

Spring 2011

# NUScience

Northeastern University's First Science Magazine

Issue 7

The Year of  
Chemistry

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From the top we've got our President, Kristina Deak, Our Editor in Chief, James Peerless, our Reviews and Interviews Lead, Lizzy Gilbert, and VP/ Designer Brad West...

## Letter from the Editor

Hello Readers!

So we are now coming to the home stretch. The weather is warm, classes are finishing up, and everyone's getting ready for whatever shifts the summer may bring. Our seventh issue, and last of the 2010-2011 school year, focuses on chemistry, celebrating the international year of chemistry the best way we know how. Thanks to our wonderful writers, we've been able to put together a broad range of topics all focused around what's going on in the chemistry world today. Our design team, subject to a mass amount of flux throughout the issue, has done a spectacular job stepping up to the task, with some designers learning as they go.

Although we believe the issue you're holding is one of the best magazines we've put out yet, it is somewhat bittersweet for me. This will be my last issue as Editor in Chief of NU Science Magazine, and the last issue I will see as a Northeastern undergraduate. Our intrepid President,

Kristina Deak, will be taking over the Editor duties for the foreseeable future. I'd like to thank all the writers I've ever worked with for putting tremendous work in on top of school and work to produce insightful works for the magazine, my editors (Kyle, Lizzy, Emily, Mike) for always coming through when I needed them, Kristina, Brad, Simon and Andrea for making all the other parts of the magazine run (as well as they can), and of course you all, our readers. I hope that my time at the magazine has provided insight and knowledge you demand and deserve from a student publication. I fully believe that this magazine will continue as an important piece of science literature here on campus, and I can hope that my work has strengthened its future.

Thank you, enjoy, and goodbye,

James Peerless

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## Possible Lead Discovered for HIV Vaccine

Since its discovery in 1981, HIV/AIDS has taken the lives of millions worldwide. This pandemic has, naturally, led many researchers to seek a cure or vaccine for the human immunodeficiency virus, though with only limited success. The virus is able to mutate very quickly, making it extremely difficult to produce a vaccine capable of preventing even a fraction of the numerous strains that exist. However, new research suggests that the task may not be as daunting as previously believed.

A vaccine's job is to train the body to defend itself from infection by teaching it to create the correct antibodies for a specific disease. Since so many different versions of HIV exist, vaccines have previously been unable to create antibodies for more than 40% of strains. Yet two new antibodies discovered in the summer of 2010, called VRC01 and VRC02, have demonstrated the ability to neutralize the vast majority of strains. Dubbed "broadly neutralizing antibodies," they are highly successful at preventing the virus from infecting cells. In addition to this, experiments suggest that most people should be capable of producing these antibodies themselves, once their body learns how. Many researchers feel that this discovery bodes well for our ability to eventually combat HIV.

In early February of 2011, intensive clinical trials began in a second location for a possible new HIV vaccine which utilizes broadly neutralizing antibodies in conjunction

with an attempt to heighten cellular immune responses. Interestingly, the drug, created by GeoVax, will be simultaneously tested as an HIV preventative and as a treatment for those already infected. The belief is that the production of antibodies stimulated by the treatment will allow a patient to better control their HIV and become less dependent on other medications. The study, lasting as long as 77 weeks, will not return its findings for quite some time and, until then, tensions remain high.

The GeoVax drug would not be the first promising HIV treatment to disappoint during clinical trials. An experimental HIV vaccine developed by Merck & Co., Inc. failed in 2008, showing almost no positive results. The study attempted to use neutralizing antibodies, not to be confused with *broadly* neutralizing antibodies, to create an immune system reaction against HIV. Unfortunately, the neutralizing antibodies were ineffective against the virus, even increasing a person's rate of infection in some cases.

Much more work is required before an effective HIV vaccine will become readily available. However, strides such as these play an essential role in making progress towards a successful treatment.

-Michael Murray, Comp Sci/English,  
2014

### Mammoth Resurrected!

The Mammoth Creation Project, founded over 13 years ago, started out with a goal to clone the wooly mammoth, a species that has been extinct for over 10,000 years. So why are we talking about it now? Advances in the field have made cloning a mammoth realistic in the next 5 years. Using an egg from an elephant and replacing the DNA with that of a sample taken from a well preserved frozen mammoth could very well result in a mammoth being born from an elephant mother.

Of course, many are questioning the ethics of bringing back an extinct species. Would we create a Jurassic Park-like situation with wooly mammoths taking over the world? Probably not. Many cells from frozen wooly mammoths have no intact nuclei with usable DNA. However in 2010, a team of scientists were able to recreate a mammoth hemoglobin protein. Using modern technology to convert mammoth DNA to RNA and using E.coli to grow the protein, scientists were able to clone multiple mammoth hemoglobin proteins and observe their function. Specifically, through testing, they were able to determine that mammoths had an evolutionary adaptation allowing them to tolerate cold temperatures.

-Tara Dhingra, Biochemistry, 2012

## THE TEAM



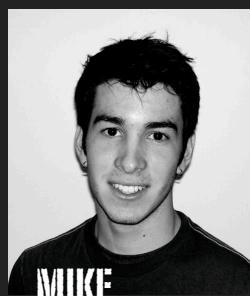
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### Who We Are:

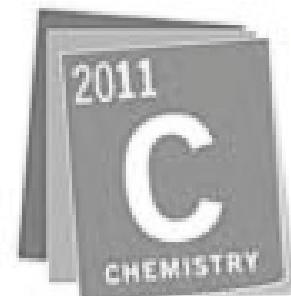
From the top we've got our Editor/ Designer, Emily Sneed, Editor Kyle Deerwester, Secretary, Andrea DeDonato, and our newest Editor, Mike Murray.

# 2011: It's All About the Chemistry

Welcome to the International Year of Chemistry. 2011 is intended to serve as a year of appreciation, outreach, and advancement for chemistry in all its forms. The decision is the result of the combined efforts of both the International Union of Pure and Applied Chemistry (IUPAC) and a proposal to the United Nations Educational, Scientific and Cultural Organization (UNESCO) by Ethiopia. The date also coincides with the 100th year anniversary of Marie Curie's first Nobel Prize for her work with radiation.

Chemistry earned the title of the "central science" well before 2011. It has connections to all of the physical and life sciences down to their atoms. More importantly, chemistry allows a greater understanding of our world and the laws of nature in fields varying in orders of magnitude from astronomy to nanotechnology. Its beauty lies in its ubiquitous and universal language; everything from stars, rocks and animals can be described and investigated with chemistry.

The International Year of Chemistry was instated to actively spread not only awareness of how chemistry affects our lives, but also to promote enthusiasm for the learning and advancement of the field. Every century, decade even, can claim its own challenges that need to be overcome. Today, we face global climate change, looming food shortages, energy concerns, and, still, the common cold.



## International Year of **CHEMISTRY** 2011

millions of repeating units, such as the massive wooly mammoth DNA. We hope to show you some of the history and future of chemistry, even if it takes all year.

-Nicholas DeLateur, Chemistry, 2014

Chemistry creates and propels solutions to all these problems and more; some of the most promising chemical technology finds a home on our own very Northeastern University campus in the forms of fuel cell technology and tropical disease fighting drugs.

Activities range from increasing exposure in ways both large and small. The American Chemical Society will be putting on a Global Challenges/Chemistry Solutions panel, as well as a daily example of chemistry's applications. More local events include various demon-

strations by the Northeastern University Student Affiliates of the American Chemical Society (NUSAACS). On the 22nd of February Dr. Nancy Jackson, the President of the American Chemical Society, spoke at Northeastern's Chemistry and Chemical Biology department about the future and promise of chemistry; chemistry shows no signs of slowing down as the integral science to expand humanity's knowledge and provide solutions to our global challenges.

In this issue we present articles highlighting chemistry, with topics ranging from small organic molecules like dopamine, to large polymers with

An interesting thing happened in late February. Walmart announced that it was expanding its ban on PBDEs in consumer products, and that, beginning on June 1st, extensive testing of suspended goods would be pursued to ensure the ban is followed. The announcement came shortly after the release of a study by the University of California-Berkeley that linked PBDE exposure to difficulty in conception.

PBDEs (polybrominated diphenyl ethers) are organobromine compounds that have been produced since the 1960's for use as flame-retardants in appliances, textiles, foams, plastics, and other practical goods. By 2000, global sales were at 70,000 metric tons. In the same year a study in Sweden by Noren and Mieryonte demonstrated that the concentration of PBDEs in human milk had been doubling every 5 years since 1970. In 2003, Dr. Schecter of the University of Texas found that breast milk from the US featured 10 to 100 times greater concentrations of PBDEs than that from Europe. Since this time, animal studies have implicated the chemical in endocrine, neurological, and develop-

mental complications.

With such evidence, why is the chemical still so prevalent in our day-to-day lives? For one, the chemical policies in the United States haven't changed much over the past 35 years, falling grossly behind our rate of scientific development.

Today, the EPA has sufficient health risk information about 200 of the 84,000 chemicals used commercially in our country. It is perhaps a great benefit of capitalism that corporations such as Walmart, Whole Foods (banned bisphenol A in 2008), and Sears (banned PVC), have addressed the concerns of their

customers about their health and the health of their children before the government could. Welcome to America, where the voice of the public may not be heard by the government and the EPA, but it will be heard and acted upon by retail giants.

-Kristina Deak, Biochemistry, 2012



# THE FUTURE OF

## Interview with Professor Sanjeev Mukerjee

NU Science had the privilege to meet Dr. Sanjeev Mukerjee, the director of the Northeastern University Center for Renewable Technology (NUCRET), to discuss his research and recent advancements made in the lab. NUCRET acts as an “avenue to collaborate,” says Mukerjee, “We predominately focus on electrochemical interfaces with an immediate impact on fuel cells, batteries and electrolyzers.” Through collaboration however, opportunities for research in other areas in which they do not have the same expertise, such as biosolar and graphene, become readily available.

Biosolar is a field that focuses on protein-based solar cells. The challenge is to make the proteins survive long enough to be competitive with commercial silicon solar cells. This project involves a collaboration of many different disciplines, including a protein engineer from Children’s Hospital, a material scientist from MIT, and from Northeastern, a mathematician working on computations and a physicist. Having such a diverse knowledge base helps foster learning and discovery, which is greatly beneficial to NUCRET.

“[Graphene] is another potential growth area,” says Mukerjee. They have a young professor working on building a portfolio on graphene. This material won the Nobel Prize in physics for 2010. It is a planar sheet of carbon atoms, one atom thick in a honeycomb lattice, and has implications in catalysis and photonics.

One of the benefits of having a center that focuses on collaboration is that it provides more opportunities to write large proposals, and receive more grants to continue research. It also aids new educational initiatives, such as master’s level courses that are multidisciplinary across several departments, which can sometimes be challenging. “It also pools a lot of equipment into a common [area],” says Mukerjee.

NUCRET allows companies in the area to come in and use the equipment, which generates revenue and helps the organization build its network.

There are a number of projects being conducted at NUCRET that are currently showing strong progress. The center currently has a project from the Department of Energy (DOE) to develop new catalysts that do not contain noble metals. Noble metals such as platinum are typically used in fuel cells; however finding an alternative to noble metals would be extremely beneficial due to their high cost. “It is very exciting because it allows us to lay the foundation of science for several decades” says Mukerjee. NUCRET also has a project focusing on the electrolyte aspect of the Lithium Air Battery; it is the “highest current density battery imaginable, by looking at the periodic table.” They are working on a new based upon the hard acid base theory. The idea is that creating different blends of electrolytes will enable different levels of electron transfer. “Oxidation reduction involves full [4] electron transfer, but if you blend an electrolyte correctly, you can stop transfer [at intermediate steps of] 1, 2, 3 or full electron transfer.

Dr. Mukerjee also received several grants totaling 8 million dollars, in the fall of 2010. These grants have helped Northeastern gain a reputation as an important place for fuel cell research. “It is great to know that people have confidence in my abilities,” says Mukerjee. These grants allow him to hire the best students and post docs that he can find, and buy new supplies and equipment. This combination allows him to publish in the best journals and “shape the technology for the future”.

# ENERGY

Dr. Mukerjee received his PhD from University of Texas A&M University, and has two master’s degrees in Chemistry and Chemical Engineering. When asked how he first became interested in electrochemistry and fuel cell technology he responded, “I fell into this by accident actually.” A friend of his helped him get an interview at a nonprofit organization, where he was hired as a research associate. He emphasizes the importance of networking to help “get your foot in the door”, but in order to grow in an organization it is up to the individual. In this position he was given complete freedom to work on a project related to fuel cells. “At this point there was nothing going on in India related to fuel cells.” He had the opportunity to design the laboratory and purchase all the equipment. At the end of the project he was told that his company would sponsor him for a PhD. He worked briefly as a Staff Scientist at Brookhaven National Lab in New York, but saw no long-term future for himself, because of his lack of flexibility in research topics. He decided to begin looking for academic positions at universities within a 200-mile radius of Brookhaven. He needed this proximity to Brookhaven National Lab because there he built, and was the first to use, a cyclotron light source for x-ray adsorption and defraction spectroscopy. A position was available at Northeastern and he applied. “They put me up in an apartment just opposite the Krentzman Quad. I remember, it was a cold February evening when the taxi dropped me off here. It was nighttime and I was tired. But in the morning when I woke up on the day of my interview, I looked out my window onto Krentzman and knew that I wanted to be in an urban environment. I liked it. You walk out onto [the] Northeastern [campus] and you have a whole vibrant world out there.” His interview went well and he was offered a position that allowed him to pursue his interests and continue researching fuel cells.

The future of fuel cell technology is a topic that is frequently debated. When asked about where he sees this technology in 10 years Dr. Mukerjee responded, “Fuel cells have been at the 10 year mark for quite some time now so I wouldn’t want to put that limit on it. However I will make a prediction, for two reasons, one is that I believe in it and the other is that it is far enough away that I won’t be around to find out if I was right or wrong.”

He predicts that the internal combustion engine will be in a museum at the turn of the century. He described that by the year 2100, children will say to their parents, “Oh that’s neat. What is it?”, and their parents will respond “Your grandfather used to have one of those, it was a noisy smelly thing.” In the future, the internal combustion engine will be reflected on similarly to how we view the horse drawn carriage today.

“In the future there will be silent propulsion from the conversion of chemical energy to electrical energy and you will need to make artificial noise to warn people that a car is coming. It will be clean and cars will be faster. You will have an automobile that will run in tandem with batteries. The battery will power the car for the first 40 or 50 miles and then the fuel cell will kick in to power the battery, and it will be hydrogen powered.”

The infrastructure change will not be very difficult. Current gas



stations will be able to switch to reformers, which will convert natural gas to hydrogen. It is not as huge of a stretch as some people make it out to be. The United States is sitting over the largest natural gas reserve in the world. “It is the Saudi Arabia of natural gas.” Hydrogen gas is very clean. This will centralize sources of pollution. Carbon Dioxide will still be produced. The goal will be to find a way to convert carbon dioxide into useful materials and recycle them. There are answers to the concerns about global warming, as long as the CO<sub>2</sub> emissions can be centralized. “You can’t capture the CO<sub>2</sub> that is coming out of a car, but there are solutions that can be put in place if the emissions are centralized rather than decentralized as they are now.”

Dr. Mukerjee is optimistic about the future of fuel cells and battery technology. He enjoys working with undergraduates and teaching undergraduate classes because “they haven’t become old, tired and jaded. I like to encourage them.” As a parting note, Dr. Mukerjee provided advice to undergraduates interested in alternative energy. He believes that it is important to find something that you are passionate about and believe in whole-heartedly. “You’re not living unless you find yourself lying awake at night just waiting to get out the door, and you can’t get to sleep because your mind is constantly churning out things that you would rather be doing.”

-Brad West, Chemical Engineering, 2013

# Looking Towards the Future: Alternative Careers in Chemistry

Theoretically, a student enters college to gain an education, not a job. Realistically, however, this pattern doesn't often hold. An important part of working in chemistry consists of weighing future career options and the choices that will lead you to them. Before we explore alternative chemistry careers, let's take a quick look at the "normative" chemistry career.

The stereotypical chemistry career once you have a Bachelor's degree follows one of two roads: straight into industry or straight into graduate school. Either way, you're looking forward to spending most of your job hours sitting at the bench, running reaction after reaction. Even after achieving the level of Ph.D., the normative career follows the same pattern: choose (more) academia or go into industry, and be prepared to spend more time burrowed in that fume hood. The field of science contains so many more possibilities that spark interest in burgeoning scientists; anything outside this normative paradigm when it comes to chemistry careers is considered alternative.

Chemjobber is the pseudonym of an influential chemical job-analyst. He notes that the time that passes from the beginning of undergraduate education to the end of receiving a Ph.D. takes much more time than the half-life of the modern rise and fall of chemical fields. If, during your sophomore year, the chemical community is crying for medicinal chemists, or electrochemists, the chances are better than not by the time you're doing your best work, the roles are reversed. Rather, such decisions of where to go with a chemistry degree should not be made based on the "Discipline of the Week" method, but a more in-depth search of the various options available that fit one's personality. For a more quantitative look at the chemistry job market, Chemjobber provides excellent coverage. (<http://chemjobber.blogspot.com/>).

These listings encompass only a fraction of the options, without even exploring the choices available in the fields of teaching, forensics, or curator. Nor do any of the professions below deny the appeal of canonical lab work in industry or academia. But for some, there's nothing like the road less travelled.

## Technology Specialist

For those that want to stay current with breaking scientific advance, without the hazard and monotony of the bench, patent law offers a wealth of opportunity. After a bachelor or masters degree, many scientists become "technology specialists". The job of a technology specialist is to help patent lawyers understand an invention. Usefulness, some level of complexity, and whether such an invention or something very close has already been done before must all be determined by a trained chemist in order to help obtain a patent. The job requires the ability to keep up-to-date knowledge in chemistry



as well as analytical skills, not to mention the ability to explain chemistry and related sciences to others without science degrees.

## Patent Lawyer

A next level exists as well for those hungry for more. After a degree in chemistry, many go for a law degree as well in order to become a full patent lawyer. Most established intellectual property firms offer programs where a seasoned technology specialist can attend law school at night, on the law firm's dime. They then emerge with patent lawyer qualifications, such as preparing or challenging patents, litigation, and prosecution (which actually means filing in patent law), while retaining the scientific knowledge and background of their chemistry training.

## Journal Editor

As a patent lawyer facilitates and guards the gates of intellectual property, the journal editor defends and promotes the scientific article. In the field of scholarly publishing, all the houses, from giants such as Nature and Science to small publications like The Journal of Turbo Encabulator Research, require editors with scientific backgrounds. These individuals pick out important and impactful papers, and then work with the leading scientists to edit, refine, and optimize the paper. The journal editor must not only be up to date with the latest advancements in science across broad disciplines, but also which experiments will have the most impact on their respective fields.

## Science Writer

While somewhat recursive, no list of alternative chemistry careers could claim to be sufficient without the science writer. Newspapers, magazines, websites, and almost every other form of journalism outlet now have regular updates on science, even if it is not the main focus. On the other extreme lie services such as New Scientist or Popular Science whose specialization perfectly connects with a chemist's education. The classic free-lancer option offers even more options with the advent of blogging and social networking. Science writers put not only their chemical and other scientific knowledge into their work, but their data-mining, researching, and analytical skills as well.

A Ph.D., theoretically, pushes the boundaries of human knowledge in a specific field of a specific discipline, and spends 4-7 years doing solely that. Contrast this to the science writer, who has a new specialty every week or month. One deadline you know all the latest research there is on alkaline phosphatase mutation for increased efficiency in medicinal testing, and the next

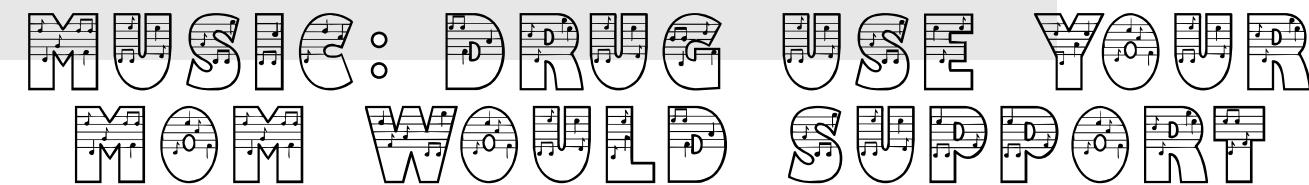
you're explaining with impeccable detail the latest evidence for language in dolphin communities. The icing on the cake comes in when you accidentally do *too* much background research: you may decide to go from an article author to a book author.

## Science Artist

Where do you think the illustrations on the cover of books

and hidden inside their chapters come from? For those with a more steady hand, the career of a science artist allows the best of both worlds from science and art to be combined. A plethora of opportunities exist ranging museum exhibits, textbooks, novels, and even commissioned designs for tattoos!

-Nicholas DeLateur, Chemistry, 2014



Music is highly valued across all human cultures. The specific sounds vary widely, even within cultures. My mom loves to listen to Gregorian chanting. I'd rather be involved in an automobile accident, but I do love The Strokes. The concept is the same, though: an abstract stimulus invokes a pleasurable response.

So is music a drug? New research published last month in *Nature Neuroscience* by Salimpoor and Benovoy indicates a strong similarity. Drugs, sex, and eating have long been known to produce pleasure by releasing dopamine in the mesolimbic system, commonly thought of as the "reward pathway." These are tangible stimuli that promote (or, our bodies think they promote) survival. Music, though, is abstract. It feels good to listen, but it doesn't provide us with safety, nutrition, or reproduction.

To test what neural pathways are engaged during musical enjoyment, Salimpoor and Benovoy first had their test group select their favorite music. A "musical frisson" test was used to identify moments of peak pleasure – if you get "chills" on hearing "DON'T STOP – BELIEVING," you're actually experiencing a measurable physiological response.

Brain activity was then measured as subjects listened to their chosen piece. Two types of brain imaging were used: PET scans were used for their precision over time, while fMRIs were used for their neural precision. The results were combined to accurately determine exactly what the brain was doing at what point in the listening experience.

Two different neurochemical responses were discovered. In the anticipatory stage – leading up to the subject's favorite part of the song – dopamine was released in the dorsal striatum. In previous studies, the dorsal striatum has been linked to learning and action selection. Researchers at UPenn have specifically linked it to cocaine cravings in addicts.

During the peak pleasure stages (measured by the musical frisson response), dopamine was released in the ventral striatum. It is not clear what role the ventral striatum plays in the reward pathway, though a previous study showed it is strongly linked to sensations of euphoria associated with amphetamine use in non-addicted individuals.

Research has been done previously on the



topic. In 2004, researchers showed that pleasant music lowers blood pressure in rats. They suggested this response might be due in part to the dopaminergic system.

In 2005, a study suggested that activation in the ventral striatum correlated with intensity of self-reported pleasurable response to music. It also showed that the nucleus accumbens (again, implicated in cocaine addiction) was activated, but their PET scans didn't have enough resolution to pinpoint activity.

The accuracy of the dual imagining used in the *Nature Neuroscience* is a significant leap from self-reporting and general mesolimbic activity. This allowed researchers to see the distinct stages of the pleasure response, without the bias of a self-report. The pattern of anticipation and release furthers the theory that there is a biological similarity between drug use and listening to music. It makes sense, especially if you've ever tried to turn off someone's favorite song "right at the good part." Only an addict could respond so violently to a 60-second pleasure delay.

- Cat Ferguson, Behavioral Neuroscience, 2013

# Taming Our Twin: ATOMS OF ANTIMATTER TRAPPED FOR THE FIRST TIME

In fall of 2010, the very first atoms of antimatter were trapped at the Large Hadron Collider (LHC) at CERN. This is a big step forward in the realm of physical research. Little is known about antimatter aside from a few very popular facts such as annihilation. This concept says that if any of it were to come into contact with regular matter, say, an asteroid or the air that makes up our atmosphere, an equivalent amount of both types of matter would “annihilate,” or convert to light. The amount of energy contained in the light made would be equivalent to the mass involved moving at the speed of light (as seen in Einstein’s E=MC<sup>2</sup>). This is an unfathomably huge conversion factor. Half a gram of it (a small butterfly) placed suddenly here on Earth would recreate the infamous atomic bombing of Hiroshima. The biggest bomb ever detonated, the 1961 USSR test bomb “Tsar Bomba,” would only require 1.35 kilograms of the stuff—just over that of your average netbook. That explosion would level the state of Rhode Island. Undoubtedly, there’s still much to learn about the illusive substance and understanding the elementary units that make it up is the first step. There are many kinds of particles, the most important of which are the elementary ones which link together to form every other particle. Today, the known elementary particles are a party of 16, including six kinds of quarks and electron, have a net electric charge. It’s these particles that have associated antiparticles with properties identical except for charge, which is equal in magnitude but opposite in sign. The remaining six elementary particles, which include the photon, are considered to be their own antiparticles.

Hadrons are particles that are made of quarks. These can be classified as baryons, composed of either normal or anti-quark trios, or mesons, made of quark/anti-quark pairs. The particles we’re most familiar with are the protons, neutrons, and electrons. Electrons are elementary particles and their anti-parts are anti-elementary particles, anti-electrons (also called positrons). Protons and neutrons are baryon hadrons and their respective antiprotons and antineutrons are combinations of the anti versions of the three quarks that make them up. Scientists have speculated on the possibility of “negative matter” for many years with few physical results. In 1928, theoretical physicist Paul Dirac first stumbled upon sound mathematical evidence for antimatter while laying down the foundation for quantum field theory. The theory, which models the behavior of very small particles moving at relativistic speeds (near the speed of light), described normal particles as leaving energy holes or deficits in the universe by virtue of existing with mass and charge. To put things in perspective, it was like looking at a basin full of liquid on one side with the other inexplicably empty. The missing energy was later interpreted as antimatter and verified experimen-

tally in 1932 by Carl D. Anderson. Anderson’s experiment consisted of allowing high-speed, charged subatomic particles entering earth’s atmosphere to enter a gas filled, magnetized chamber. The charges on the particles left trails as they moved through the gasses in the chamber, the curves dictated by each particle’s individual charge and mass. Some trails resembled mirror versions of electron trails and thus the positron was born. The antiproton was verified in 1955 at the University of California, Berkeley and the antineutron in 1956 at Lawrence Berkeley National Laboratory.

Creation of antiparticles, both naturally and artificially, is actually just as common as that of normal particles. This is because matter is always formed in anti/normal pairs. Said event occurs whenever there is a very dense presence of kinematic energy. When these conditions are met, energy from the system is likely to be converted into mass by the reverse of Einstein’s equation. Naturally this may occur in large explosions in outer space or thunderstorms here on earth. Artificially it happens in particle accelerators when charged particles are slammed together at tremendous speeds by magnetic fields. It happens in particle accelerators when charged particles are slammed together at tremendous speeds by magnetic fields. The movement of antiprotons and positrons is easily manipulated upon creation by controlled magnetic fields due to their charge. Atoms of anti-hydrogen have been in production at CERN since 1995 but because of their neutral charge, could not be controlled and quickly vanish.

The recent experiment at CERN, dubbed “Anti-hydrogen Laser Physics Apparatus” (ALPHA), found a way around this problem by taking advantage of the atom’s polar properties. As a structure composed of two oppositely charged ends, the hydrogen (anti or otherwise) atom is an electric dipole. And because said charges are revolving about each other, it is also a magnetic dipole—the physical term for a basic, bipolar magnet. Like flags in the wind, magnetic dipoles spin in a magnetic field to align themselves with the field; this is exactly how compasses work. In order to apply a pushing force rather than a spinning force and gain control of the atom, the magnetic field must be nonuniform, or different from place to place. This is analogous to spinning a coin on a desk. If both ends of the coin are equally thrust, the coin will (theoretically, at least) spin in place. If one end is pushed more than the other, the coin should both spin and move. This is the essence of ALPHA. Decelerated positrons and antiprotons are introduced to the apparatus, join to form anti-hydrogen and then gently sway back and forth in the non-uniform magnetic field set up by the device’s octupole or eight-end current magnet. In principle, this could have been accomplished as electric dipoles in an electric field, but it is much harder to control an electric field this way. The particles were detected by allowing them to

hit the annihilation detectors that encompass the machine. The experiment was crude, yielding only 35 successful particles after using about half a trillion positrons and antiprotons in 315 trials, but the success lies in the proof-of-principle which will pave the way for more refined tests. The ability to trap anti-hydrogen presents opportunities for further, in-depth studies. Ultimately, it will give us a better insight to the origin of the universe and the inner workings of the fundamental forces, which will lead us to new discoveries. The mathematics involved suggest that antimatter be interpreted as normal matter traveling “backwards” in time, a curious observation that will be studied more thoroughly. New information will also lead us to the development of more practical uses such as positron emission topography (PET).

PET places radioactive material whose decay includes positrons in human bodies to image organs by the gamma rays released upon annihilation. Scientists are also looking to study the atomic structure of antimatter in order to compare it to that of normal matter.

Finding the light emission spectrum of anti-hydrogen would be one of the first ways of doing this. This chemistry redo will allow us to check for discrepancies that may violate universal symmetry laws that account for the symmetry of space, time and electric charge. A suspicion that symmetry may be violated lies in the apparent lack of antimatter in the universe. There is a possibility, however, that far away structures, perhaps even those visible in the night sky, may be composed of antimatter. If this were the case, the “anti” would just be a

-Edward Nunez, Physics, 2013

matter of perspective.

## The Chemistry of Cooking:

### Molecular Gastronomy

It is well known that cooking is chemistry in action. Recently, a new technique in cooking sweeping through the culinary and scientific world is molecular gastronomy (MG). MG looks at the scientific processes behind every-day reactions like cooking asparagus. The color brightens when put into boiling water because the air cells on the outside burst, but turns to gray when the heat starts to break down the cell wall. Made popular by cooking shows and perfected at gourmet dining establishments, molecular gastronomy is a new culinary genre embracing the scientific approach to cooking food. It is a new way to apply scientific techniques to everyday situations. Essentially, the goal of MG is to determine why certain food prepared via a certain technique tastes, looks and smells a certain way and to apply the scientific method to produce nutritious, delicious food with the minimum amount of effort. This is unlike food science which looks at food safety in production and nutrition. For example placing asparagus in boiling water brightens the green color, but if it’s overcooked, the color changes to gray. MG asks why these changes in color occur.

Scientists and chefs alike are looking into molecular gastronomy to optimize the taste of the food we eat through its preparation. The discipline involves the chemical reactions that take place transforming raw ingredients to a final, edible meal. MG essentially turns cooking into an experiment, testing old wives tales, and utilizing new tools and ingredients in the kitchen, such as gelling agents and liquid nitrogen. This approach divides recipes into multiple parts. First, one looks at the ingredients of a dish like pear jam, such as the makeup of pears as they are heated in sugar and water. Next, one looks at the processes involved in the transition that takes

place to get from ingredients to dish, which have been dubbed “precisions.” Molecular gastronomists also pass over general terms in favor of more technical diction when describing their food. A dish is made up of “colloids”, where a basic colloid is one phase (either gas, solid or liquid). And a plate is made of several colloids. For example, mayonnaise is an example of a basic colloid. More specifically it is an oil-in-water emulsion.

A part of MG is testing “precisions” for scientific truth. For example, many chefs have sayings about what temperature mayonnaise should be cooked in with really no scientific reasoning behind them. To check if cooking at room temperature would result in poor mayonnaise, the scientific method was applied. An experiment involved cooking mayonnaise with ingredients at different temperatures was carried out and the observations recorded. The conclusion was that temperature had no effect on mayonnaise quality because oil-in-water emulsions are stable over a wide range of temperatures. Temperature only becomes a factor at oil’s freezing point or at the temperature where proteins denature.



Arizona Foothills Magazine

These precisions or preconceived notions of how to carry out a recipe result from failures. MG looks at why these failures occur and what precisions are true. In the near future, the application of the scientific method to the culinary arts will produce new unique dishes that will transcend the gourmet circuit and enter into the homes of the average family.

-Tara Dhingra, Biochemistry, 2012

# Review: Dr. Derek Lowe's

## Things I Won't Work With



A perennial course thrust upon undergraduates of most scientific majors, from biology to chemical engineering, is organic chemistry, complete with lab. The lab section is not what is dreaded however, and why should it be? The exercises are relatively simple, not too long, and perhaps most importantly, are not deadly. Compounds such as concentrated sulfuric acid and diazonium salts should always be treated with respect and care, even if a blast shield is not required. Chemicals exist, however, that very few people in their right mind would touch with a 100 foot pole made of solid steel.

Enter Dr. Derek Lowe's Things I Won't Work With. These series of blog posts by a seasoned organic chemist gained attention with their amusing and alarming accounts of materials that no one should work with, and yet have papers published explaining their synthesis.

Starting with a classic, the first compound is hydrogen fluoride (HF). Not hydrofluoric acid mind you, which is HF dissolved in water. Hydrofluoric acid's most infamous quality lies within its ability to dissolve glass. Synthesis of hydrofluoric acid in a glass round bottom flask would not be advised. Without being dissolved in water HF is a gas, and a rather nasty one. Although not a noble gas explicitly, elemental nitrogen finds great stability in forming a diatomic gas with itself. Like oxygen, nitrogen gas does not consist of single nitrogen molecules but rather two linked together, very much happy with their arrangement. Nitrogen is frequently used when anaerobic conditions are needed and there are concerns with a reagent reacting with the atmospheric conditions. With that small primer, we face the polyazides and other nitrogen containing structures.

An azide consists of three nitrogen atoms bonded in a row. Those two end atoms find it extremely tempting to leave the constricted molecule and be free as stable nitrogen gas. It will not react further, but it will quickly and violently search for an exit through whatever barrier has it contained, i.e., explode. Even compounds with such a high ratio of azides to cations as titanium tetraazide have been synthesized. Proper safety protocol during the synthesis of polyazides calls for "goggles, blast shield, face shield, leather suit (!) and ear plugs." Cyanogen azide also makes the list, with only one poor carbon to keep tame all four other nitrogen, one can see why; the boiling point for CN<sub>4</sub> has not been recorded as of yet. Salts of CN<sub>7</sub> makes an appearance and Dr. Lowe vividly gives examples of just how easily anything anyone does anywhere in the lab will make them explode. Assuredly

this does not end his inquiry into precarious nitrogen containing molecules that he refuses to work with. Not all the nitrogen has to be in azides. Sometimes, all the nitrogen atoms are covalently bonded to one another. Situations such as this extend our list of compounds to run the complete opposite direction from. One such compound links eight nitrogen together; I do not know if they are going for the world record but I doubt there is too much competition in the field.

Computational chemistry allows the research and exploration of molecules that do not exist or, more importantly, should not. Dioxygen diflouride, or FOOF, resides in the field of molecules that one should only run on simulations rather than create in a lab. Besides blowing up at temperatures around -180° C, -300° F, it will also burn/explode anything and everything it falls on. Similarly, chlorine triflouride, charmingly described as "the most vigorous fluorinating agent known, and is much more difficult to handle than fluorine gas" along with "a stronger oxidizing agent than oxygen itself", makes the list of "chemicals that can set anything, no really anything, on fire". It shares the peculiar quality of being capable of burning wet sand with thermite and other self-containing oxidizing chemicals.

Other reagents mentioned include nickel carbonyl, pure liquid hydrogen cyanide, carbon diselenide, Magic Methyl, thioacetone, and dimethyl zinc. Overall the series provides an entertaining window into the life and reactions of some of the more adrenaline seeking research chemists. Dr. Lowe's commentary from the perspective of a bench chemist with a fair amount of experience working with volatile or corrosive materials gives a clear and humorous account, without ever losing respect for these dangerous chemicals. If you've ever found yourself complaining about your chemistry lab or job, then these articles might help you gain some perspective.

Sometimes work with dangerous or explosive reagents becomes a necessity. Out of the millions of chemicals synthesized every day for the industrialized world to keep turning, many come from toxic, flammable, or volatile starting materials or processes. Paints, fuels, and ammonium perchlorate come to mind as some examples. However where industry pursues profit and business; in academia there's not much, if any, financial gain to push the boundaries of mankind's knowledge of explosive organic compounds. Still, there'll always be at least one person interesting in risking it, for the sake of science. I'll be supporting Dr. Lowe from one town over, though.

-Nicholas DeLateur, Chemistry, 2014

# Understanding Neglected Diseases and the Pharmaceutical Industry

## An Interview with Dr. Michael Pollastri

**NU Science:** As a relatively new professor on campus, what attracted you to the field of medicinal chemistry?

Dr. Pollastri: I was trained as an organic chemist, and then I went to industry. I worked at Pfizer and did drug discovery for about 9 years. I got into the field because I was interested in finding applications for organic chemistry and I was always drawn to the interface between chemistry and biology. Also, I am interested in what we would call translational research, by that I mean getting a concept from an idea into something that is going to impact patient care. So I joined Pfizer as a medicinal chemist, I worked there for a few years as a master's level chemist. And then I also got my Ph.D. while at Brown, sort of like a co-op Ph.D. actually. My primary focus at the Pfizer site in Cambridge was what is called 'hit to lead' medicinal chemistry. This involved taking high-throughput screening results, very early stages, and getting to the point where the company would decide if they want us to continue working on the project or not. We call it "target validation" or "proof of concept". The drug industry is contracting pretty seriously right now for a number of reasons. There have been a lot of new drugs brought out that cannot support the infrastructure that the drug companies have built so they are laying off thousands of people. I left in 2007, sort of seeing that it was coming I decided that I wanted to A) start an academic career where I would have more control over my destiny and B) work on neglected diseases.

I look at it from a moral perspective, we're the richest nation in the world and the fact of the matter is that in the 25 years period from 1975-2000, there were 1400 or so new therapeutics brought to market. Out of those, only 13 were for neglected diseases. Clearly there is a gap where 90% of the health care dollar affects only 10% of the population, a huge disparity. So I said from a moral perspective, 'I want to apply my interests and skills to trying to improve the lives of people, in a small way.' Because drug

discovery is hard, right? You may never discover a drug but the point is at least you are working towards it. So when I left Pfizer, I went to Boston University and started a research program and a medicinal chemistry center for a couple of years. Then, I got funding from the NIH (National Institutes of Health) to work on a project with a collaborator to develop new drugs for sleeping sickness and ultimately came here to Northeastern on a tenure-track position.

**NU Science:** You mentioned sleeping sickness and neglected diseases, could you clarify the difference between a neglected disease and a rare one?



Dr. Pollastri: Neglected diseases comprise a collection of diseases for which the World Health Organization has said, 'we need new drugs, but there are no new drugs in the pipeline'. They are neglected because most of the biopharmaceutical work is done for the developed world and have primarily been focused on so called "blockbusters". These are drugs that you can sell to a lot of people who can pay a lot of money for them, things like diabetes, cancer, and erectile dysfunction.

Neglected diseases are those where there is no money to pay for anything, basically. You need to be able to provide medications for free or very low cost. There is no money directed for research for new drugs from the industry because there is no financial upside to this and they would lose a lot of money doing it. You put up billions of dollars on drug discovery and you can't sell anything. That

clearly is not a way to stay in business. It is not to judge the pharmaceutical industry certainly, they have their business model and they are responsible to their shareholders, and there is no financial driving force. However, there is a good amount of P.R. that can be obtained by drug companies supporting this kind of research in the external environment. For example, a drug company can sponsor us and not do the research themselves, instead sending bits of money or resources to people like us in the non-profit sector.

Neglected diseases affect only the poorest parts of the world. Including malaria, millions and millions of people are exposed to diseases with therapeutics that are just not great. To give you an idea, in African sleeping sickness you get bit by a tsetse fly and acquire flu-like symptoms and feel lousy for a couple of weeks. In sub-Saharan Africa, nobody goes to the doctor with flu-like symptoms because they must travel for miles and miles, often on foot, to get a doctor. The symptoms go away for a short period and life goes on. But some time later, the parasites (called Trypanosoma brucei) invade your nervous system and cause mental disturbances and sleepiness among other clues and then, if you are not treated, you die. It is bad, 100% fatal unless you are treated. During the bloodstream form of the disease, the first stage, you feel lousy and there are drugs available that can be taken but most people don't take them because they don't see the doctor. Most people come when they have the stage two symptoms. And there are two drugs that are currently used for this, one is called melarsoprol, it is an arsenic-based drug. You don't have to be a doctor to know that arsenic is a bad thing; in fact the drug itself kills 5% of patients. But you are talking about patients who are guaranteed to die, otherwise. This drug was discovered in the forties; it has to be taken multiple times a day intravenously and is incredibly painful for the patient to receive it because it's corrosive. Frequently patients will even beg to die instead of taking the drug. The other drug is called eflornithine, which was developed originally for cancer therapeutics, has toxicity problems and bioavailability problems also- so you have to give patients enormous doses over long periods of time in order to get therapeutic effect. And, again, the side effects for both of these are just awful. This is an example of what we have to deal with when it comes to neglected diseases, there is no research going into making better drugs; therefore we use what we have.

#### **NU Science: Is your goal basically to eliminate the gap, this use of 70-year-old technology?**

Dr. Pollastri: We know a lot about how to handle antibiotics, we have pretty reasonable methods for discovering drugs for cancer and these other things, and it turns out the problem is not that much harder for developing drugs against these parasites. You might have all the best research and technology in the world but if it is not focused on the problem, then the problem is never going to be solved. So we built a lab that recapitulates what I had at Pfizer in terms of technology and our approach to drug discovery. We are focused with the idea that we should be able to take what we know about human drug discovery and re-purpose it to what we can do for parasitic drug discovery.

#### **NU Science: Are you aware of any statistics for what percentages of those who are infected with sleeping sickness are actually receiving treatment? Or is it too difficult put a number on?**

Dr. Pollastri: You can go to the WHO website and look up the stats for these diseases, but those numbers are gross underestimates because the vast majority of people are never diagnosed. They don't have high-tech diagnostics, so the only way you can get diagnosed with stage two sleeping sickness is through a spinal tap. Just imagine being in a field hospital, in the middle of nowhere, somebody is sticking a needle into your spine to decide

whether you have sleeping sickness or not. Think of the opportunities for infection, it's just horrendous.

**NU Science: There is certainly a technological disparity between the development of drugs and treatment, but do you also feel there is a disparity between the raising awareness of these diseases and those at risk?**

Dr. Pollastri: There are a number of organizations that focus on raising awareness, not just to the general public, but also with a focus on public policy. This is because the money has to come from governments to do this research, and maybe drug companies. The WHO would be one and also Universities Allied for Essential Medicines, a student activist group with a very wide reach ranging from biomedical scientists to public policy students to medical students. Their primary focus is making medicines that are developed in universities available for the poorest in the world. They are also raising awareness for the importance of this kind of research. In fact, the Obama administration has basically stuck a flag on the hill about this and said that global health is a priority, and emphasized the importance of NIH funding for this kind of research.

#### **NU Science: What advice would you give to the Northeastern student wishing to make an impact on the lives of those in poverty through the use of medicinal chemistry?**

Dr. Pollastri: My advice is to excel in science. While you keep your mind on the target, which is 'down the road I want to work on this area', hyper focus on what you are doing at the time. So if you are thinking 'I want to work in drug discovery' but you do not nail Organic 1 and 2, you are just not going to get there. With Northeastern co-ops, if you are thinking of working in drug discovery you should seek a co-op in drug discovery. Go work for a drug company and see how it is done, learn how to do medicinal chemistry. Finding unique niches in any of these areas through co-op is a huge opportunity. To run one of these projects you typically need an advanced degree, so you need to expect to go to graduate school and do Ph.D. work. However, there are a lot of other needs besides just doing drug discovery. I get this question invariably from someone in the audience all the time when I give a talk on my drug discovery, 'So what? If you discover a drug, how are you going to get it to people? Who is going to do the clinical studies?' You have a compound but it doesn't become a drug until you get it to humans and show that it is safe and works well.. But who is going to do that? In addition, the drugs have to actually get to a sub-Saharan Africa: it's hot, and you can't have drugs that will decompose because of the heat. How are you going to store them? How are you going to transport them? How will you distribute them? There is a whole area in global health logistics that is in massive need. So that would be my advice, if you are a scientist, focus on doing good science. If you are not a scientist, but still want to work in this area, there is plenty to do on the policy side, the implementation side and so on. There is more work than we can possibly do now.

(To find out more visit the World Health Organization's website at WHO.int and the Universities allied for Essential Medicines website at essentialmedicines.org)

-Nolan Carr, Biology, 2015

# **Bioencryption with E. Coli**

## **Possibility for Massive Data Storage**

For most people, the idea of E. coli brings to mind food poisoning or unsanitary conditions. However, science may soon offer another mental association for the species. A team of researchers at the Chinese University of Hong Kong have created a process through which the noncoding segments of E. coli DNA can be used to store enormous amounts of computer data. Called bioencryption, it allows a single gram of bacteria to contain well over 900 terabytes, or 900,000 gigabytes. Most new computers today have hard drives with one or two terabytes of storage, containing somewhere between one and four gigabytes per gram. This means that, by weight, E. coli has 225,000 times the storage capacity of current hardware.

Bioencryption is the process through which data is encoded in the genetic material of a living organism. One of the most essential developments that made this incredible feat a reality is the format in which the data was encoded. Since their invention, the language of computers has been binary, in which data is represented in base two, that is, in zeros and ones. This system is used to represent either the presence or absence of electric current through a circuit. However, for all of binary's many benefits, files require significant amounts of space. In contrast, when working with E. coli, scientists were able to use each of the protein bases that make up DNA (adenine, cytosine, guanine, and thymine) to represent the data in base four. This allows zero, one, two, and three as potential values for a single bit, resulting in a stunningly large increase in storage capability.

The idea of one's valuable information encoded in the DNA of bacteria understandably raises a number of concerns. How much risk is the data exposed to when kept in a living organism? Can the E. coli present a health risk? How is the data organized and accessed when distributed across a bacterial culture? Fortunately, the researchers anticipated these issues and resolved them with creative solutions.

It turns out that bioencryption serves as an extremely reliable method of storing data. Bacteria are innately resilient organisms, able to survive many harsh circumstances. As the cells replicate themselves, they also back up all of the information stored on them. This both ensures data safety and allows the computer to access the desired data more quickly, due to the nature of the system's organization. The research team both engineered the bacteria to retain data correctly despite drastic changes in its environment and set locations to store information that would not have an adverse effect on the cells' health. In addition, this strain

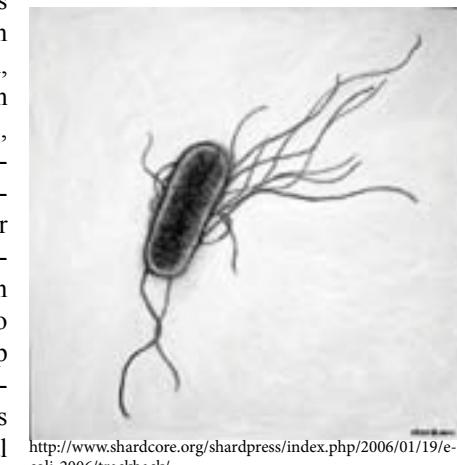
of E. coli does not pose a health risk to people, removing a potentially dangerous aspect of this new technology. Another major hurdle was the organization of files amongst different areas in the system. Small pieces of information may easily be encoded in one section of DNA. However, larger files must be broken up, as long sections of code can have adverse effects on cell health. This necessity results in fragments of code being scattered across various locations in the system. For this reason, all data is compressed before being specially encoded. Each piece of data is made up of three sections to ensure that the computer is able to retain the order of sequences. First is a header, a sequence of eight bases that make up an identifier similar to a memory address in traditional hard drives. This allows the computer to know what piece of data the packet contains. Next is the actual set of bases that represent the data. Last is the footer, marking the end of the fragment and containing tools to help interpret the information and recover data lost by minor mutations. This method allows fragments of code to be scattered throughout the bacteria and recovered intact, although the computer has to search for each packet of code as it needs it. However, as stated above, when the cells replicate, they also create duplicates of the data they contain, granting sections a better chance of being found quickly.

The unheard of storage capacity of E. coli is a significant breakthrough in and of itself. It is one of the first major developments in bioencryption since a 2001 team succeeded in encoding small files, first proving that bacterial DNA could contain a file. However, the

team from the Chinese University of Hong Kong succeeded in doing far more than creating an astronomically large system of data storage; they also sought to address the issue of data security from potential cyber threats. For this reason, all stored data is encrypted using a highly advanced system, making it extremely difficult to hack. The team states that one of their concerns is "the leakage of national confidential information," suggesting that bioencryption may one day be employed as a key element of countries' national defenses.

It is unlikely that you will own your own E. coli hard drive at any point in the near future. Large elements of the technology are still theoretical and no part of it is inexpensive. For the time being, the applications of bioencryption are most likely either experimental or governmental. However, such an incredible leap forward in data storage will inevitably have a noticeable impact on our lives as we move into the future.

-Michael Murray, Comp Sci/English, 2014



<http://www.shardcore.org/shardpress/index.php/2006/01/19/e-coli-2006/trackback/>

# Whats on Tap?

Hopefully none of the 90+ contaminants that the Environmental Protection Agency regulates in drinking water.

The water that you drink everyday is not pure H<sub>2</sub>O. Inside your glass, present in such minuscule amounts that you might even forget about them, are a variety of dissolved compounds, disinfectants, and even radionuclides. All sources of drinking water contain some naturally occurring contaminants. At low levels, these contaminants generally are not harmful in our drinking water. Removing all of the contaminants would be extremely expensive, and, in most cases, would not provide increased protection of public health. A few naturally occurring minerals may actually improve the taste of drinking water and might even have nutritional value at low levels. So what kinds of contaminants are regulated, and how are they kept to levels that can be considered safe?

Contaminants in drinking water can either be naturally occurring or they can originate as the result of human activities. Examples of natural contaminants include microorganisms such as cryptosporidium, a bacterium which can cause severe sickness, and heavy metals like arsenic, cadmium, chromium, lead, and selenium, which can cause severe circulatory system or kidney damage when consumed for a long period of time. The levels of nitrates and nitrites must also be carefully monitored, as in high levels they can be dangerous to infants.

Erosion of underground deposits of certain rocks can cause the radioactive elements radium and uranium to be present in drinking water. If consumed over a length of time, small concentrations of these elements can be absorbed into the body causing damage to the immune system and increasing the risk of cancer.

Water contamination through human activities can be caused agriculturally, residentially, and industrially. Storm runoff can absorb certain chemicals from herbicides, pesticides, and fertilizers, bringing them underground into the water supply. Seepage from landfills and septic systems can also contaminate ground water. Industrial chemical factories can be a large source of ground water contamination if they improperly discharge certain chemicals such as benzene, carbon tetrachloride, vinyl chloride, dichloromethane, dioxins and hundreds of other chemicals. One organic compound, methyl tert-butyl ether (MTBE) was commonly used as a gasoline additive until it became known how much it contaminated ground water supplies. Along with many of these chemicals, MTBE is believed to be a carcinogen and could possess other negative health effects.

Water suppliers use a combination of treatment processes to remove these contaminants from drinking water. The most

commonly used processes include coagulation, filtration, and disinfection. Water utilities select the treatment combination based on the specific contaminants present in that source water that they would like to remove. Coagulation causes large suspended particles such as dirt to form sediment, while filtration uses layers of charcoal, sand, and gravel to remove any remaining smaller particles. Some water systems also incorporate ion exchange and/or reverse osmosis, which are more advanced treatment techniques. Water is usually disinfected before it enters the distribution system to ensure that dangerous microbial contaminants are killed. Chlorine, chlorinates, or chlorine dioxides are most often used to accomplish this. Unfortunately, sometimes a disinfectant will react with a naturally occurring material in the water and produce an unintended byproduct which can be detrimental to a drinker's health. In addition to the disinfectants and microbes themselves, these byproducts, such as bromate, chlorite, and Trihalomethanes (THMs) like chloroform, must also be closely regulated by the EPA, as many of them are carcinogens.

Thinking about switching to bottled water? You may want to reconsider. Studies are showing that bottled water is not significantly cleaner than tap water, and may contain high levels of disinfectant byproducts. Unlike tap water, where consumers are provided with test results every year, the bottled water industry is not required to disclose the results of any contaminant testing that it conducts. Not to mention that bottled water costs an average of 1900 times more than tap water per gallon.

Because some contaminants are dangerous in smaller concentrations than others, the EPA sets an amount for each contaminant called a Maximum Contaminant Level (MCL), which is the highest level of a contaminant that is allowed to be present in drinking water. These are typically measured in milligrams per liters, which is equivalent to parts per million (ppm), or, for very potent compounds, in parts per billion (ppb). MCLs are enforced EPA standards (National Primary Drinking Water Regulations). Other contaminants that may simply cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects in water (such

as taste, odor, or color) are addressed by the EPA's National Secondary Drinking Water Regulations which are non-enforceable guidelines. Examples of items on that list include zinc, iron, pH, and manganese.

Testing is done regularly on water supplies to make sure that they are consistently meeting standards for all contaminants.

Recently, the EPA announced that it will begin to regulate perchlorate in drinking water on a national level. Perchlorate is a component in rocket fuel, flares, and fireworks. In most cases, perchlorate water contamination has been caused by improper disposal at rocket testing sites, military bases and chemical plants. The EPA says the chemical can disrupt the thyroid's ability to produce hormones that are vital to developing fetuses and infants, although studies are still being conducted to determine if the concentrations found in drinking water are high enough to cause that kind of damage. The EPA believes that between 5 and 17 million Americans in 26 states could have perchlorate in their water, with particularly high rates present in Texas and California.

The EPA's move reverses a judgment by the Bush administration, which decided not to regulate the chemical but instead recommended that concentration levels not exceed 15 parts

per billion.

The EPA says the regulation will take two years to enact and no specific MCL has been announced as of yet. Two states currently have perchlorate regulations, Massachusetts (at 2 ppb) and California (6 ppb), although there is a movement in California to reduce the limit to just 1 ppb, which is the equivalent of a half of a teaspoon in an Olympic-sized pool. The EPA also announced that they will be regulating, as a group, 16 cancer-causing chemicals known as volatile organic compounds, which are chemicals that include trichloroethylene (TCE) and tetrachloroethylene (PCE) as well as other industrial contaminants and solvents. In the past, chemicals have been regulated on an individual basis, but research is showing that many contaminants cause cumulative damage to the body, and the new approach is to address them as groups.

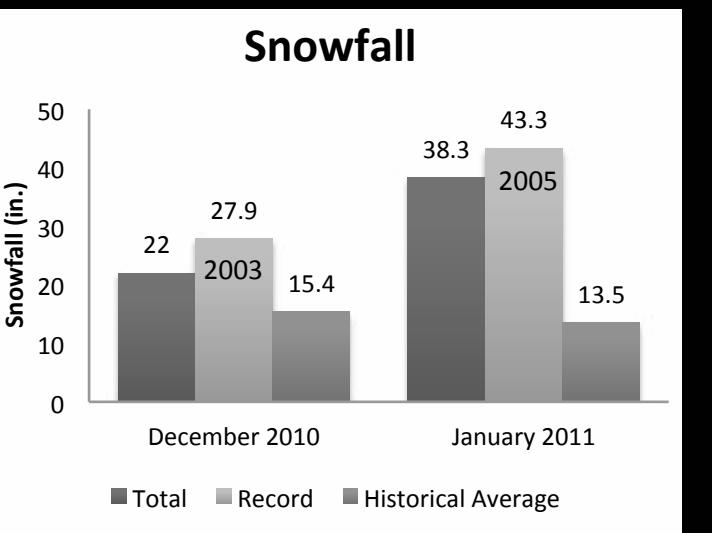
If you're curious about test results from your local water supply, you can check it out online at <http://www.ewg.org/tap-water/whats-in-yourwater>.

-John Jamieson, *Chemical Engineering*, 2015

## DIGGING OUT Taking a look back at the last winter that buried Boston

The 2010-2011 winter was certainly one that will not quickly fade from our memories. Although few students are charged with maintaining driveways and sidewalks, we all felt the squeeze of cancelled classes, ice patches, knee-deep slush puddles, delayed T's and cabin fever. Those of us unfortunate enough to have a car have had to undergo massive dig-outs, if not to actually drive, then to at least expose some part of the car so that plows know it's there.

As of mid-February, Boston has received 71.2 inches of snowfall since December 1st of 2010, nearly triple our average snowfall (up to this point) of around 26 inches. Although the snowfall may be staggering (3rd most in recorded history), the biggest problem is that it's not melting. Up until mid February,



there had been very few warm spells past the first blizzard in December.

What results is plows and locals merely piling snow on top of snow from storm after storm. The few spans of warm weather that occur merely melt the top layer, which then freezes overnight and serves to further insulate the snow underneath. All of this amounts to a volume nightmare. We can expect large parking lot snow piles, such as the ones in the Columbus lot, to last until April. The snow-farms in which Boston dumps the massive amounts of snow cleared from streets and public walks won't expect a full melt until mid-summer.

With the statistics below (data provided by the National Weather Service), it is clear what made this December and January different than ones in the past. The temperatures are on par with historical averages, only differing by 5 degrees or so. It's our snowfall that has burned the 2010-2011 winter into our memories. January snowfall (38.3 inches) was only 5 inches short of the record set in 2005 (43.3 inches) and nearly triples the historical average (13.5 inches).

A historical note, the worst winter Boston experienced in recent memory, and the benchmark for snowfall Armageddon, was the winter of 1995-1996. Leaders in the Boston Public Works sector had begun to compare 2010-2011 to that archetypical nightmare by mid-January. By the end of January, the '95-'96 season had produced 15 more inches of snow than we have now, with lower temperatures meaning even less melt. Let's just hope these statistical anomalies continue to occur only every decade or so, or we may be witness to yet another sign of drastic climate change here in New England.

-James Peerless, *Chemical Engineering*, 2011

# Interview with Dan Dongeun Huh, Ph.D.

Imagine the physiological capabilities of the human lung placed onto a silicon micro chip. This groundbreaking technology, developed at the Wyss Institute at Harvard, will revolutionize the future of the biomedical field. NU Science Magazine had the opportunity to visit the lab of Dan Dongeun Huh, a technology development fellow within the Institute and innovator behind the lung chip, to discuss the development of the technology, its current use, and future applications.

## Background on the Wyss Institute

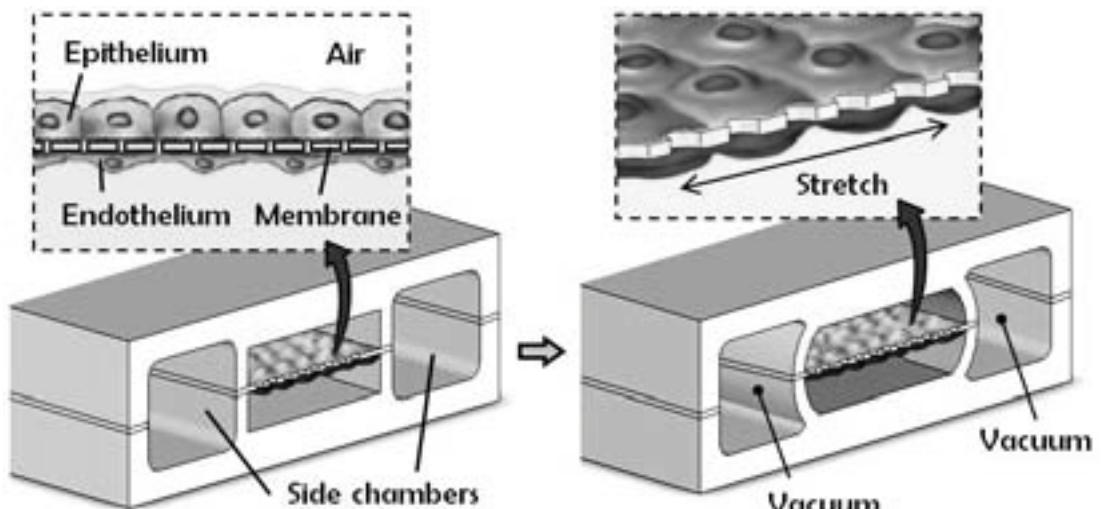
Huh explained that the Wyss Institute was founded almost 2 years ago, made possible through the donation of \$125 million dollars by a Swiss entrepreneur by the name of Hansjörg Wyss. Huh's advisor, Donald E. Ingber, played an integral role in obtaining this funding and founding this facility. The Institute is broken down into 6 "Enabling Technology Platforms", including Anticipatory Medical Devices, Bioinspired Robotics, Biomaterials Evolution, Programmable Nanomaterials, Adaptive Architecture, and the platform under which the lung chip was developed, the Biomimetic Microsystems (<http://wyss.harvard.edu>).

Huh elaborated further on the Biomimetic Microsystems platform, "Here we develop 'organ on a chip' micro engineering systems to mimic the functionality of living human organs; the lung on a chip is an example of the type of work we are doing here. The idea is to utilize the micro and nano-technology initially developed for the computer chip industry and adopt it to develop biomedical devices."

Within the platform there is a combination of specialists working together with an interdisciplinary approach to develop the technology, including engineers, biochemists, molecular biologists and clinicians. Huh referred to the arrangement of specialists working together as, "colaboratories", explaining that researchers from 4-5 laboratories will work together within the Biomimetic Microsystems platform in a common space. In the case of Huh's lung on a chip, he worked with a clinician from Children's Hospital, Benjamin Matthews, who works within the pediatric intensive unit and is interested in lung injury. Huh stated that through the use of Benjamin Matthews' animal model, "We are able to confirm that what we saw in our in-vitro model system actually happens in the body, using his animal models, which was crucial for enhancing the impact of our work."

## Q. How does the chip work?

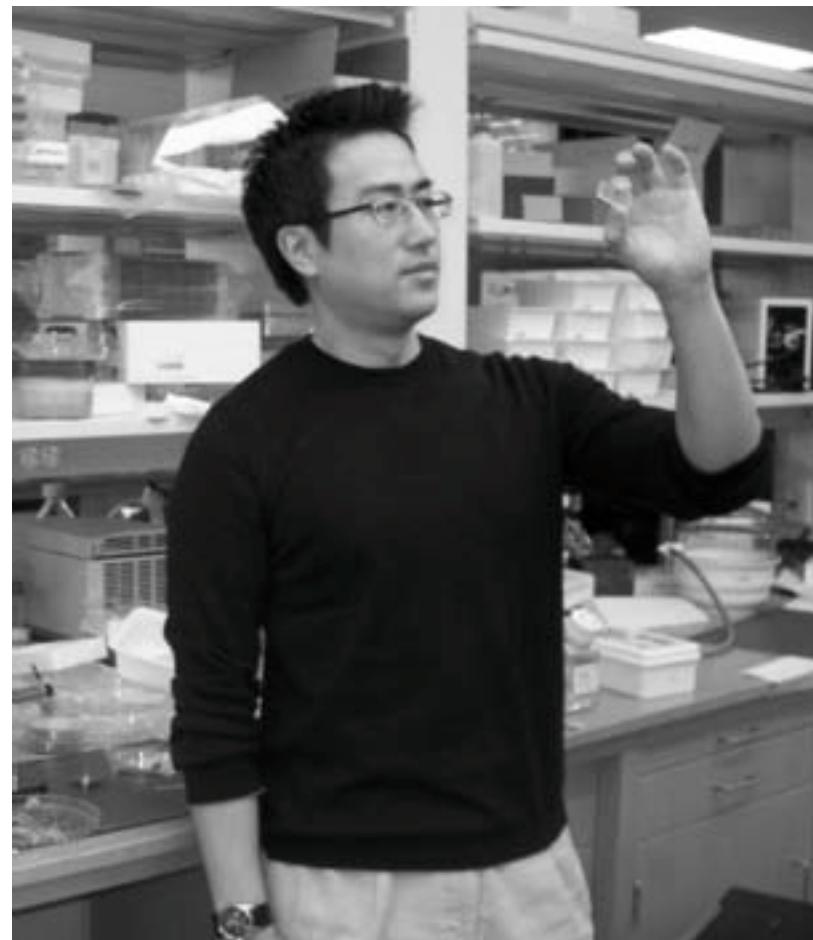
A. In the lung, the most critical functional unit is the alveoli; these are microscopic elastic air sacs. When you breathe in and out, these air sacs expand and contract, that's how you breathe. The key functionality of these units is gas exchange. To do this, the alveolar air sacs are covered with pulmonary capillaries. If you examine the area between the capillaries and the air sacs, you see three distinct layers. On the lung side, there is a thin layer of alveolar epithelial cells, then a thin interstitial layer called basement membrane, and then on the blood-side is a layer of capillary endothelial cells that line the inner wall of the blood vessel. What we were trying to do was to mimic this three-layer structure. We did this by growing these cells in a small micro fluidic device. In the device, we have two chambers separated by the thin porous flexible membrane, fabricated using microchip technology. On one side of this porous membrane, we cultured lung epithelial cells. On the other side we cultured capillary cells to mimic the original structure of the alveoli. The alveoli mechanically move and stretch, to imitate this we have two chambers right next to the cell culture chambers. The material is transparent and elastic like rubber. We apply a vacuum to the side chambers, enabling the stretching of the membrane, thereby stretching the cells sitting on the membrane. By doing this in a cyclic manner, we can imitate breathing motion. We call this a bio-inspired system because the way we induce the cell-stretching mimics what happens in the body when you breathe in and out.



## Q. How was this technology first developed?

A. I worked with Don Ingber, the founding director of the Wyss Institute; I joined as a post-doctoral fellow. I was challenged to develop a system where we could look at the toxicity of different nanomaterials on mammalian cells. We proposed to look at the toxicity of lung cells in particular. I thought about making this alveolar system. We tested the toxicity of the responses of lung cells to different types of nanomaterials that might be used in an industrial or research setting. We further improved the system to mimic the interface between air and blood. By having this blood vessel side, we could also look at inflammation in the lung.

Diagram: Huh, Donegun. "Reconstituting Organ-Level Lung Functions on a Chip."



## Q: What applications does this technology have/will it have in the future?

A: Potentially, this technology could be used to develop the next generation drug testing platform. Currently, people use animal models. But animal studies are expensive, time-consuming and often not predictive of human anatomy and physiology. Other conventional methods include the use of static culture models to look at the toxicity of drugs in preclinical studies. These days, when a pharmaceutical industry comes up with a drug they want to test, and they want to know if the drug is going to fail, they want it to fail cheaply and rapidly. They want a good in vitro model that can predict the response to these drug compounds in a reliable and timely manner. After the publication of the paper based on our findings, we got a lot of inquiries from biopharmaceutical companies about opportunities to collaborate. At this point we are trying to establish disease models, building upon this technology, and use these models for drug testing applications. Imagine developing a model of asthma, the physiological characteristics associated with the disease, and once we have the model, using it for testing asthma drugs that are already on the market and for drugs in development. We can look at the efficacy as well as the safety of these drugs.

We were recently awarded a grant from the NIH FDA; we proposed to develop a micro heart-lung machine. The idea is to link our lung on a chip system with a heart on a chip system developed by Keven Kit Parker's group at Harvard. The heart on a chip technology enables quantitative measurements of heart contractility. This is important within drug development because heart toxicity is examined by the contractility of heart muscle cells. The idea is to integrate the heart on a chip system with the lung on a chip system, to serially connect these two systems. We are going to use this integrated system to look at heart toxicity of lung drugs and lung toxicity of heart drugs. There is evidence that some of the asthma drugs might exert significant toxic effects on heart cells, which conventional drug testing methods would not pick up. This new technology allows an examination of multiple organ systems.

We could also use the disease models to better understand how these lung diseases develop and progress. The beauty of this system is that the materials are transparent; you can do real-time imaging at high resolution, and see what's happening inside the channel in the cell. We also can apply different types of chemical and mechanical cues to more precisely mimic the *in vivo* microenvironment of the body. It has implications in studying fundamental processes in various diseases.

## For further information regarding this technology and Dan Dongeun Huh's research:

Huh, Dongeun. "Reconstituting Organ-Level Lung Functions on a Chip." *Science* 328 (2010): 1662-668. [Sciencemag.org](http://www.sciencemag.org/content/328/5986/1662.full). 25 June 2010. Web. 16 Feb. 2011. <<http://www.sciencemag.org/content/328/5986/1662.full>>.

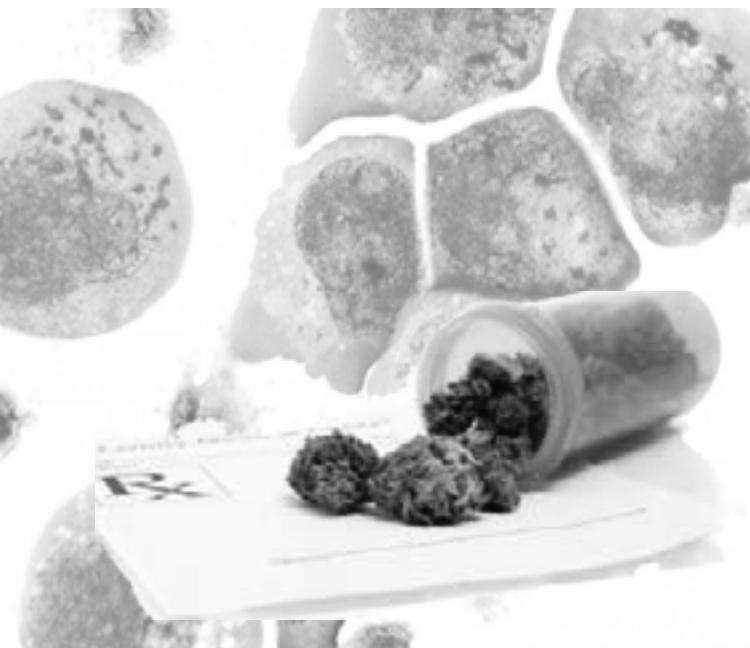
-Elizabeth Gilbert, Health Science and International Affairs, 2013

# Giving Cancer Cells the Munchies

Debate over the medicinal uses of marijuana and its active compounds has been growing in this country over the past few decades, although marijuana has been used as an herbal treatment for centuries. Use of the marijuana plant for its practical and medicinal use dates as far back as the stone age in China, as archaeologists have unearthed fabrics made of hemp and a medical text, Pen Tsa'os, which lists marijuana as a potent medicine. First, the drug was used in ceremonies as a form of magic, but as its potency as a treatment for ailments such as rheumatism, gout, and menstrual pains were discovered, marijuana was elevated from magic to medicine.

Back in our current era, a similar revolution is underway. Marijuana, best known for its magical properties to make any Phish song or ordinary snack seem like a mystical experience, has revealed another amazing property currently under investigation. This breakthrough in understanding was an international effort by research laboratories in Spain, France, Italy, and the Cancer Genetics Program run in part by Beth Israel Deaconess Cancer Center in conjunction with Harvard Medical School. Conclusions were published in the Journal of Clinical Investigation May 1st, 2009 and state the main psychoactive ingredient, delta9-tetrahydrocannabinol (THC), has been shown to induce autophagy in cancer cells. Autophagy is the process of a cell ‘munching’ on its own organelles and cell components which eventually kills the cancer cell. Many studies have recently reported the cancer fighting properties of cannabinoids, but this was the first to give direct evidence of THC-mediated cell death in glioma brain tumors, one of the most difficult cancers to treat.

While this study highlighted the use of THC to treat brain tumors



in mice and in tissue samples, a final experiment was conducted with two human patients who received intracranial injections of THC to treat recurring glioblastoma multiforme, the most common, malignant, aggressive, and infiltrative primary brain cancer. Patients showed increased cancer cell death and reported no adverse side effects. While this is a small sample group, the results agree with the mouse and primary cell culture results and offer hope to cancer researchers experimenting with cannabinoids as treatments.

Marijuana's effectiveness is due in part to the following mechanism: THC and cannabidiol (CBD) act on cannabinoid receptors throughout the body like natural endocannabinoids. This cannabinoid pathway activated by CBD has been shown to suppress vascular endothelial growth factor (VEGF) in cancers such as gliomas, breast cancers, and lung cancers. VEGF is the main signal for angiogenesis, the formation of new blood vessels. This factor vital for tumor growth and survival since tumor cells will die off when they are not connected to a steady flow of blood and nutrients. As a result, drugs may be developed to mimic CBD which will disrupt VEGF in cancerous cells. These drugs may be potentially effective against a wide array of cancer types, even if they are resistant against chemotherapy agents.

Whether marijuana should be legal or not is a matter for the politicians. However, as far as the scientific community is concerned, there is mounting evidence that the active ingredients THC and CBD hold therapeutic benefits. If the mysteries that have surrounded this plant are to ever be unraveled, research must continue unabated. Perhaps one day all we can agree on the medicinal benefits of marijuana as we use its components as potent weapons in the war against cancer.

-Alex Sweeney, Biochemistry, 2011

**"PATIENTS SHOWED INCREASED CANCER CELL DEATH AND REPORTED NO ADVERSE SIDE EFFECTS."**

# Robert Burns Woodward

## Chemist, Professor, Nobel Prize Winner



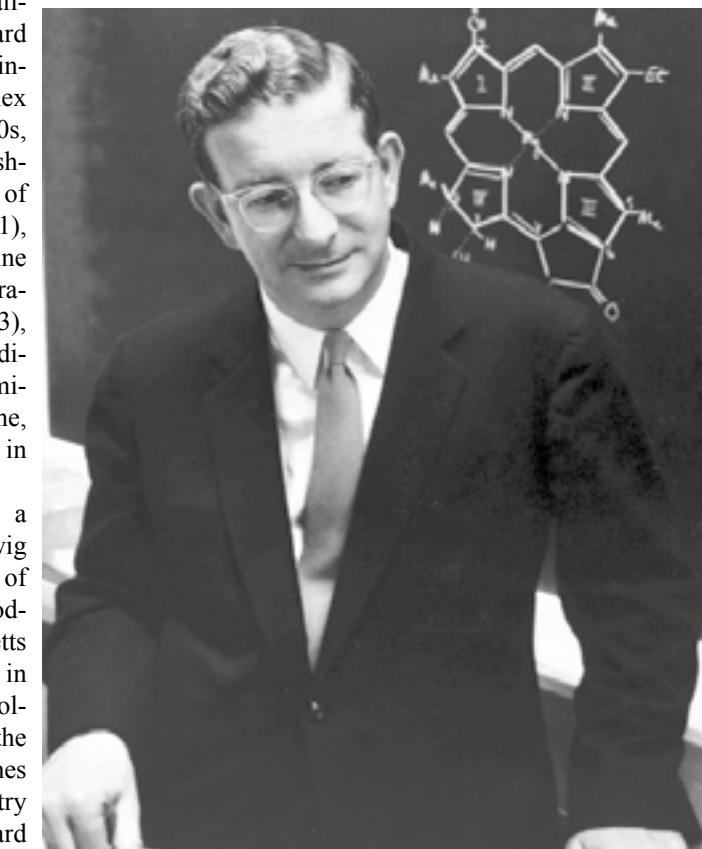
Organic chemistry has a nearly 200-year history stemming back to Frederich Wohler's synthesis of urane in 1828. The field remained somewhat stagnant until the twentieth century, when a sudden rapid increase in the synthesis of organic compounds caused the study of organic chemistry to blossom. Robert Burns Woodward, a Nobel Prize winning American chemist, ushered in the appropriately named “Woodwardian Era” in 1937, a time that total synthesis of organic compounds was used to prove their structure. Total synthesis is a method of creating an organic compound in a laboratory, starting from the smallest possible components. Woodward mastered this process, determining the structure of many complex molecules throughout the 1940s, 50s, and 60s. His major accomplishments include the total synthesis of cholesterol and cortisone (1951), terpene lanosterol (1954), reserpine (1956), chlorophyll (1960), tetracycline (1962), colchicine (1963), and cephalosporin C (1965). In addition, he helped determine the chemical structures of penicillin, quinine, strychnine, and various antibiotics in the 1940s and 50s.

Woodward, arguably a boy genius, had purchased Ludwig Gatterman's Practical Methods of Organic Chemistry at age 14. Woodward started at the Massachusetts Institute of Technology (MIT) in 1933. Nearly dropping out the following year, he started again in the fall of 1935 upon the urging of James Flack Norris, an organic chemistry professor at the school. Woodward graduated from MIT in 1936 with a bachelor of science, and then in 1937 with a doctorate in philosophy. He taught at Harvard University as a professor, retaining an association with the university for about 40 years until his death in 1979. He cultivated a lifelong affair with organic chemistry that made his field grow by leaps and bounds.

In 1965, Woodward won the Nobel Prize for chemistry. His greatest achievement, however, came in 1971, with the synthesis of vitamin B12. Albert Eschenmoser, a friendly professional rival of Woodward's, collaborated with him in the vitamin B12 synthesis. The two finished the synthesis after a series of 100 chemical reactions. Woodward also developed the then most forward-thinking theoretical system in the field of organic chemistry, what became known as the “Woodward-Hoffman” rules of orbital symmetry. Woodward's method of experimentation was just as forward-thinking as his discoveries. He insisted on using the most advanced

technologies to assist his experimentation. Instrumentation he helped popularize included the infrared, ultraviolet, and NMR spectrometry technologies.

What marked Woodward as a particularly fascinating person was not his contributions to chemistry, but rather his presentation of himself. Steeped in media coverage and idolized by his students, Woodward has been called an “artist” in modern science journals. In the speech announcing his attainment of the Nobel Prize, he was called a master of total synthesis second only to nature itself: “It is sometimes said that organic synthesis is at the same time an exact science and a fine art. Here Nature is the uncontested master, but I dare say that the prize-winner of this year, Professor Woodward, is a good second.”



Woodward's lectures as a professor were notoriously long, commonly lasting three to four hours. His trademark ability came in being able to come up with a solution to a problem after a careful analysis of all facts possibly available to him. His influence pronounced itself on many of his students. A few even ended up earning the Nobel Prize in chemistry themselves, namely Geoffrey Wilkinson, in 1973, and Roald Hoffman, in 1981.

During the Woodwardian era, an organic compound not yet synthesized merited attempts to synthesize it, in order to determine and understand its

structure. Yet, as time passed and the world of organic chemistry emerged from the Woodwardian era, total synthesis became a tool for experimentation and discovery. Because there were other developing methods to determine the structure of a compound, total synthesis could be used to test new chemical reactions and strategies. What had once started as Woodward's tool for discovery of a compound's structure had transformed into a tool for experimentation in uncharted waters. Even after his passing in 1979, Woodward led the way for chemical discovery, inspiring chemists to try new and unknown things with a method he perfected.

-Jessica Melanson, Journalism, 2014

# Interview with an E Ink Co-op Student

## Color Your World

Andrew Barlow is a sophomore chemical engineering major here at NU. For his first co-op, he has been working at E Ink, a company that produces ink in displays for products such as the Kindle and other e-readers. Barlow met with NU Science in February for an interview.

### Can you briefly explain what E Ink does?

They make the display technology in the Kindle, Sony and Nook e-readers. So their product is also called E Ink. It's just charged ink displays, which differ in several ways from LCD displays.

### What project are you currently working on?

Currently we're working on different ways to charge some of the inks that are more difficult to charge. We're looking at different kinds of pigment to put in the displays, looking at different colors and kind of figuring out how to charge the colors that have been proved more difficult to charge in the past. That's how the displays work. You have to charge the ink.

### How does that work?

It's actual ink. Some of the ink I've worked with is just regular Ink Jet printer ink. So we'll get ink dispersions from companies that make that kind of ink, and we'll then apply our proprietary polymers and such to the ink so that we can control them with an electric field. That's kind of how E Ink sells itself. Instead of an LCD display, which is just light, the ink is actually there. It would be no different than if it was printed on a page. It's the same kind of ink, so it looks more like it's a written word.

### What's your favorite part about working at E Ink?

I think it's a really relevant company. That's always cool. That doesn't necessarily affect my work, but it's just cool to be able to go there and say, "We make this physical thing that people are talking about now," and not something that nobody's ever heard of. I really like the environment that I'm in. It's a very young company. It's not very small, but it's still a pretty small company. They buy us lunch every other week, the entire company, and everyone sits in the cafeteria. I went to their company holiday party and looked around for the intern table, and I kind of realized everyone here could be an intern. Everyone looks so young. Most of the people I work with are under 30. The environment's definitely my favorite part of it.

### Would you recommend this co-op to other future co-op students?

I would. I've thought a lot about what I do here and how fulfilling it is to me. I think you have to come into a co-op with reasonable

expectations, especially a chemistry type co-op, that as a sophomore, you're not going to be making high-level chemistry decisions, but you will be working with people who are making them.

The reason I would recommend it is because they're explaining it to you. They're pretty much teaching you the chemistry that goes on that you're doing. It can be a little tedious at times because you're adding things to beakers six, seven times, and then doing it over again in the afternoon; but I like it because even though I'm doing that and that sometimes can get tedious, the people that I'm doing it for will explain to me why we're doing this and the chemistry behind it and what the expected results are, and if it doesn't work, what the next step is. They don't just put you in the dark and tell you to go do something. They explain to you why you're doing it and what they're expecting to see.

### How has this co-op helped you shape your career or academic goals?

It's made me think more about whether I want to be a total chemist or work somewhere else that's related to chemical engineering and not directly just chemistry, because a lot of the people I work with are just chemists. They don't have engineering degrees. They have chemistry degrees. It's made me think more that, although I like the chemistry, that I don't want to do something that's 100 percent chemistry. I want to do something that's chemistry and maybe something else. Batteries come to mind because that's what I'm very interested in. It's like chemistry and electronics together, so it's made me realize that I'm more interested in combining fields.

### Do you think you'll change fields for your next co-op? Where do you want to work post-graduation?

I think it's definitely made me realize that I want to work at a company that's more interdisciplinary, and it's also made me realize that after graduation, if I were to go to grad school or were to work, I'd probably want to work somewhere more toward the electrical field, but still chemistry, so kind of like the overlap that lies between chemistry and electrical engineering. So I've definitely started thinking about co-ops there. My next one, I really hope to work at a battery company.



### Do you own a Kindle? Do you think the display of a Kindle is better than what you would get on a computer screen?

I do not own a Kindle. They said specifically in the interview, "No free Kindles," which I thought was kind of funny. I see them a lot on the subway going home, so I kind of look over people's shoulders because I feel like I have a right to do that – I worked on it all day, so I can look at it. I think it is really cool because it's just like a printed word in a book, so the light doesn't hurt your

## Watson: The Next Big Leap for A.I.

Ken Jennings and Brad Rutter were the uncontested champions of Jeopardy!. They were untouchable. Their intellect, their strategy, their reflexes- they seemed to play like perfectly designed machines. That is, of course, until Watson came to play.

Designed by the research team at IBM's Watson Research Center, Watson's big achievement was not simply defeating the poster children of Jeopardy! (after all, it had 16 terabytes of RAM and 2880 processor cores at its disposal), but developing a new way to parse questions and search for answers. All questions in the game were presented exactly as they were phrased to the contestants (with the exception of being delivered by text file). This means that even the cryptic clues and puns that can be found on the Jeopardy! board could be deciphered by the software. More astonishing is the degree of confidence with which Watson can answer. Though there were a few flubs, Watson was overwhelmingly accurate.

While fun to watch, the field of beating humans at game shows is not a terribly lucrative one. It is, therefore, more interest-

ing to see where Watson's technology may appear in the future. Already, IBM is looking to extend into medical diagnostics, speech recognition software, financing, and even customer service. IBM hopes to revolutionize the way computers and humans interact. Perhaps this technology will be the first big stepping stone to more seamless integration.

-Kyle Deerweester, Behavioral Neuroscience 2013





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