planets in the Gliese solar system. The planets' near-circular orbits are quite similar to the orbits of Earth's solar system.[2]

It took over a decade's worth of observations for Gliese 581g, a unique planet that has the potential to hold life, to finally come to light. With a mass three times the size of Earth's, it is surmised that Gliese 581g has a rocky terrain and mostly likely can support a habitable atmosphere.[3] The planet is estimated to have a 36.6-day orbit period and a rotation period of about 94.2 days.[2]

Perhaps the most prominent feature of this discovery is its location in the habitable zone, nicknamed the Goldilocks zone. The Goldilocks zone is an area in the universe where the temperature is ideal for sustaining liquid water.[1] Previously discovered planets were located outside the zone with temperatures being either too hold or too cold to realistically hold liquid water. Gliese 581g has an average temperature range of -31 ˚C (242 K) and 13 ˚C (288 K), which suggests that a livable climate can exist.[2]

For now, the Vogt and Butler's team continues to seek more information on this Earth-like planet. Their article says, "Confirmation by other teams through additional high-precision RVs(radial velocities) would be most welcome," and would help building the context of the Gliese solar system itself.[2] However, just knowing that another Earth could exist leads us to wonder just how many more life-sustaining planets are waiting to be discovered.

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Will the Volt jumpstart an electric car revolution?

BY NOAH PAULSON

In November 2010 Chevrolet begins to deliver the much anticipated Volt, a plug in hybrid vehicle with a significant electric-only range. Charged from a wall socket, the Volt's battery will provide 25-50 miles of purely electric driving. The Volt's 16kWh lithium ion battery can be fully charged in 4 hours with a 240v Chevrolet charger, or in 10 to 12 hours from any 120v outlet. After the battery meter dips below 35 percent capacity its 84 horsepower gas motor begins spinning the 55kW generator, and in certain cases drives the wheels along with the vehicle's 111kW electric motor. At this point the battery is emptied of its initial charge, and 33mpg can be expected. The real question, however, is whether the Volt's extended range capabilities and technology outweigh its $40,280 MSRP ($32,780 with full federal tax savings), especially when electric competitors like the Nissan Leaf are out on the market. The Leaf is a fully electric vehicle with a 100 mile electric range and a $32,780 MSRP ($25,280 with full federal tax savings). Consumers in the market for electric or hybrid vehicles must look at their daily driving habits to match their priorities with each vehicle's capabilities.

For more information about the Leaf and the Volt go to www.autoblog.com.

Cancer cells controlled by bioelectric signals

BY DAN SLATE

Led by Tufts Professor of Biology Michael Levin, researchers in Tufts Center for Regenerative Medicine and Developmental Biology recently discovered that thebioelectric potential of "instructor cells" impacts the development of cancer. Thegroup examined neural crest stem cells of frog embryos, which migrate throughoutthe body of vertebrates during development. The bioelectric potential of these stem cells was manipulated using a specific chloride ion channel, which allowed the researchers to control the amount of chloride transiting the cell membrane, and thus the cell's membrane potential. Altering the membrane potential of the stem cells caused cancer-like growth in a completely different population of cells.

The researchers believe the change in chloride ion concentration, and thus the cell membrane potential, leads to the release of serotonin, a neurotransmitter, which causes the downstream biological effects on other cells. The group's findings wererecently published in Disease Models and Mechanisms.

More information can be found on the Tufts Center for Regenerative Medicine and Developmental Biology's website: http://www.cellregeneration.org/

Designer Genes

Craig Venter Institute creates first self-replicating bacterial cell

By MING LIN

The future vision of synthetic genomics was propelled into the next stage of scientific revolution this past May, when researchers at the J. Craig Venter Institute, founded by scientist Craig Venter, successfully created the first self-replicating synthetic bacterial cell. Since the compilation of the entire human DNA sequence by the Human Genome Project in 2003, research in the field of genetics has surged to a new level of popularity. The institute's recent accomplishment is, at the very least, a new scientific milestone worth noting as it brings us to the next stage of genetic research.

The efforts of this 15-year-long project finally paid off when the team of researchers at Venter synthesized a 1.08 million base pair chromosome of a genome called *Mycosplasma mycoides*. The new synthetic cell, named Mycoplasma mycoides JCVI-syn1.0, is special because it is controlled by a synthetic genome; a genome that was chemically fabricated in the lab and then transplanted into a cell rather than being replicated from another original source. In another sense, the success in constructing such a cell further enroots the plausibility and accessibility to modify and control a cell's gene sequence to perform a specific function. As Dr. Ham Smith, a member of the research team, puts it, they can now "dissect the genetic instruction set of a bacterial cell to see and understand how it really works."[1] This breakthrough predicts a broadening of prospects for the future of many technological developments and medical advancements such as more innovative methods of environmental conservation and new forms of cancer treatment.

The arduous research project involved a long and complicated process to construct a synthetic genome sequence. Starting with the original genome of the bacteria cell, the research team arranged a total of 1,078 DNA cassettes, each 1,080 base pairs long. With the 1,078 cassettes, the team constructed a new genome through a series of stages. In the first stage, one hundred 10,000 bp segments (base pair segments) were created using sets of 10 cassettes of DNA. These bp segments were then divided again into sets of 10 to construct eleven 100,000 bp segments. Finally, these bp segments were transferred into yeast cells as a synthetic genome, where the genome was allowed to develop as an artificial yeast chromosome. Once the synthetic genome had fully matured, it was transplanted into another bacterial cell *Mycoplasma capricolum*, known as the recipient cell. To allow for successful integration of the new genome into the recipient cell and its replacement of the existing genome in the new cell, all restriction enzyme genes in the recipient cell were removed prior to transplantation. The synthetic genome was then transcribed into messenger RNA and finally translated into new proteins that can later be constructed into a new DNA sequence for the recipient cell.

The research encompasses two very important scientific processes that are fundamental to the field of genetics: horizontal transmission and DNA sequencing. Horizontal transmission, the transferring of DNA into bacterial cells, is categorized into the methods of conjugation, transduction, and transformation. In bacterial conjugation, DNA is transferred from one bacterial cell to a recipient cell when the cells make contact. The initiation of this process involves the establishment of a viable mating pair, where the pili of the two cells are able to touch, allowing the cells to conjugate. During conjugation, a single DNA strand is transferred into the recipient cell where it replicates into a double-stranded DNA and becomes integrated into that cell's genome. The second method of horizontal transmission, transduction, involves the use of a phage to inject DNA into a recipient cell's cytoplasm. The DNA can then combine with DNA sequences in the recipient cell and construct a new genetic strand. In the last mode of horizontal transmission, transformation, some bacterial cells transport free-roaming DNA into their cytoplasm by means of protein receptors on their pili. Once inside the cell, the DNA can recombine and replicate, thereby becoming a part of that cell's gene sequence.[2]

Photo by Richard Newstead. Getty Images. <http://www.gettyimages.com/detail/103164356/Lifesize>

In DNA sequencing, chromosomes are first separated into smaller pieces, where their base pairs are used as templates to form fragments of different lengths. These fragments are then further separated to be later sequenced by means of gel electrophoresis. In the final step, computers are used to sequence and assemble the gene fragments into a single strand, making sure the base pairs of the sequence are compatible.[3]

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Immortal Jellyfish

How a certain Cnidarian achieves immortality under the sea

By STEPHEN WALSH

Hollywood might not be the only place where you can find a "curious case" of something that actually ages backwards. However, unlike the computer-generated imagery used to fashion Benjamin Button, the jellyfish species *Turritopsis nutricula* is able to age backwards after sexual maturity as a part of its natural lifecycle. The species is even able to repeat this process in an oscillation between maturation and reverse aging: it transforms itself from the mature "medusa" form back into the immature "polyp" form[1]. In theory, this makes the jellyfish biologically immortal, indefinitely defying the aging process. The discovery of *T. nutricula* led the scientific community to ask: how could this almost paradoxical feat possibly be achieved?

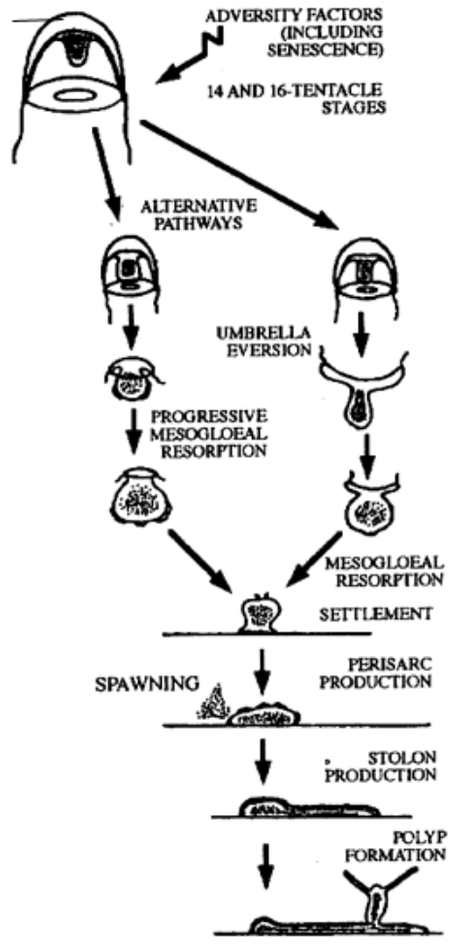
Jellyfish are classified as hydrozoans, or very small aquatic predators. The usual lifecycle of a hydrozoan jellyfish begins when sexually mature individuals release reproductive cells, or gametes, freely into the ocean. These gametes eventually meet spontaneously, fuse, and mature into a small life form known as a planula larva[1, 2]. The larva continues to mature into a polyp by attaching itself to a surface area of the ocean and growing outwards. The polyp can then sprout off multiple immature medusae, the more recognizable form of jellyfish, that undergo further maturation. The lifespan of medusae, however, is often short, ending with programmed cell death or "apoptosis" in the jellyfish[1, 3]. In the species of *Turritopsis nutricula,* this inevitable onset of apoptosis is avoided by a modified lifecycle.

Turritopsis nutricula reside most prominently in the Caribbean because of the warm water there, though they now live in waters across the Earth. They were first discovered in 1883, but their unique transformational abilities were not found until the 1990s[4]. The discovery, published by researchers at the Woods Hole Marine Biological Laboratory (about 80 miles away from Tufts) enhanced the understanding of how the organism transforms, not just at the organismal level, but at the cellular level as well.

What might trigger the jellyfish to undergo this transformation at a particular time? Researchers have found that when the species is exposed to adverse conditions, such as limited food resources, sudden changes in water temperature or water salinity, or significant injury to the organism's body, the transformation occurs[1]. Dr. Maria Miglietta of the Smithsonian Tropical Marine Institute, describes this protective evasion as a transformation of "all of its existing cells into a younger state" instead of "sure death"[4].

Not only used as a means of survival, the process averts aging itself by integrating the transformation into its normal lifecycle. This begins when the bell shape of the jellyfish, or the umbrella, turns inside out, extruding a cluster of its internal organs known as the "manubrium"[1]. The tentacles, along with a middle layer of tissue called the "mesoglea", are retracted and absorbed into its body[2]. The organism continues degenerating into a cyst-like form, eventually attaching itself to the ocean floor. The organism then generates structures called a "perisarc" and "stolons" that help it stabilize and protect itself[1]. A series of polyps usually grow from this structure two days later[2], eventually able to sprout hundreds of genetically identical medusae[4], which reach about 4-5mm at full maturity[3] (see figure of jellyfish anatomy/transformation). Although the *T. nutricula* are not indestructibly immortal, their ability to repeat this process indefinitely implies their theoretical biological immortality.

The cells of the jellyfish also undergo transformations to accommodate for the new tissues and organic structures formed through its lifecycle. This cellular change, known as "transdifferentiation," occurs when cells with well-defined functions (differentiated cells) are able to express different genes, effectively becoming a new type of cell[1]. For example, a muscle cell could undergo transdifferentiation to become a nerve cell. In the case of *Turritopsis nutricula*, cells of the exumbrellar epidermis and parts of the radial canal (see figure of anatomy) transdifferentiate into the stolons and perisarc of the reverted polyp[1,2]. This



The lifecycle reversal can be seen above, starting with the jellyfish's absorption of tentacles and inversion of its bell, exposing it's insides. Later, the organisms settles on the ocean floor, and changes into a polyp, growing "stolons" and a "perisarc" for additional structure and protection. During the transformation process, the new structure spawns hundreds of genetically identical medusae.[2]

process is not to be confused with the differentiation of stem cells, which are special cells that transform, or differentiate, into a vast variety of specific cells.

Transdifferentiation is important--without the presence of new tissues, the reversed aging process could not occur[1]. This does restrict the conditions required to transform, but unlike an organism's limited amount of stem cells, transdifferentiation of the jellyfish's tissue can occur indefinitely through the spawning of many other *T. nutricula.* Additionally, the Woods Hole research team has found that stem cells in the manubrium (the cluster of internal organs) did not differentiate during the transformation process, suggesting that the transformation from medusa to polyp can occur without the presence of stem cells[1].

In addition to the growing knowledge of *T. nutricula* as a biological anomaly, their theoretical immortality could cause a widespread problem with invasive species in the future, although the ramifications of a potential invasive species have not yet been observed[5]. Since the jellyfish are a predatory species[3], this could results in drastic changes within ecosystems if the jellyfish were concentrated enough. In addition to the expanding research of *T. nutricula* in nature, scientists hope to expand their knowledge of transdifferentiation, specifically regarding the role that DNA plays in the process and how it may relate to aging in humans[1]. This continuing research could develop treatments of various diseases, broaden knowledge of cellular biology, or even allow a family of Benjamin Buttons to roam the earth.

Stephen Walsh is a freshman majoring in biology.

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However, the research did not immediately provide the expected results, as the first synthesis of the genome failed to produce viable cells. The error was later discovered through DNA sequencing to be due to a single base pair deletion in a gene. To rectify this error, the research team combined both natural and synthetic DNA segments, which generated semi-synthetic genomes. Through this process, the team was able to verify that each combination of synthetic and natural segments could be both transplanted and viable.

The success of the J. Craig Venter Institute's research has brought forth new and invigorating expectations of the future of science. The expertise and innovations of the institution have allowed expansion in genetic research: last year, the Institute established facilities to further explore the building of algae biofuels by using synthetic genomes, further displaying the institute's expertise in the field of genomic science. Concurrently, the continuation of synthetic genome leads to promising prospects: the development of new vaccines, cleaner water, and greater variety in food products. Yet it is equally important to not dismiss any ethical complications that such rapid scientific expansion engenders. The possibility of synthetically creating viable, fully biofunctional cells poses concern for potential abuse and bioterrorism. To address these fears, the institute has been collaborating with bioethicists and other legislative panels to safeguard against unethical abuse of the research and to promote public awareness of the research. With such a mutual engagement between the general public and scientific experts, it is promising to expect a lot more discoveries from the institute.

Ming Lin is a freshman majoring in biology.

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Searching for Life's Origins

Did a comet bring amino acids to Earth?

By JULIA HISEY

The origin of life on Earth is a much debated topic in science. How life came to be is a question we may never know the answer to, regardless of the number of hypotheses presented, theories explained, or experiments done. That said, we continue to wonder and experiment.

One of the most famous experiments investigating the origin of life was performed by Stanley Miller in 1953. Miller was interested in determining if life could have evolved from substances already on Earth and in the atmosphere. He simulated conditions on early Earth using a flask containing methane, ammonia, and hydrogen (compounds thought to have been in the atmosphere at that time) connected to another flask filled with water, imitating the ocean. The water was boiled continuously, functioning as evaporation and precipitation, and electrical charges were sent through the entire system as a source of energy.[1]

When Miller tested the solution, he found that hydrogen cyanide (HCN) and formaldehyde (H_2CO) were formed. These compounds are precursors to larger and more complex organic molecules such as amino acids. Amino acids and other organic molecules can then evolve chemically into life. Amino acids connected to each other through peptide bonds form proteins, the next step towards life. Therefore, Stanley Miller showed that the theory of chemical evolution, where compounds evolved to be more complex carbon-containing compounds through early Earth's conditions, could explain how life formed.[1] However, the original components of Earth's atmosphere cannot be known for certain.

Since Miller's time, many origin of life hypotheses have been tested, including one involving key life ingredients arriving on Earth via comets. This idea is similar to exogenesis, the theory that microscopic organisms came to Earth from outer space on a comet or a similar object.[2] The difference is that the components of life are traveling in the comet, not life itself.

It was believed that the precursors of life on earth could not have come from a comet due to the high temperatures involved in the impact. This belief was tested by Nir Goldman, Evan Reed, Laurence Fried, I.-F. William Kuo, and Amitesh Maiti in an experiment that simulated a comet impact on Earth.[3] They created a mixture of water (H_2O), methanol (CH_3OH, NH_3), carbon monoxide (CO), and carbon dioxide (CO_2), which are compounds that have been found in comets. This mixture was subjected to high temperatures and pressures to simulate the intensity of a comet crashing into the Earth. While the outside of the comet becomes incredibly hot while traveling through the atmosphere, the inside of this icy comet does not reach too high temperatures, and the organic compounds can therefore remain intact.[3]

During the experiment, many carbon-nitrogen bonds were formed and the complexity of the molecules increased as temperature and pressure increased. Carbon-nitrogen bonds are essential to the formation of amino acids which are necessary components of life. These carbon-nitrogen bond containing molecules broke down into smaller molecules as the pressure and temperature of the mixture was lowered. One of these smaller molecules was $^-$OCO-NH-CH_2-COOH. This molecule is extremely close to the amino acid glycine, just one proton away. As the mixture cooled even more, H_3O^+ formed in the mixture, eventually bonding with $^-$OCO-NH-CH_2-COOH to form glycine, which is shown in the image. The experimenters also observed HCN and H_2CO as in Miller's experiment.[3]

If life did not form from components already on Earth, this experiment shows it is possible that life on Earth began from extraterrestrial sources. Since the simulation of a comet's impact on Earth produced amino acids from molecules present in comets before their landing, chemical evolution could have then brought those elements to life on Earth today.

Photo by Dieter Spannknebel <http://www.gettyimages.com/detail/86046865/Stockbyte>

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The Story Behind Stuxnet

An unusual worm and its implications for the future

By JENNA SCHOEN

The international media erupted over the summer with reports of a highly sophisticated and potentially dangerous computer worm. The malware called Stuxnet was rumored to be an attack on Iran's controversial nuclear enrichment program. The worm, first reported by the German computer security company VirusBlokAda, stunned highly trained computer analysts, who had never seen such an intricate and malicious piece of malware. Perhaps more intriguing than the complexity of the worm itself are the implications of its appearance—the fast spreading theories of its origins and potential political objectives. As Iran and the West remain in conflict over Iran's nuclear program, cyber warfare could become a new obstacle for discussions and a new flash point for confrontations.

Photo by Phillipe Colombi. Getty Images. <http://www.gettyimages.com/detail/BU010291/Photodisc>

Stuxnet is a computer worm, a genre of malware that differs from a computer virus in that a worm doesn't rely on an existing program or a human action. VirusBlokAda first reported Stuxnet on June 17th, 2010, but early versions of the worm were detected in June of 2009. The first of its kind, it takes control of the inner workings of industrial facilities rather than just stealing information.[1]

Entering via a USB flash drive, Stuxnet goes straight to the programmable logic controller (PLC) of a factory. PLCs are the computers that automate the processes of the factory, controlling devices like pressure valves, water pumps, turbines, and nuclear centrifuges used to purify nuclear fuels[2]. The worm attacks Siemen's Simatic Step 7 factory system, a program that runs on Microsoft Windows.[2] Unlike most malware, Stuxnet attacks the software through four vulnerabilities unknown to the software developers (called zero-days). Stuxnet is extremely rare in implementing four zero-days; usually worms only use one.[2] The worm is also the first of its kind to hide in a rootkit, which is software that allows the worm continued privileged access to the computer. Stuxnet can also update and check itself; it used a stolen certificate to access Iran's industrial computers on July 16th and then knew to use a new one the next day once the previous certificate was revoked.[3]

Once the worm infects the PLC, it searches for a specific type of machinery, then reports back to a central control server located hundreds of miles away. The central server sends commands back to the worm over a trail of servers located around the world. This method has made the worm nearly impossible to trace, which means the source is even harder to find. After the worm connects to its control servers, it changes data in the PLC, leaving the hackers free to control the mechanisms of a factory half way across the globe.[2]

Stuxnet has infected 50,000 plus computers, 60% of which have been Iranian[1]. Though it wasn't reported until 2010, the worm was in development for at least a year prior to detection.[1] No one knows the objective of the worm, since its capabilities are numerous and its action is dependant on the equipment it infects. So who created Stuxnet, and who or what they were targeting?

Iran has definitely suffered the most from Stuxnet, but whether or not the worm was aimed at dismantling their nuclear enrichment program remains unclear. Two different theories have surfaced in the media. Ralph Langner, a computer security researcher who published an extensive investigation on the worm, backs the theory that the target was Iran's Bushehr nuclear facility, the first of the Iranian nuclear factories set to open, where it could have entered the system via a USB from a Russian construction worker.[1] The chief technology officer for a Berlin security firm, Frank Rieger, prefers another explanation. He believes the target was Natanz, the primary location of Iran's nuclear enrichment program, where there is a greater capability of production.[1] His evidence stems from the fact that Stuxnet started infecting computers in January 2009 and in July of that year Wikileaks reported a mysterious nuclear accident at Natanz. Wikileaks is an organization that publishes "classified" information from anonymous sources and leaks, known recently for collaborating with *The New York Times* and *The Guardian* to release documents concerning the War in Afghanistan. Wikileaks' theory also matches up with the mysterious resignation of the head of Iran's Atomic Energy Organization and the shrinking number of operating centrifuges (devices designed to purify uranium) around the time of the accident.[1z]

Iran has not confirmed which comput-

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Caterpillars Go with their Gut!

Tufts researchers discover a completely new form of locomotion.

By DAN SLATE

When Tufts researchers discovered that caterpillars "go with their gut," they didn't mean the insects follow their instincts. Instead, they uncovered a completely new type of locomotion, almost entirely by accident. Michael Simon, the lead author of the paper published in *Current Biology* in July, explains, "The original idea had been to examine fluid flow inside the tobacco hornworm, but we discovered, quite accidentally, that the gut seemed to be moving back and forth independent of the rest of the body."

Simon, who earned his Ph.D from Tufts' Department of Biology in May, was a member of Dr. Barry Trimmer's lab. The lab examines the neuromechanics of soft-bodied locomotion using the tobacco hornworm, *Manduca sexta*, as a model system. "The critical distinction between the caterpillar and other animals like ourselves is the presence of bony structures," Simon explains. Rigid internal structures make locomotion far more predictable and infinitely easier to control from a neural perspective. Think of this distinction as a Physics problem: in the case of rigid structures, you are presented with a simple lever problem in which you plug in the torque provided by the muscle at one end and output a resultant torque at the other end. In the case of soft materials, the previously described lever is no longer a rigid beam that faithfully transmits forces, but rather a floppy and flexible material with extremely complex mechanical properties. Besides being a nightmare of a physics problem, Simon believes inspiration can be drawn from the caterpillar to create more complex robotics built from soft materials.

Simon's examination of the internal tissues of the tobacco hornworm began during a trip to Argonne National Laboratory to use phase-contrast synchrotron X-ray imaging to visualize internal tissue and fluid movements. The caterpillars were placed on a custom designed treadmill to keep them stationary relative to the X-ray beams as they crawled forward. The imaging allowed Simon and the other researchers to visualize the trachea, or small air tubes that branch throughout the body to facilitate gas exchange with the tissues. Some of the trachea are attached to the gut and others are free-floating. This observation was confirmed using a slightly unconventional experiment: "We actually confirmed that some of the trachea were connected to the gut by feeding the caterpillars glitter and observed that the movements of the glitter matched the movement of the gut associated trachea." One night, while observing the live X-ray results, Simon and others noticed something completely unexpected: the trachea attached to the gut appeared to move independently of free-floating trachea. This suggested that the gut moved independently of the external structures. However, comprehensive analysis of the data would confirm this fact.

The data analysis was done with the help of Tufts Senior Jay Serebrenik. In the analysis, Serebrenik and Simon found that the gut movement showed positive correlation with the head and terminal ends of the caterpillar, but these correlations were not consistent to all points on the body. In fact, the analysis revealed that the correlation between the gut movement and the body wall movement was dependent upon the position of comparison along the body. The experiments also revealed that while the gut movements correlated positively with the head and terminal end of the caterpillar, the external markers on the body wall did not. Serebrenik confirmed these results in an experiment run on hatchling caterpillars. The hatchlings are transparent, allowing Serebrenik to compare the gut movements with the external body movements using transmission light microscopy. This experiment revealed similar correlations to the X-ray results.

The data analysis suggests that the caterpillar gut is elastic and is differen-

Jay Serebrenik and Michael Simon display a caterpillar. Photo by Noah Paulson.

CATERPILLARS
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Tufts Faculty Profile

Biochemist Dr. Juliet Fuhrman emphasizes teaching and research.

By NAKAMI TONGRIT-GREEN

Dr. Juliet Fuhrman vividly remembers the day she fell in love with biochemistry. Her older brother had brought home a book about the structure of DNA and at the age of twelve Fuhrman says she knew, after looking through the book, that she wanted to be a biochemist. Now the associate professor in the Biology Department here at Tufts University, Dr. Fuhrman has dedicated much of her life to scientific research and education. Although neither one of her parents received a college degree, she attributes her success to their emphasis on education. Countless hours spent in the library as a high school student, labs and lectures at Princeton University and John Hopkins University have brought Dr. Fuhrman where she is today, as her passion for science continues to drive her research and teaching at Tufts.

At the time Dr. Fuhrman was introduced to DNA in her Long Island home, not much was known about the structure or composition of DNA. The double helix structure of Deoxyribonucleic acids (DNA) had been introduced to the world for no more than a decade and biochemistry was a fairly new, and rapidly advancing scientific field. Dr. Fuhrman nurtured her passion for science during this revolutionary time through rigorously pursuing her education. She was accepted into Princeton University, among the third class of entering women. Although being a woman in biochemistry came with its challenges, Dr. Fuhrman was engulfed in the rich scientific community at Princeton, where she discovered her passion for lab work. "In the lab, it didn't matter what you looked like, your gender, race...everyone was there because of their commitment to the research," says Dr. Fuhrman. She enjoyed being mentored as an undergraduate student by graduate students and still believes strongly in this functional hierarchy as an enjoyable, beneficial way to learn. Dr. Fuhrman concluded her work at Princeton University with

Image courtesy of Dr. Juliet Fuhrman.

a physical biochemistry thesis on histone modification and its effects on the interaction between DNA and nucleosomes. She performed experiments with chromatin and nucleosomes, to uncover chromatin structure, topics in molecular biology which she now teaches as a biology professor at Tufts. After graduating from Princeton University in1975, Dr. Fuhrman went on to John Hopkins University, where she received her PhD in Biology in 1982, specializing in immunology. She then went on to do post-doctoral research at the Harvard School of Public Health.

An expert in the field of immunology, Dr. Fuhrman is currently experimenting with parasitic nematodes which are the cause of river blindness, human elephantiasis and heartworm found in dogs. Elephantiasis is also known as Lymphatic Filariasis, and is characterized by the enlargement of the limbs. This enlargement is a result of obstruction within the lymphatic system, which dictates circulation of fluids within the body's tissues. The obstruction causes severe swelling which may lead to further infection and medical complications, without treatment.[1] The parasite, *Brugia Malayi*, which is responsible for the obstruction of the lymphatic system in human elephantiasis, contains a nitrogen-based polysaccharide called chitin. Chitin is a structural component which provides protection for various organisms and is also found in the egg shell of nematodes. Dr. Fuhrman's research involves several biochemical and molecular experiments in the chitin metabolism of *Brugia Malayi*, in order to better understand the significance of chitin in the survival of this parasite. Weakening the function of the roundworm through chitin metabolism could disable the parasite from obstructing the lymphatic system in humans, which could suggest a possible cure for elephantiasis. Dr. Fuhrman spends an average of 15 hours on her research every week, in addition to being a biology major advisor for 20-32 students per year, and a full time professor.

Although her unwavering passion for research is evident, Dr. Fuhrman stresses the importance of good teaching and advising. She has received six awards throughout her 20-year career at Tufts, including the Tufts University Faculty Research Award, Marshall Fund in 2001 and 2004, and the Lerman-Neubauer Prize for Outstanding Teaching and Advising in 2005. Fuhrman loves what she refers to as the "light bulb moments." She enjoys watching Tufts students who she describes as "diverse and remarkable" as they grow in their knowledge and love of science. She expresses gratitude towards her colleagues here at Tufts, who she believes are "...truly invested in the education of young people. They are people who want to take the natural world apart for us to understand and think about it more clearly." Her advice to students is to stay excited: "Love your ideas because it's a slog to prove them, disseminate them...it's hard work. So if you don't love your questions and love your ideas, it's going to be a really long day."

Nakami Tongrit-Green is a freshman who has not yet declared a major.

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The History of Blowouts

A look into the devices and techniques of a high pressure job

By ERIC KERNFELD

What sort of problems do you face when you're trying to extract huge quantities of very light hydrocarbons up from their subterranean home under miles of very heavy rock? What if you're also trying to do it at the bottom of the Gulf of Mexico? How do you avoid being drenched by an uncontrolled spurt of black gold as soon as the drill hits the reservoir? And what do you do when, all of a sudden, you need to switch to plan B?

Underground oil deposits are under huge amounts of pressure, and in the early days of drilling, blowouts were part of the standard operating procedure. They were unsafe and extremely wasteful. In one famous instance, the 1901 Spindletop blowout near the southeast coast of Texas, 500,000 barrels of oil spewed out over nine days before the well could be controlled. To add insult to injury, a fire consumed the site shortly afterwards.[1]

The solution came along with James Abercrombie and Harry Cameron's blowout preventer (BOP). It's a device affixed to the top of the shaft before the drill even hits the oil. It maintains fluid at a very high pressure inside the borehole, above the drill, so that the oil can't shoot out once the drill breaks into the reservoir. The first blowout preventers could withstand 3,000 pounds per square inch (psi) of pressure, and some modern devices can produce 15,000 psi. (Your bicycle tires probably hold 40-80psi.)[1] Blowout preventers are now a vital component of our economy, allowing companies to draw petroleum more safely from traditional wells as well less likely places.

At one point oil was coming out of a seven-inch diameter steel pipe at 60,000 barrels per day.[3]

Unfortunately, they are not foolproof. The pressure produced by the water above the site of the BP blowout was over 2000 psi, and the pressure of the oil was around 9,000 psi.[2] The blowout preventer did not do its job, and at one point oil was coming out of a seven-inch diameter steel pipe at 60,000 barrels in a day.[3]

The saga began on April 20th with a giant fire onboard the Deepwater Horizon drilling rig. Two days later, the rig sank, bending and snapping the pipeline connecting it to the Macondo well at the ocean floor. Engineers discovered the leaks in the pipe, indicating that the BOP on the well had failed. Robotic subs were sent to activate the BOP, but they failed as well. By April 25th, it was clear that existing machinery was not enough to stop the leak, and new solutions would have to be devised.[4]

At the Deepwater Horizon Site. Photo provided by Dana Yoerger.

So what's an engineer to do confronted with an enormous submarine geyser of oil? The first strategy to combat the spill was a containment dome, a 40-foot steel funnel placed over the giant mess of broken metal and gushing hydrocarbons. The dome was designed to sink 15 feet into the mud on the ocean floor, capturing everything and channeling it up to the surface. Unfortunately, any pipe or funnel is vulnerable to clogging. Icelike crystals known as gas clathrates formed in the dome's mouth, and the setup had to be removed.[4]

With the dome defunct, BP turned to a pair of new approaches: the "top kill" and the "junk shot." Each involves pumping substances into the defunct BOP—a dense substance called drilling mud for the top kill and a collection of shredded tires and golf balls for the junk shot.[5][6] The top kill was meant to press the oil down into the well using just gravity: drilling mud is a thick substance, twice as dense as water.[7] The junk shot was just meant to clog the nonfunctioning BOP on top of the borehole. As it turned out, neither approach succeeded.

July 15 was the beginning of the end of the disaster. BP installed a custom-made cap on top of the ruined BOP, and over the course of a day and a half they were able to close the valves on the cap and stop the flow of oil.[8] Why wait a day and a half, when that could mean another 90,000 barrels of oil floating around the Gulf ecosystem? Even though they had a working cap on the source of the oil, they couldn't close it immediately. Sudden and extreme pres-

GLOSSARY

Drill String — a concrete and steel tube extending between the oil deposits and the machinery on the surface.

Borehole—any shaft dug deep into the earth, whether for oil, coal, or something else.

sure changes can damage equipment and the surrounding rock. (This is for the same reason that a loud clap can damage your ears.) The rubber seal fixing the cap to the BOP could have come undone. In addition, the initial explosion back in April may have left the two-mile-long drill string vulnerable. Another sudden change in pressure could allow oil to seep out the sides of the drill string and emerge from the ocean floor, where it would be harder to deal with. Strange as it may sound, the ocean floor is not watertight (or oil-tight). Seeps with low flow rates occur naturally in the Gulf of Mexico.[8]

In order to end the risk of seepage and put more of a barrier between the oil and the Gulf, BP drilled an entire new well, known as a "relief well," and used it to execute the eventual solution, a "bottom kill." A relief well is dug parallel to the original borehole down almost to the oil deposits, where it turns and intersects the original drill string. Then, drilling mud and a cap of cement are pumped into the borehole to seal it.[9]

There are considerable technical issues with locating an 18" diameter pipe hundreds or thousands of meters inside the Earth's crust. In order to calculate the drills' positions, the machines used in constructing the relief wells were equipped with the same accelerometers used in missiles. Once they approached the steel casing, sensors detected the pipe's magnetic field and provided the precision necessary to intersect the drill string. The "bottom kill" was pronounced successful on September 21, ending the release of oil from the Macondo well.[9]

It seems much less expensive to construct better BOPs than it is to mount a five-month well-killing operation. The total cost to BP of the disaster as of mid-September was $9.5 billion.[10] Costs in bad publicity for BP, in lost tourism for the Gulf region, and in habitat and ecology for the Gulf itself are hard to estimate. However, BOP maintenance itself can cost hundreds of millions a year.[11] Numerous problems with the regulations and industry standards pertaining to blowout preventers have been examined in the greasy wake of the disaster, but in the end, it is extremely difficult to test machinery at conditions equivalent to those at an ocean floor oil leak. There is always a risk that we will be unable to control oil wells, and no BOP is perfect. In undersea drilling, like in many other arenas, we face a choice between foregoing immense resources and endangering our livelihood and environment. Ultimately, the debate over offshore drilling extends beyond technological details and finger-pointing over regulatory enforcement into a much broader set of tradeoffs and decisions about our lifestyle and our civilization.

Eric Kernfeld is a freshman who has not yet declared a major.

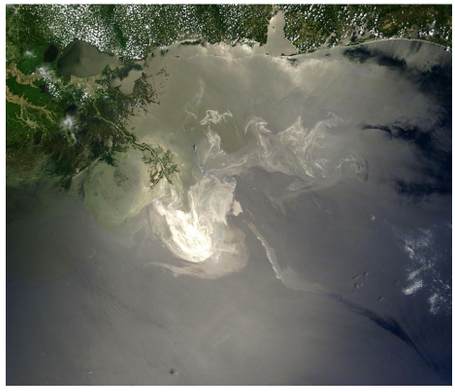

Image courtesy of NASA.

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Mapping the Spill

Using robotic mapping to track the oil plume in the gulf

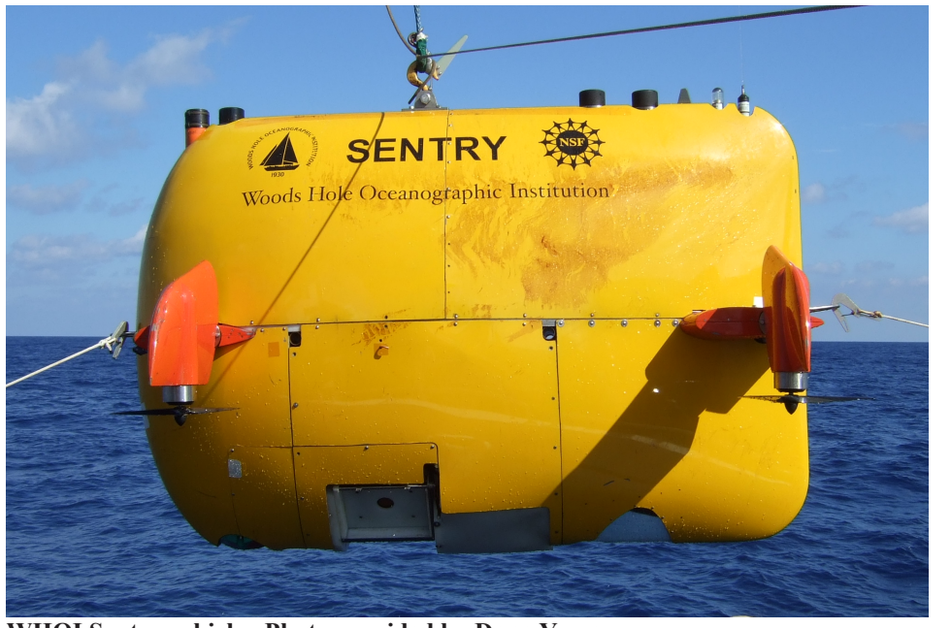
By CATHERINE HOAR

During the first few months after the Gulf oil spill that resulted from the Deepwater Horizon drilling rig explosion on April 20, 2010, the presence and location of spilled oil remained unclear due to conflicting statistics and predictions. But, on August 19, researchers at the Woods Hole Oceanographic Institution (WHOI) offered sound evidence of a plume of oil over 35 km long in the Gulf.[1]

The WHOI team's report, "Tracking Hydrocarbon Plume Transport and Biodegradation at *Deepwater Horizon*," was published in *Science*. Data in the report was collected from a ship-cabled sampler and from *Sentry*, an autonomous underwater vehicle (AUV) from the National Deep Submergence Facility.[1] This data has already provided a clearer description of the spill zone. Research of the data continues, however. Senior Scientist in Applied Ocean Physics and Engineering at WHOI and member of the research team, Dana Yoerger explained, "When the analysis of the water samples is complete, we will have estimates of the size and shape of the plume, the mass flow within the plume, and the concentration of hydrocarbons in the plume."

The WHOI team conducted three surveys in the Gulf, collecting data from over 57,000 chemical analyses.[2] These surveys were carried out from June 19 to June 28 and mapped the plume at around 1100 meters deep in the Gulf of Mexico. The amount of hydrocarbons detected suggested that the rate at which oil entered the Gulf was faster than the rates of natural oil seeps, which in turn indicated that the Deepwater Horizon spill was the source of the plume. The report also suggested that biodegradation, or the breaking down of oil by organisms, was not a significant factor, at least up until the time of the survey.[1]

Sentry, the AUV used for this investigation, collects data through sensors and is controlled by on-board computers. During the oil spill surveys, conductivity, temperature, and oxygen sensors were used, according to Yoerger. Also, both *Sentry* and the ship-cabled sampler used *TETHYS* mass spectrometers to measure hydrocarbons, which are found in oil. *Sentry*, which can explore to a depth of 4,500 meters,[3] surveyed the plume region at depths of about 1000 meters.[1]



WHOI Sentry vehicle. Photo provided by Dana Yoerger.

Communication between *Sentry* and a research team onboard a ship is acoustic. Yoerger likened this communication to text messaging with the team's ability to "send and receive on the order of a few hundred bytes every minute." Although limited, this restricted communication is essential to the programming and directing of the AUV. Yoerger explained that the communication gives the team some of *Sentry*'s data summaries and some information about *Sentry*'s condition. From onboard a ship, researchers are also capable of revising a mission programmed for *Sentry*. The WHOI team used this capability to program *Sentry*'s search patterns at specific depths.

Communication between *Sentry* and the ship also allowed for the use of *Sentry*'s "dynamic re-tasking capability."[1] During the third and last survey, *Sentry's* mass spectrometer stopped sensing hydrocarbons. Using dynamic re-tasking, the team was able to reprogram *Sentry*'s depth and tracklines so that it could find the plume and continue tracking hydrocarbons.

In addition to the AUV, the team used a CTD (Conductivity, Temperature, and Depth) sensor to collect measurements and samples during the Gulf surveys. A CTD is made of a sample collection rosette; a large metal wheel with sensors and containers to hold water samples. These containers can be closed remotely in order to collect water samples form different areas at different times.[4] The CTD used for the oil spill surveys collected water samples in the plume. Additionally, the CTD for these surveys had a *TETHYS* mass spectrometer for chemical analysis. The CTD, unlike *Sentry*,

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The Environmental Impact

The spill's full impact, sure to be far-reaching, remains uncertain

By CATHERINE HOAR

Scientists are beginning to observe environmental changes likely caused by the Gulf oil spill, but the overall impact of the blowout remains uncertain. Given the size and extent of the spill, it is unclear what biological problems may result and where the oil will eventually end up.

Efforts to track the plume, such as the surveys conducted by the Woods Hole Oceanographic Institution (WHOI) team, have provided a preliminary understanding of the oil's distribution. Other teams of scientists are looking to track the spill's biological ramifications. Researchers on a National Oceanic and Atmospheric Administration (NOAA) ship recently reported the finding of dead coral near the wellhead. These reports give us a sense of the spill's extent or its possible effects on the environment, but, as marine geochemist and member of the WHOI team, Christopher Reddy, told *Science*, "We're just in round one."[1]

Getty Images. Credit: D. Falconer/Photolink. < http://www.gettyimages.com/detail/SO000080/Photodisc>

Although it will take more research and more time to determine the environmental impact of the plume, some immediate effects were visible within the first weeks of the spill. For example, documentation of marine wildlife in the Gulf provided by the (NOAA) Fisheries Office of Protected Resources reveals the number of certain marine species found "visibly oiled" in the Gulf since April.[2]

Reports indicate that the numbers of some marine animals found dead or injured during the period after the spill were greater than those normally reported for the same time frame each year.[3] Sea turtles were of particular concern because all five of the sea turtle species present in the Gulf are endangered or threatened. NOAA reported a total of 474 visibly oiled turtles as of November 2.[2]

Other animals being monitored include dolphins and whales. Marine mammals and sea turtles are at risk of inhaling dangerous chemicals when surfacing to breathe. Another concern was the spill's effect on fish, especially blue fin tuna, which spawn in the Gulf in the spring.

The effects of the spill on other animals, such as birds, are still being studied by various organizations. As of November 2, NOAA wildlife documentation reported the finding of 4,342 visibly oiled birds, 2,263 of which were dead.[2] The U.S. Fish and Wildlife Service's oil spill response plan focuses specifically on birds. Like many other spill response plans, it extends to an undetermined point in the future. Immediate surveys will be followed by evaluation of migratory birds, and other long-term evaluations that could last for decades.[4]

The need for continued research into the spill's effects is a theme common to several fronts, since many factors can impact the environment. This concept is addressed in the report "Tracking Hydrocarbon Plume Transport and Biodegradation at *Deepwater Horizon*," written by the WHOI team. The report states, "Because our analysis focuses on a limited range of hydrocarbons, the total amount of petroleum hydrocarbons in the plume and the full extent of possible risks to marine biota remain uncertain."[5]

Additionally, evidence and data related to possible impacts of the spill may not be measurable until a significant amount of time has passed. This uncertainty is illustrated by research into a "sea snot blizzard" that may have been caused by the Gulf spill. Near the spill area, clumps of organic matter in the ocean, or "sea snot," were found to be significantly larger than normal. The sea snot may have been enlarged by phytoplankton "mucus," a sticky material produced in greater amounts when phytoplankton are stressed. The spill could have been responsible for increased stress on the phytoplankton.[6]

Research indicates that after the spill, a blizzard of sea snot occurred, during which the sea-snot fell to the seafloor. In this case, the "marine snow" may have brought oil down with it. The unusually large amounts of oil brought down by the storm could be toxic to marine life both on the seafloor and in the water through which the storm passed. The effect of this event on future generations of fish may remain unclear for a long period, because certain fish mature at different rates.[6]

The presence of significant biological responses to the presence of oil in the Gulf has also been uncertain. A report published on August 24 entitled "Deep Sea Oil Plume Enriches Indigenous Oil-Degrading Bac-

ENVIRONMENT
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The Future of Television

Is 3D technology coming soon to a living room near you?

By JACKSON DOLAN

Although 3D technology seems like a recent development, it has been a surprisingly long history. The concept first originated in the 1870's with the production of a childhood treasure, the pop-up book. Since then, it has become substantially more complicated and impressive, tempting moviegoers the world over into paying a couple of extra bucks to wear uncomfortable glasses for a few hours.

3D movies themselves have been around for a long time as well. Anaglyph, the original style of 3D movies, dates back to 1922[1]. It uses the cheap glasses with a red filter over one eye and a cyan filter on the other. These glasses are used in conjunction with anaglyph images.

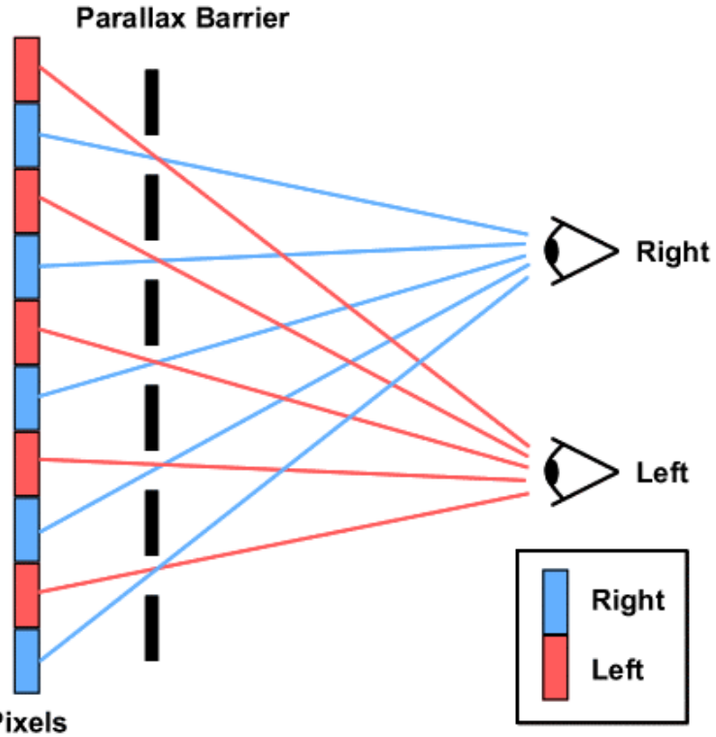
Anaglyph images are actually two slightly different pictures superimposed on to one screen. Each picture is layered with a different color, typically opposites such as red and cyan, which are then filtered by the glasses and combined in your head to produce a depth effect[1]. An enormous issue with anaglyph films is that the image appears outlined in red and cyan, or whichever colors are being used to produce the effect. While anaglyph movies were a novelty in the fifties, they have since largely been relegated to a gimmicky status. Since the origin of anaglyph movies, technology has improved the color schemes, but they seem to be on the way out, given the success of films such as Avatar that use a different technique.

If you have seen Avatar or any other 3D movie since then, you must have donned the grey spectacles that resembled dime-store sunglasses. Cheap and uncomfortable, sure, but they are a step up from the red and cyan glasses in both picture quality and style.

These glasses are used in combination with a special lens and backdrop, resulting in a polarized system. Instead of a red/cyan filter, these glasses have polarizers over each eye[2]. Imagine the polarizer as a window covered in horizontal or vertical lines. As the light passes through the polarizer, it aligns itself perpendicular to the lines. Therefore, a horizontal plate would only pass vertically oriented light waves, and a vertical plate would only pass horizontally oriented waves.

The glasses worn at movies utilizing this technology have a horizontal polarizer over one eye and a vertical over the other. The film itself is the sum of a horizontally polarized and vertically polarized projection. The glasses separate the images so each eye sees something slightly different, which produces the three dimensional effect.

A huge drawback to this method is that two different projectors playing exactly in sync are needed to produce the effect. Fortunately for the 3D aficionados out there, projection company RealD developed a circular polarizer that conveniently fits over a projector's lens. This circular polarizer rotates and is capable of switching polarity 144 times a second. Since our eyes can only perceive changes at a third of that rate, the flicker is unnoticeable and a projector using the RealD polarizer can show a single film that switches between the two different polarizations in time with the circular polarizer instead of using two entirely different projectors. This is the method used in the majority of theaters because the glasses are cheap and disposable and the result is a clear image that is not affected by color filters like an anaglyph film.[3]



A diagram of a parallax barrier, the type of technology used in the Nintendo 3DS and some 3D televisions. The slits cause each eye to view a different polarization of light without the use of special glasses. However, the effect can only be observed from a certain angle.
< http://mag.udn.com/html/digital/bahamut/2010/04/0000364978.PNG>

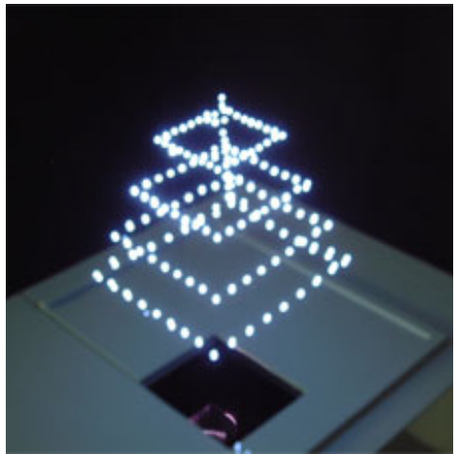
The glasses are still a turnoff for many a moviegoer, myself included. There is hope, though, albeit from an unlikely source. Nintendo is releasing a handheld system known as the 3DS that can create 3D images without cumbersome glasses. The 3DS is slated for release in February in Japan, with a release date for the US sometime after. [4] However the 3D effect can only be viewed from certain positions, a drawback of the parallax barriers used by 3DS. The barrier is essentially a screen with narrow slits in it that result in each eye seeing a slightly different image., as shown in the image to the lower left. Given that the device is a handheld video game system built for one person, this is not a problem. Taking a broader view, though, it does mean that the same technology cannot simply be slapped on to an HD television for the whole family to enjoy.

Toshiba is hoping to be the first company to solve this problem. The company intends to have two 3D televisions on the Japanese market in time for Christmas. Viewers will not need glasses, and the device will be able to accommodate an audience larger than one. There are a couple of different technologies at use in this up and coming field, such as lenticular lenses and the aforementioned parallax barriers. Lenticular lenses are ridged plates that result in different images being projected at different angles. They are already in use on printed material. If you have ever seen a corduroy style plastic cover that changed pictures depending on how you looked at it, you have experienced a lenticular lens.

360 degree viewing devices, called volumetric displays, are particularly exciting, especially because they are no longer confined to science fiction.

Unfortunately, Toshiba will have a difficult sell with its televisions. The screens are disappointingly average in scale, clocking in at 20" and 12". The price points are also a stretch for the size, with the smaller model being released in Japan at around $1,400. The 20" model is double that figure. At prices that high, it is difficult to imagine 3D televisions becoming fixtures of everyday life.[5]

In the hullabaloo over 3D movies and TV, it appears that the real goal is being lost. When will we see those awesome holographic displays seen in Star Wars? 3D television is cool, but the perspective is still limited to 180 degrees at best. 360 degree viewing devices, called volumetric displays, are particularly exciting, especially because they are no longer confined to science fiction.



A 3D image displayed by a volumetric device.[7] Photo by the National Institute of Advanced Industrial Science and Technology.

The most impressive volumetric display uses lasers. Two beams converge at a point in space, and the energy released at that point is enough to create small, bright balls of plasma. The inherent problem here is power usage and accuracy. Such powerful lasers require a fair amount of energy, much more than a standard 2 dimensional display. It is also an arduous task to have multiple beams converging at exactly the same point, and a poorly aimed laser could end up in a person's eye, potentially causing damage. The necessary precision is difficult to achieve, and the more difficult something is the more it costs to do it.[6] Portable versions of these displays are unlikely to be hitting the market anytime soon, but their existence creates a new and exciting field to explore.

With developments occurring in a variety of different technologies, it seems that development of 3D media is unlikely to be the passing fad it was in the 1950s. The rapid technological improvements are likely to produce affordable glasses-less televisions in households within a few years, and true volumetric displays will eventually. In the meantime, I can only hope the glasses become more fashionable.

Jackson Dolan is a senior majoring in mechanical engineering.

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Quark Gluon Soup

Researchers at the LHC see evidence of a primordial plasma

By LAUREN WIELGUS

Though the elusive Higgs boson, the proposed particle which gives other particles mass, has yet to make an appearance in the Large Hadron Collider at CERN, the Compact Muon Solenoid (CMS) collaboration recently released some exciting new results. The CMS particle detector, which observes collisions of the high-energy protons accelerated by the LHC, has recorded correlations between the motions of particles leaving collisions that suggest the creation of a quark-gluon plasma. This plasma has only been previously observed in heavy ion collisions, where it is easier to create such energetic plasma due to the larger masses of the ions. A quark-gluon plasma is made up of extremely hot, loosely bound quarks and gluons. Quarks are the point-like elementary particles that are bound by gluons to make up protons and neutrons. No free quarks have ever been observed.

The ... quark-gluon plasma may mimic the conditions at the time of the Big Bang, allowing physicists a glimpse into the universe's creation.

Building 40 at CERN, home to the CMS and ATLAS experiments. Photo by Burton DeWilde.

One theory posits that at the start of the universe, there were no protons or neutrons, only quarks and gluons that later condensed to form the nucleons, protons and neutrons. The conditions in the quark-gluon plasma may mimic the conditions at the time of the Big Bang, allowing physicists a glimpse into the universe's creation. Observing this plasma can give us insight into how the strong force, which binds the protons and neutrons together in the nucleus, works, and how the universe evolved.

At the Brookhaven Relativistic Heavy Ion Collider (RHIC), two beams of gold ions are accelerated into each other at nearly the speed of light. The quark-gluon plasma created from these collisions reaches temperatures of 4 trillion degrees Celsius, about 250,000 times hotter than the sun's core. The temperature of the plasma can be measured by observing the frequency, or color, of light emitted. Higher temperature sources emit light at a higher frequency.

How do particle accelerators work?

The Large Hadron Collider is a 16.8 mile diameter ring located 109 yards, or the length of a football field, below ground. Observing collisions below ground helps to filter out cosmic ray particles falling from space. As the protons travel around the ring in a vacuum tube, they are directed and accelerated by large magnets. Charged particles that travel through a magnetic field will feel an electromagnetic force. The LHC uses 9593 magnets to control the speed and direction of the positively-charged protons. By colliding 2 beams of protons traveling in opposite directions, the collisions in the LHC can reach massive energies.[4] Large particle detectors, including CMS and ATLAS, sit around the ring. High-energy protons are accelerated by the LHC and then diverted to the different detectors along the ring.

Einstein's famous equation $E = mc^2$ tells us the energy is equivalent to mass times the speed of light squared. With more energy produced in the collisions, more massive particles can be created. These collisions may create new particles that have never been seen before in the laboratory. Researchers at the LHC hope these high-energy collisions may reveal the Higgs boson, or even the sources of dark matter and dark energy.

One can observe this relation between the color of emitted light and the source's temperature when looking at a flame. The blue cone in the center is much hotter than the flame's orange edges, as blue light has a higher frequency than orange light. Researchers at Brookhaven can learn more about the nature of this plasma from the ejected particles. Physicists infer that the plasma is extremely dense because jets of particles that traverse it decelerate dramatically. Just as a person slows down rapidly when bumping into others on a crowded street, the particles slow due to their many collisions in the dense material. The plasma's components also have a coordinated motion, with almost no viscosity, or resistance to flow. Due to this coordination, particles with the same charge are ejected along the same angle of motion.

Recently, the CMS experiment has observed similar correlations in the motions of final state particles from proton-proton collisions, suggesting the creation of a quark-gluon plasma. The protons used in the CMS experiment are accelerated to energies of 3.5 TeV (tera electron-volts) for a total collision energy of 7 TeV. This is an astronomical amount of energy for a single proton. For comparison, the kinetic energy of a mosquito, which is 1024 times as massive as a proton, is approximately 1 TeV. Researchers at CERN are hesitant to say that these correlations are definitive evidence of a quark-gluon plasma. Sharka Todorova, a Tufts post-doctoral researcher working on the ATLAS experiment, another experiment studying the proton-proton collisions at the LHC, cautions that these correlations may be background noise the experimenters failed to take into account. If the new findings are significant, ATLAS should be able to confirm their existence in the near future. Though it is uncertain whether these observations will withstand further scrutiny, they give us a tantalizing suggestion of the new physics the LHC could uncover.

Lauren Wielgus is a senior majoring in physics.

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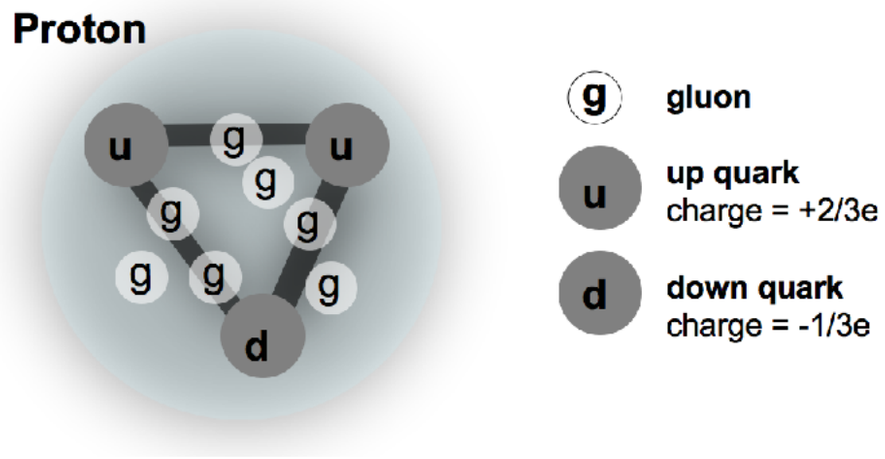
What are quarks and gluons?

Quarks are the point-like particles that make up the hadrons, a class of particles which includes protons and neutrons. Quarks come in six flavors: up, down, top, bottom, strange and charm. No free quarks have ever been observed.

Gluons are the particles that carry the strong force. The strong force is one of the four fundamental forces. In the standard model, these forces are electromagnetic, weak, strong, and gravitational. The strong forces acts through the exchange of gluons between the quarks, and binds the nucleus together.



A diagram showing the constituents of the proton. Though once though to be an elementary particle, the proton is made up of quarks. The two up quarks, each with a charge of +2/3 times the magnitude of the electron's charge, plus the down quark, with a charge of -1/3 times the magnitude of the electron's charge, add to give the proton a charge of +1e. The neutron is made up of two down quarks and 1 up quark, which add to give it zero charge.

Modeling Consciousness

Can quantum mechanics help describe how we think?

By Jackson Dolan and Lauren Wielgus

In a recent Tufts Physics and Astronomy colloquium, Professor Efstratios Manousakis from Florida State University discussed his research about developing a mathematical structure using quantum mechanics to describe subjective experience.

Quantum mechanics posits that the act of observing a particle fundamentally changes its state. Before the position of a particle is measured, one can only describe the probability of finding it in a particular location. We express this probability distribution with a wave function, whose amplitude at a certain point tells use the probability of finding the particle at that point. However, when we measure the location of a particle, its wave function collapses. The measurement has localized the particle. We no longer describe the particle by the probability distribution of its location over all space, as we know it is at a single point with 100% probability. The measurement has fundamentally changed its state from a wave spread over space to a particle at a single point. According to Professor Manousakis, this concept can be applied to consciousness.[1]

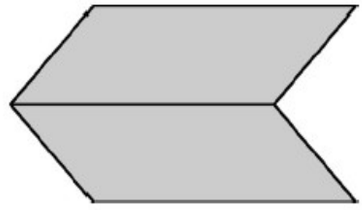


Figure 1. Does the folded paper project into or out of the page? [1]

We can consider the ambiguous drawing of a folded paper in Figure 1. Does its fold appear to project into the plane of the page or out of the plane? Our mind alternates between the two options, and the drawing can be described as having a wave function similar to a particle. It has the potential to project into the page or out of the page, just as the particle has the potential to be measured in a range of locations. When we observe the image, it becomes one of the two images, with the potential to change into the other image with further observations.

Professor Manousakis' experiment measured the time it took for an image to change in the mind of a spectator.[2] He used the old 3D glasses that covered one eye with a red filter and the other with a blue filter in order to take advantage of the concept of binocular rivalry. Binocular rivalry is when each eye sees a different image simultaneously, and the brain is forced to alternate between the two images. In the case of the experiment, one eye saw vertical lines and the other saw horizontal lines.

Manousakis held the true image (a criss-cross of blue horizontal and red vertical lines) on screen and his test subjects pressed a button when they perceived the image to switch between the horizontal lines and the vertical lines, or vice versa. This produced the graph below (Figure 2), which shows that most of the subjects perceived a change in the image within a few seconds.

The next experiment involved displaying the image on screen for one second, and then taking it off for three seconds. The subjects had the same task to push a button when they perceived the image to change. The resulting graph is shown below (Figure 3). Notice that subjects only perceived a change in the image when it was on-screen. With a lack of visual input, a person

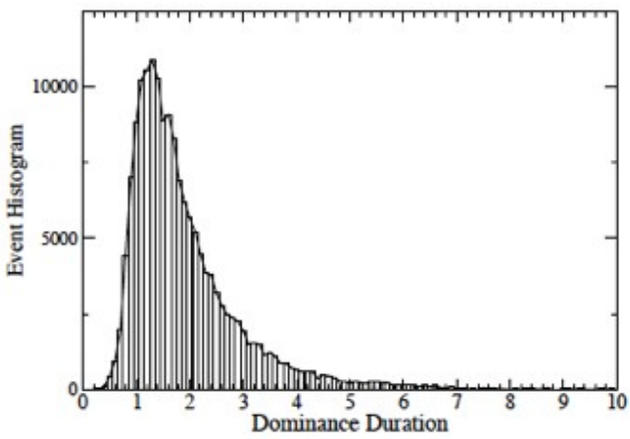


Figure 2. Measured dominance duration for a continuous stimulus.[2] The x-axis is time, in seconds, for the subject to register a change in the image.

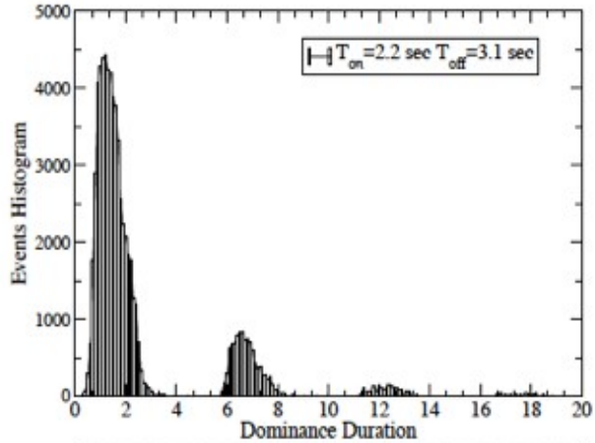


Figure 3. The measured dominance duration averaged over 42 subjects for Ton = 2.2 sec and Toff = 3.1 sec. [2] We can see that these peaks add to give us the curve in Figure 2.

does not perceive a change in the image. If a subject saw vertical lines before the image disappeared, then the subject will remember the image as vertical lines until something else enters his or her mind to change that. The separated graph is shown only for a pause of a few seconds, but Manousakis recorded similar results for pauses up to one minute. After that, it became too difficult to control the experiment and prevent outside stimuli.

A particularly interesting feature of this spliced graph is that if you remove the gaps, the response times closely mirror that of the steady image. In Manousakis' words, while the image is off the screen, "perceptual time stands still." Manousakis was hesitant to make broad claims about consciousness, but the data seems to suggest that the quantum mechanical idea of an observer is applicable. Only by making a new observation can we change the image held in our minds. Manousakis's results open up exciting questions about what we may learn from applying the principles of quantum mechanics to consciousness.

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CATERPILLARS

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and orientation of its gut. Simon and Serebrenik also look forward to future experiments to determine how the caterpillar's body orientation relative to gravity impacts gut movements. When asked whether the piston-like gut was a consequence of the caterpillar's locomotion or in fact played a significant role in its locomotion strategy, Simon pointed to the question as a source for future research. Simon and Serebrenik's findings have them wondering if the gut movements confer an evolutionary advantage on the caterpillar. "We're trying to sort out whether the gut movement is simply a byproduct of the caterpillar's locomotion or whether it had to be there first to achieve something."

Dan Slate is a senior majoring in biology.

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STUXNET

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ers were infected with the worm, though they have stated that 30,000 IP addresses were attacked. All of them have now been successfully cleaned of Stuxnet[4]. On October 12th Microsoft issued its biggest ever security fix, aimed to correct vulnerabilities exploited by Stuxnet[5]. But since Stuxnet is such a complicated worm, and since it has the ability to check and update itself, the threat still exists.

Theories on who created the worm have somewhat less support. Symentac, the world's largest computer security company, has been leading the investigation of the virus. The company found some interesting details hidden within the code that seem to incriminate Israel. For one, Stuxnet has a registry value of "19790509," which stops other versions of the worm from infecting an already infected computer[1]. This coincidentally happens to be the execution date of the Persian Jew Habib Elghanain, who was caught in Tehran while spying for Israel. Also, at one point the word "myrtus" appears in the code, which is another name for Queen Esther, who saved Persian Jews from genocide in 4th century BC[1]. While it would certainly be stimulating if these were hacker signatures, the code easily could have been left to frame Israel, especially since the worm does such a good job of covering its tracks in all other aspects.

Regardless of the true target and creator of the worm, the implications of Stuxnet remain: malware that can direct the mechanisms of a nation state's infrastructure has potentially frightening consequences. In 2007 Estonia declared themselves under attack of "cyber war" after Russian hackers blocked one of their political party's websites[6]. Russian hackers also infiltrated and shut down Lithuania's government and corporate web sites in 2008, filling them with massive spam of Soviet Union era images[7]. The United States' expanding plans and spending on a national power grid makes our own infrastructure increasingly vulnerable. As Tufts' Professor of Computer Science Ming Chow notes, "What I find surprising is stuff like this is not what you call 'sexy' topics on the news [...] we don't know where it comes from, what it is does," but it is certainly "politically sensitive." When hostile politics and developing science have mixed in the past, the results have been catastrophic. And a threat like Stuxnet is wrapped in a web inextricably connecting the entire world. It may be this kind of technology, whether it is Stuxnet or another form of cyber warfare, that snaps the feeble ties between irritable nations.

Jenna Schoen is a freshman who has not yet declared a major.

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MAPPING

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was attached to the ship by a cable, which allowed for real-time feedback.

Yoerger explained that the CTD was lowered to areas of the plume where *Sentry* picked up the strongest signal of hydrocarbons, giving the team a vertical profile of the plume sensed by the CTD's mass spectrometer. Data from this vertical profiling revealed the measurements of certain substances in relation to depth. According to the report, this "confirmed the presence of a large plume at approximately 1000 to 1200 m depth, as well as a more diffuse plume existing between 50 and 500 m depth."[1]

Samples collected from the CTD are still being analyzed. Yoerger said that together with the measurements collected by *Sentry*, data from the CTD will reveal "how much of the spill went into the deep plume and… which components of the oil and natural gas went into the deep plume."

Robotics like those used for the surveys at Deepwater Horizon allow for a level of mapping control that reaches beyond that of traditional sampling. In the case of the Gulf oil spill, robotics have provided a method of collecting clear and detailed information about amounts of hydrocarbons and thus the plume's extent. Yoerger identified this "controlled, spatial coverage" as one benefit of robotic mapping. And the instruments continue to improve: for example, *Sentry* succeeded WHOI's AUV Autonomous Benthic Explorer (ABE) with advanced speed and maneuverability.[3]

But robotic mapping does have its limitations. Batteries provide limited amounts of energy to robots like *Sentry*. Human ability to program robots is another limiting factor that Yoerger addressed. "Fortunately," he explained, "we are making good progress in both these areas." He foresees developments in robotic mapping from better batteries to improvements of instruments used on robotics. More effective, smaller instruments would require less energy, reducing the limitations posed by batter power.

And in the case of *Deepwater Horizon*, it seems there is certainly motivation for developments in AUV research and robotic mapping. Dr. Yoerger recalled the WHOI team's reaction upon arriving at the site of the spill: "We all felt a strong sense of obligation to add to the understanding to such an overwhelming and unexpected event." Yoerger continued, "Of course we all wished we could stop the flow, but that was not within our power. The best we could do was… provide the best data possible to understand the consequences of the spill."

This need for understanding was apparent during the first few months of the event, while various claims about the spill and the amount of oil in the Gulf circulated. "Based on earlier observations," Yoerger explained, "we hypothesized that there was a deep plume and tested that hypothesis." The team's report was the first peer-reviewed publication relating to observations of the spill[2] and further analysis of data continues to add to an understanding of the spill's extent.

Catherine Hoar is a junior majoring in biology.

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ENVIRONMENT

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teria" explored the possible bioremediation of the plume by microbes.[7] Such microbes consume oil by converting oxygen and hydrocarbons into carbon dioxide.[8]

Oxygen levels determined in the report "Tracking Hydrocarbon Plume Transport and Biodegradation at *Deepwater Horizon*" did not support the hope that microbes were quickly eliminating the remaining oil.[5] However, "Deep Sea Oil Plume Enriches Indigenous Oil-Degrading Bacteria" revealed that while the rate of oil degradation by the microbes is unknown, a large amount of microbes are moving to the plume. Research for "Deep Sea Oil Plume Enriches Indigenous Oil-Degrading Bacteria," conducted by microbiologists for the University of California, Berkeley, indicates that the concentration of microbes was greater inside the plume than outside the plume.[8]

Current reports feature data collected over specific periods of time after the spill. Determining the impact of the *Deepwater Horizon* blowout will therefore require more time and more data. The various impacts predicted, however, indicate the widespread, indirect, and complex possibilities.

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Fun Science Experiments

Learn quick and easy experiments that can be done at home!

By JACKSON DOLAN

Mentos and Coke

-Mint Mentos
-Diet Coke (a 2 liter bottle works best)

This is an easy. classic demonstration for many chemistry classes. Just uncap a bottle of Diet Coke and toss in some mint Mentos. I'm not going to spoil what happens here for those of you not in the know. Just go try it.

For the more enterprising(read: engineers) readers, knot one end of a string, poke some holes in the Mentos, and run the string through them. Attaching a weight near the knotted end, such as a washer or nut, will help. Make a hole in the Diet Coke cap and run the string through this as well. Recap the soda, being careful not to let the Mentos touch the Coke. Release the string and enjoy.

Note that the Mint Mentos is actually an important factor due to the surface roughness. The standard colorful and smooth Mentos will not be nearly as effective.

Photo by Jose Luis Pelaez. Getty Images. <http://www.gettyimages.com/detail/90097914/Photodisc>

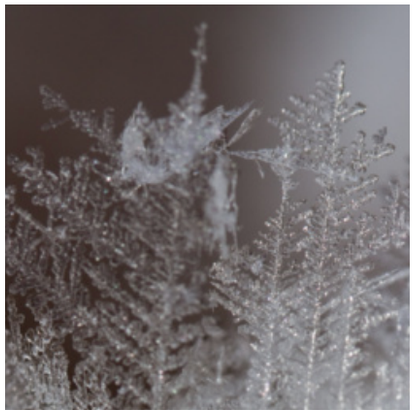

Photo by Dann McKenzie. Getty Images. <http://www.gettyimages.com/detail/97840856/Flickr>

Superglue Snowflakes

-Snow
-Clear Liquid Super Glue
-Glass (Microscope slides and slipcovers are ideal)

You will have to wait for some wintry weather to do this, but that is not going to be a problem. Before the snowfall begins, put the slides and slip covers in the freezer for at least an hour. It will also help to cool the superglue a bit, but only for 10-15 minutes.

With your chilled supplies in hand, head outside and start catching snowflakes on your microscope slide. If you are picky about the quality of your crystals, you can attempt to pick up individual ones with a brush or tweezers. Once you have a satisfactory specimen, drop a bit of superglue on top and cover it with the slipcover. Press down on the slipcover, but not so much that you risk crushing the crystal.

Put the captured snowflake in your freezer for a few days to let the glue set, and enjoy your permanent winter art.

Frozen Bubbles

-1/2 cup soap powder
-1/2 cup sugar
-3 cups hot water
-Bubble Wand

Freezing bubbles is awesome. Like the snowflake preservation, it requires it to be freezing outside, and the colder the better. Before you go out and start blowing store bought bubble mix into the crisp Medford air though, you might want to consider using a special recipe.

Mix the soap powder, sugar, and hot water together, stirring until everything is dissolved. This should result in more durable bubbles. Then head outside and start huffing and puffing until you produce bubbles worthy of keeping. It probably is not going to get cold enough here for the bubbles to freeze in midair, so try to catch them on your wand and let them sit there for a few minutes until they solidify. Unfortunately, unlike the superglued snowflakes, these will not survive warmer temperatures so do not bring them indoors.

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BREAKTHROUGH

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