NUScience

Northeastern University's First Science Magazine

Issue 6

Co-op

Meghan Cahill's experience abroad in Costa Rica

Wondering How LIFE *really* BEGAN?

Music Heals!

Life in the DARKNESS

How Hydrothermal Vents Create Complex Biological Communities Absent from Sunlight

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E-Board Quotes

What is your favorite extremophile?

Metal-extremophile: known to live in the amps of only the most heavy of the metal legends. Thought to originate in the amp of Dimebag Darrell, and were the only creature able to withstand his insane riffs.

Is it even a contest? The Waterbear. It's practically a DC superhero. If it was fifty feet tall it would have a legitimate shot against Superman.

I would have to say *Xerophile*. We may soon have to learn to implement how they thrive with hardly any water!

The GFAJ-1 strain of the Gammaproteobacteria family, the first known extremophile to thrive in an arsenic-based environment, which is something scientists always thought impossible. It's the little extremophile that could!

Denocooccus radiodurans. It is the worlds toughest bacterium in The Guinness Book of World Records. It can survive, extreme cold, dehydration, a vacuum, acid and high levels of radiation. I wish I could do that.

My favorite would have to be the Antarctic krill. They live beneath sheets of ice, in water around -30 °F. They're bioluminescent and create swarms as dense as 10,000 - 30,000 krill in a single cubic meter.

My favorite would have to be hypoliths, they live in deserts, beneath rocks.

Deinococcus radiodurans. Vaccuums? Loves them. Acids? Eats them for breakfast. Ionizing radiation? Please. Give it a challenge, like digesting heavy metals. Oh wait, it can do that too.

Mine is a halophile!!!

My favorite is an osmophile. We share the same NEED for sugar :)

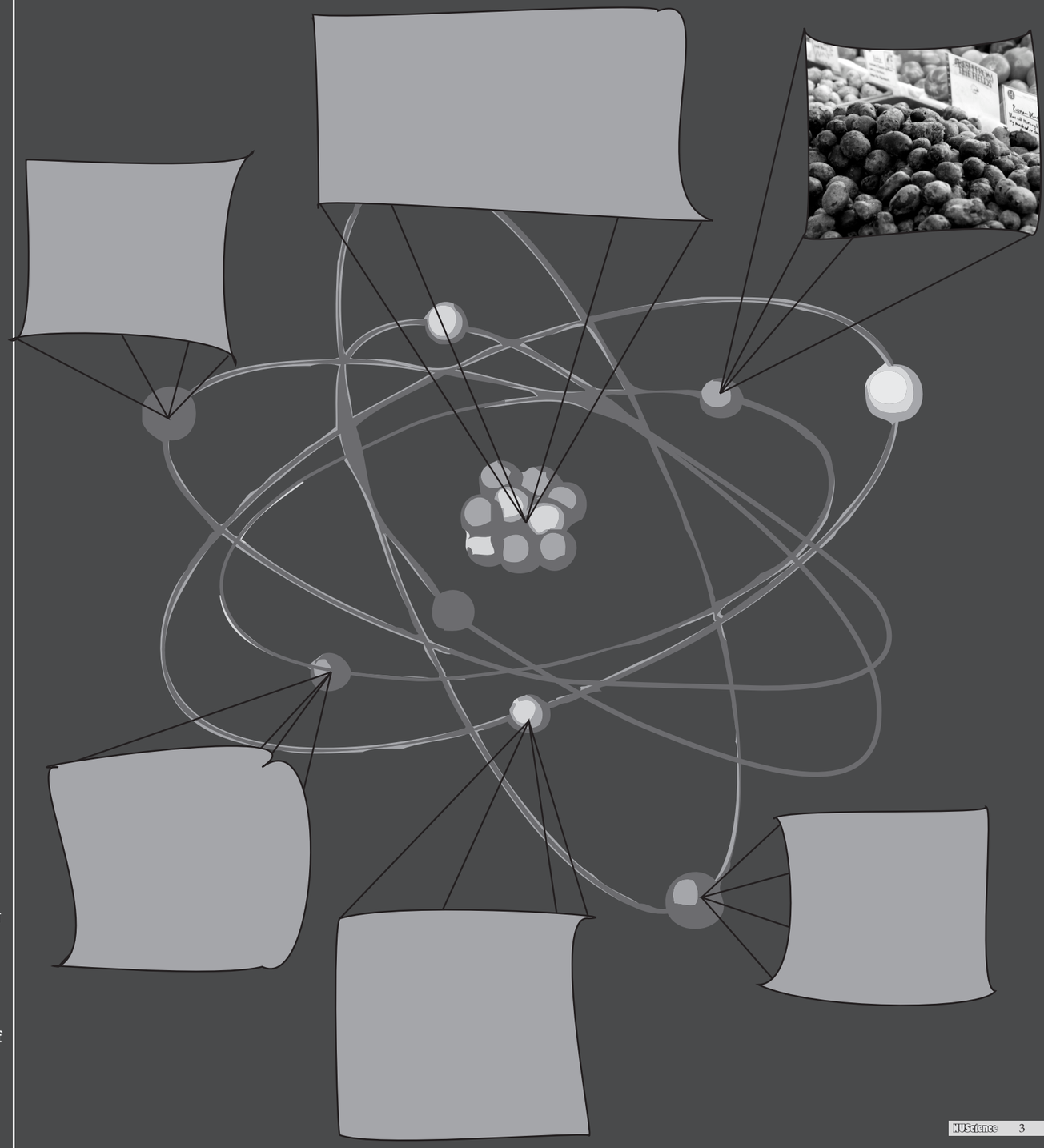
Letter from the Editor

Hello Readers!

Hope you're all hunkered down and surviving the cruel Boston winter, ready for that home stretch with spring just around the corner. Here at NU Sci, we've battled fall finals, coordination over winter break, snow cancellations and long distance relationships to bring you our fifth issue. In light of our challenges, we've focused this issue on the most resilient life-forms discovered by man. These extremophiles are sure to make any gripes over cold or snow seem trifling at most. Thanks to the stellar (as usual) of all our writers and our much more robust design team, we hope that this issue continues our upward trajectory of bringing you the best science magazine we can. With the worst of the winter past us, I hope you all stay warm, and stay curious.

Thank you, and enjoy,
James Peerless

Inside This Issue:



The Newly Established College of Science's Dean Demonstrates Interest in Pursuing Innovative Technologies as well as a Commitment to Experiential Education

NU Science had the opportunity to sit down with Dr. J. Murray Gibson, the Dean of the newly founded College of Science, to discuss what the recent division of the College of Arts and Sciences will mean for NU students and to learn more about the establishing dean himself.

Can you tell us about your educational background?

I grew up in Scotland, in the UK. My first degree is in Physics, from the University of Aberdeen. It is actually in Natural Philosophy, that's what they called Physics in the old days. I graduated in 1975 and moved to University of Cambridge to complete a PhD in Physics. My research, which I started as a PhD student, is in the area known as condensed matter physics or materials physics. I use electron microscopes to look at the structure of materials and understand how that relates to their functions and properties.

Would you describe your research and career positions in the scientific field?

I graduated in 1978, and I came to the US. I was motivated to come to New York because I had been there as a student and thought it was the greatest place on earth. I was very lucky and found a great job as a post-doc at IBM Research. That got me into the world of semi-conductors. They were doing basic science underlying silicon technology. Then I got a job in Bell Laboratories in 1980. It was a great place to work. I was there for eleven years. Their approach was to give you half a million dollars and a lab and tell you to go in and do whatever you want. If you were successful after five years you got more. And it was very inter-disciplinary; I interacted with many different people. It was an incredibly productive place; many Nobel prizes were given to those that worked there and key technologies were invented. It was an environment that was supportive for scientists to do work to benefit the entire country instead of just the company itself. Then in 1991, I moved to the University of Illinois as a professor of Physics and Material Sciences and Engineering.

What motivated you to make the switch from researching in the field to academia/education?

It actually wasn't such a switch. And this comes back to my philosophy about the College of Science. Research and education are so intimately linked. In my opinion, you can't teach science if you don't do science. And doing science is research. There has to be a strong connection between the two. I was attracted to teaching because there is a limit to what you can do as a scientist on your own. It's wonderful to work with young people, bringing in undergraduate and graduate students, getting to interact with them. I have always enjoyed teaching. And I was able to expand my research at Illinois in how to control the structure of materials on the nano-scale. I was professor there for about seven years before I moved on to Argonne National Laboratory, a government research lab funded by the Department of Energy in Chicago.

I was initially the director of the Materials Science division, and then I became the director of a major national user facility called the Advanced Photon Source for about nine years until I came here. It was similar to this environment running a college at NU in that we operated a stand-alone facility within a large lab. We were funded directly by the government so I had to ensure we would have the necessary monetary resources and make sure they were spent strategically. That is the model that Northeastern University has chosen to move to with Deans. It allows autonomy - if you have a beneficial idea, you have the resources and authority to accomplish it. It is a good system that creates an environment where you can facilitate new directions. I was attracted to this opportunity at NU because this type of model is new for the university. It came from the desire to help the university go to the next level, to empower the deans. Breaking up the College of Arts and Sciences allows individual deans to be more knowledgeable about what's going on. When you look at journalism and political science, they are very important, but they are so different from say, physics, in terms of how they work and use resources. That doesn't mean you put boundaries between science and political science that are difficult to cross. In our model, the deans are entrepreneurs. They see the value in working together. They can talk to each other. Two deans can operate together, seeing the value in each other's expertise. This change in model had to occur in order to liberate us to go further.

What was the reasoning behind your decision to come to NU?

Northeastern is different; it is unique because it is, in fact, the best of its kind. But we have places that we can improve. We have places to go, and we have to figure that out together. I am interested in change. It is a fascinating opportunity to make a difference. There is a significant amount of hiring right now. Within the College of Science, there is a tremendous opportunity to influence in what areas of science to hire new faculty.

I chose this position because I love the people side of science, interacting with the faculty and the students. The university has fantastic experiential learning and research opportunities within the university and outside with co-op. We need to expand that in the sense that we need to provide new faculty who will bring research in new areas that will be important in the future. Just to randomly expand research doesn't make sense. That is the part I find so interesting- working with the faculty to find areas (to expand) strategically.

How will the recent division of the College of Arts and Sciences into three different colleges impact the students that now belong under the new College of Science in terms of academics, co-op and research opportunities?

Ultimately we are all pursuing the best in faculty and students, but that shows in different ways in different disciplines. In the science research lab I worked at previously, it was very large and it was a great place with quite a few students. But it did not have areas beyond science; there was no political science or economics. I think that many of the really important problems require teaming of these areas. For example, one issue that excites me is urban sustainability. Science and engineering are critical tools to solving the energy crisis. But understanding and predicting what will happen requires social and political understanding and economics of course. Those things have to be tied together, which they haven't been previously. The right solution will actually involve discussion between these different groups. The College of Science pertains to science, but at the university the deans work closely together so it's an opportunity to interact and discuss. It is one of the key things that first attracted me to come back to academia.

Northeastern has a strong emphasis on experiential learning, as demonstrated through our co-op program. What is your perspective on co-op, and how do you hope to see it evolve and/or progress in the coming years?

Soon after I was contacted about a job at Northeastern I ran down to the bookstore to check out the college guide and discovered that Northeastern was one of the top 50 schools to go to- why? Experiential education, co-op. There are two things about the co-op that I think are critically important. One is that students come, and go back and hopefully they work to make their education interact better with the co-op experience. That is something that we can do better perhaps. The second part I knew as someone who has had students in the lab in industry - if you have a student who comes for a period of time, say three months, it's just not long enough to really engage with a student. If a student comes more than once for six months, the student gets a real exposure to the world, and gets engaged in the world outside the university that otherwise just doesn't happen. That's a unique aspect of the co-op that we have that we can perhaps build on in the future.

What do you particularly enjoy within the Undergraduate Science community in terms of students, faculty and undergraduate research?

I think this is a very exciting place to be. The combination of the extent to which students are involved (in co-op), and the high research profile- those things don't come together anywhere else. We should be capitalizing on this strength and making it better. It's great to work with young people because they are the future. The whole thing is a partnership, it is important to get the undergraduates involved in working with us, planning with us. I see the students as playing an integral role in my success, hopefully having a good dialogue with them. I started a council of undergraduate students. My idea is to have an opportunity for the students to raise issues and for me to bounce ideas off of them, to get their perspective. It's meant to be an informal channel to communicate better with the students. It's the feeling that we are all on a journey together.

What changes do you hope to see made within the College?

There is nothing broken, there is just a tremendous opportunity. I just see the excitement in deciding among the options of how we invest. We have the commitment of the university to invest resources, we have the luxury and challenge of deciding where we make those investments, and my job is to lead that process. I enjoy it; it's exciting.

-Elizabeth Gilbert, Health Science and International Affairs, 2013

Thriving Drunk

How caffeine makes alcohol even more dangerous

Alcoholic energy drinks are a hot topic across the country. In November, the FDA sent a warning letter to four companies that produced the beverages, and all agreed to remove caffeine from the ingredients list.

So why is the combination so dangerous?

As most Americans learned in middle school DARE classes, alcohol is a central nervous system depressant. It effects several neurotransmitter pathways, leading to several stages of drunkenness, from euphoria and generally reduced inhibitions to coma and death, depending on how much alcohol is consumed and how quickly it is absorbed.

Caffeine is a stimulant that works by blocking adenosine receptors. Adenosine builds in the brain over the course of a day, making you tired. When caffeine prevents that adenosine from signaling the brain to take a nap, the brain continues to function alertly.

Because they affect separate pathways in the brain, caffeine and alcohol don't cancel each other out. Instead, the drinker still loses inhibitions and motor skills, but they don't feel tired. This leads people to think they're less drunk than they really are, and so drinkers are more likely to keep drinking (and make poor decisions, like driving drunk).

The other danger of alcoholic energy drinks – one not present in other caffeine and alcohol combinations, such as Red Bull and vodkas – is how they are packaged. The large cans, which often contain the caffeine of several cups of coffee and the alcohol of four drinks, are packaged to be drunk in one sitting.

Four Loko and Joose are both being rereleased without caffeine. Irish coffees and Jägerbombs are still available at bars, though hopefully the widespread publicity about the dangers of the caffeine/alcohol combination kindle new respect for it.

-Cat Ferguson, Behavioral Neuroscience 2013

The Current State of Government Science Funding

Science is typically a top priority in governmental funding. The necessity for research and development is evident in many aspects of our future society. In the past, both the Republican and Democratic parties have supported the push for science funding. In 2009, amidst the economic decline, the American Recovery and Reinvestment act provided science research with $31 billion. Additionally, on February 1st of 2010, President Obama supported research and development with $66 billion in his first federal budget proposal. Although the president proposed a three-year freeze on funding that was not dedicated to security and defense, he still supported science generously.

More recently, the midterm elections this past November helped shift the power of the House of Representatives to the Republican Party. This caused some reallocations in the funding for research and development. Specifically, the agenda for the Republican Party would cut funding by $8 billion dollars from the funds that Obama previously proposed. This would equate to approximately 5 to 10 % cuts in the original allocations for 2011 and 2012. However, there is still much debate as to how these proposed agendas will ultimately effect the funding of science in the upcoming years. Most of the money approved to science research is used for grants and contracts. The research itself only uses up a fraction of the funding. Therefore, these cuts would mostly affect renewal grants, continued research and new investigators.

Many believe that science funding will help to stimulate innovation and economic growth, which is why there are concerns regarding these changes. According to the 2011 R&D Global Forecast, the outlook for the next year in terms of R&D growth doesn't look too promising. Although most experts agree that the recession is over, the economy still remains frail, making federal spending difficult and priorities even more difficult to determine.

-Andrea DeDonato, Biology 2011

Alone in the Universe: An Unlikely Fate for our Earth

How the study of astrobiology is seeking life on other planets, with a little help from life here on earth.

Of all questions sought to be answered by mankind, one remains largely unresolved: are we alone? Thankfully, with advances in modern technology and our unfolding understanding of the universe, scientists are beginning to unveil the truths behind this fundamental question. The study of astrobiology integrates astronomers, biologists, chemists, physicists, and geologists who work together to determine the characteristics that make planets habitable for sustaining life. Scientists around the globe from private enterprises, university institutions, and government agencies work diligently to infer whether or not such suitable conditions exist in places other than Earth.

Astrobiology confronts three fundamental questions: how does life begin and evolve, does life exist elsewhere in the universe, and what is the future of life on Earth and beyond? Research over the past few decades has changed the fundamental knowledge about what comprises all known life on Earth. These findings can then be projected out into the far reaches of our galaxy and the universe to search for habitable planets. A planet that can sustain life must provide extended regions of liquid water (or fluid medium), conditions favorable for the assembly of complex organic molecules, and energy sources to support cellular metabolism.

When determining whether or not a planet could support life, the central condition is whether or not there is a presence of liquid water. Water is comprised of the two most abundant chemically reactive elements in the universe (hydrogen and oxygen) and is a necessary ingredient for our Earth's type of life. Liquid water supports dynamic properties of an Earth-sized planet, and permits convection within the planetary crust. This interaction creates a local chemical disequilibrium that provides energy required for life. Further, water maintains a strong polar dichotomy with many compounds, which allows life-forms to develop independent stable cellular structures.

Funded and supported by NASA, the Astrobiology Team is responsible for the search of potentially habitable planets within and outside our solar system. NASA's Kepler Mission is the first of its kind in that it actively seeks Earth-sized planets that could potentially house liquid water and orbit around stars similar to our sun. The Kepler instrument is a specially designed 0.95-meter diameter photometer telescope. Its immense field of view allows for the observation of over 100,000 stars within our Milky Way Galaxy. Apart from discovering Earth-size and smaller planets with potentially habitable characteristics, the Kepler Mission will determine the fraction of the billions of stars in our galaxy that might contain such planets.

In conjunction with the Kepler Mission, numerous other NASA initiatives have encountered planets and satellites (moons) within our solar system that exhibit qualities to potentially sustain life. The Galileo Mission uncovered strong evidence of subsurface liquids on three of the four Galilean satellites of Jupiter – Europa, Ganymede, and Callisto. Satellite observations show that these moons are maintained by internal tidal heating, which could provide a favorable environment for life.

NASA's Cassini-Huygens Mission has confirmed one of Saturn's moons, Titan, houses an atmosphere and surface enriched with prebiotic organic compounds. Titan can be viewed as a natural laboratory where scientists can gain insight into the origins of life here on Earth. More importantly, the presence of liquid lakes and hydrocarbons on Titan suggests the possibility of life forms altogether different from those found on Earth due to the existence of alternative solvents and energy sources. The Cassini-Huygens Mission also imaged plumes of water vapor erupting episodically from the surface of another one of Saturn's icy moons, Enceladus. This incredible discovery indicates the possibility than interior habitable zones with liquid water may exist on multiple planetary bodies throughout the outer Solar System.

Even during the last decade, significant progress has been made in our understanding of the potential for past and present habitable environments throughout our Solar System. The greatest example of such progress is our growing study and comprehension of our close neighbor, Mars. The Mars Global Surveyor orbiter, Mars Exploration Rovers, Viking I and II, Mars Pathfinder, and the Mars Reconnaissance Orbiter reveal that in early Martian history, water played a significant role in the shaping of the planet. Hundreds of river channels, lakebeds, river deltas, and flood basins can be easily identified by the satellite imagery provided by the Mars Reconnaissance Orbiter.

Fairly recently, atmospheric methane has been discovered, indicating that a subsurface habitable environment might even exist on Mars today. In the next two years, NASA's newest rover mission to Mars, the Mars Science Laboratory Mission, will conduct multiple in situ experiments to determine the occurrence of present or past microbial life. Findings will help scientists uncover the means to which life originated here on Earth, and will greatly aid in the search for habitable planets outside of our Solar System.

It is possible that life outside of our Solar System developed differently than as seen on Earth. However, our understanding of the nature of terrestrial

life provides an essential starting point to guide future exploration. For example, studies of microorganisms in extreme environments, including regions where biota are sustained by chemical energy (hydrothermal and deep sub-surface areas), have revolutionized our understanding of the potential for life in areas such as Mars or Saturn's icy moons. Even a recent study of Mono Lake in California reveals the first known microorganism on Earth able to thrive and reproduce using the toxic chemical arsenic. These extremophiles have proven life's persistence in the most inhospitable environments here on earth, and their study can provide scientists with insight into life's persistence in space.

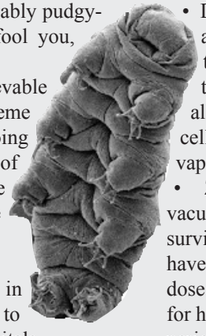
Building on these discoveries, we can address the following steps in regards to future exploration of extraterrestrial life and the expansion of our understanding of Astrobiology. First, we should continue to refine our understanding of the nature and development of past and present habitable environments on Earth and throughout the Solar System. This will allow us to zero-in on exactly which stars and planets to target in the Milky Way Galaxy. Second, we must determine the most favorable landing sites for future in situ missions to detect past or present life. Third, we need to refine our methods for detecting fossil biosignatures in surface/subsurface rocks, soils, and ices on other planetary bodies. Fourth, robotic drilling systems capable of reaching subsurface environments on Mars and other inter-solar bodies for examination must be advanced. Finally, the ability to collect and return high-priority samples from Mars back to Earth for study using advanced terrestrial laboratories would greatly impact our understanding of life's origins.

The growing field of Astrobiology is shifting the world around us, and is revolutionizing the way we view the origins of life. Ed Weiler, NASA's associate administrator for the Science Mission Directorate eloquently describes this expanding field: "The definition of life has just expanded… as we pursue our efforts to seek signs of life in the solar system [and universe], we have to think more broadly, more diversely and consider life as we do not know it." And as NASA Astrobiology Research Fellow Felisa Wolfe-Simon puts it, "If something here on Earth can do something so unexpected, what else can life do that we haven't seen yet?" The possibilities for discovering life on other planets is seemingly endless. The opportunities for an ever-evolving understanding of our universe are boundless. Chances are we're not as alone as we had thought, and it's likely we're very far from it.

-Emily Snead, Environmental Science & Geology, 2012

The Waterbear: The Unstoppable Being

This issue we've focused on forms of life that push the boundaries of what conditions we consider hospitable. Whether they be organisms from the deepest chasms of the sea, the tumultuous and fiery infancy of our planet, or even the far reaches of our solar system, there is one organism that's just more unstoppable than all the rest: the waterbear. Scientifically named a Tardigrade, or adorably reffered to as a moss piglet, this titan of the elements stands up to 1.5 mm tall and boasts four pairs of clawed feet protruding from its huggably pudgy-looking body. But don't let their lovable gait fool you, we're lucky these creatures just eat moss.



The waterbear's claim to fame is it's unbelievable to survive, and even reproduce under the most extreme conditions. Their main form of survival is by going into a state of cryptobiosis, which is a method of suspending an organism's metabolism. Holding the heavy-weight belt for poly-extremophiles, these little guys have quite the resume:

- Bake 'em: Tardigrades have been put in autoclaves at 151°C for minutes and survived to fight another day. That's the temperature hospitals and biological labs use to sterilize equipment.
- Freeze 'em: They can survive hours at temperatures of -200°C and even a few minutes at -272°C. For those of you keeping track at home, that's one degree above absolute zero, the temperature at which all molecular movement ceases. In other words: matter ceases to have any thermal energy at all… Tough to beat.
- Pull on 'em: Most animals have trouble with the low pressures on Mt. Everest. Try space! A few lucky Tardigrades got to take a trip to low earth orbit where they were injected into space for 10 days. In this 2008 study by Jönsson et al, these animals not only survived, but had the time to reproduce.
- Push on 'em: The deepest ocean trenches on earth sport pressures of 1070 Atmospheres. Waterbears have been able to withstand pressures of 6000 Atmospheres. That's just showing off.
- Dry 'em: Tardigrades can survive up to a decade in a dessicated environment. In a metabolic marvel that also factors into their above abilities, they can transform their body from 85% water to only 3%. This allows not only the ability to live without water; their cells won't get ripped apart by water freezing or rapidly vaporizing.
- Zap 'em: In the space study referred to above, the vacuum of space wasn't the only danger. Few animals can survive that amount of direct solar radiation. Moss piglets have been shown in the laboratory to have a median lethal dose of 5000 grays of Gamma Rays. The mean lethal dose for humans, and most other animals, is 4.5 Gy over a short period.
- Take 'em home! Actually a collection of over 1,000 different species, Tardigrades are most commonly found on fresh water moss and lichens. However, they can also be found on beaches and in all types of sediments from pole to pole.

-James Peerless, Chemical Engineering, 2011

Image: http://commons.wikimedia.org/wiki/File:Waterbear.jpg

Extremophiles and the Origin:

How life may have begun from the indestructible organism

Around 4.5 billion years ago, when excess materials surrounding the sun coalesced to form planet Earth, the conditions are thought to have been very different from those we observe today. The surface exhibited constant volcanic eruptions and collisions from meteors and comets. Earth was extremely hot, and meteor impacts would cause drastic temperature changes. The atmosphere did not contain oxygen, instead consisting mainly of water vapor, carbon dioxide, carbon monoxide, nitrogen, ammonia, methane, and possibly hydrogen. Without oxygen, there was no ozone layer, so ultraviolet radiation from the sun habitually bombarded the Earth.

Yet it was from this kind of volatile environment that life first emerged, sometime around 3.9-3.5 billion years ago, according to evidence found in Greenland and Australia. Scientists have wondered for decades how any life could have survived these conditions. However research on extremophiles has helped scientists to understand more about life under extreme conditions and has expanded scientists' ideas of the types of environments that are able to support life.

Scientists have studied abiogenesis (the beginning of life from non-living earthly matter) for decades trying to determine if and exactly how it could have occurred. How do chemicals just mix together and create life? It is believed to be a gradual process over millions of years in which non-living matter become cells in small evolutionary steps. These steps include the formation of amino acids that merge into proteins and the development of genetic material, all which occur before even the smallest of microbes can begin to form.

If this process takes millions of years, however, it may have needed to be sheltered from the constant bombardment of meteors hitting the surface and sterilizing the landscape. Thomas Gold and several Soviet geologists independently have promoted the theory that life may have originated deep in the Earth's crust. Here these organisms could have been chemolithoheterotrophic hyperthermophiles, organisms that cannot fix their own carbon, obtain their energy from oxidation-reduction reactions with inorganic energy sources such as sulfur (instead of from photosynthesis)and are able to withstand the very high temperatures that would have existed underground.

With similar reasoning, Günter Wächtershäuser proposed the Iron-Sulfur world theory and suggested that life might have originated at hydrothermal vents. To test this theory, Koichiro Matsuno and colleagues at the University of Tokyo built an artificial vent in which water is heated to between 110°C and 350°C in one chamber, pressurized to 200 atmospheres, and cooled to near-freezing in another. The water then returns to the heating chamber, in the same way that sea-water cycles through the circulation system of a natural vent. When they added glycine and copper, materials they believed could have existed in vent systems billions of years ago, long peptide chains were formed. Matsuno claims that this test proves that hydrothermal vents could be the answer to the origin of life. These organisms could then have gradually spread to the surface, according to physicist Paul Davies in his seminal work, The Fifth Miracle: the Search for the Origin and Meaning of Life.

However, other scientists have suggested that life may have originated not in a warm and wet environment, but instead one of ice. The idea has been around since 1994, but has been brought to attention by Laura F. Landweber of Princeton University and a team at SomaGenics led by Alexander Vlassov. Their research with ice has now filled a hole in one of the classic origin of life theories, the RNA-world theory. Most scientists believe that RNA, not DNA was the first genetic material because it is involved in a wider variety of functions than DNA. The RNA-world theory believes RNA carried out almost every function of early life. One problem with the theory is that the strands of RNA that have been recreated experimentally have been far too short to be useful in creating life. What Landweber and the team have found is that ice contains small microscopic compartments that can hold molecules inside and force them to react together more often, creating longer chains of RNA. In the past, an icy origin has been overlooked because freezing usually slows down chemical reactions, and cold places are generally considered to be hostile to life. Research on psychrophiles, extremophiles that live in cold conditions, however, has added to the possibility that ice could have been the environment that first permitted life.

Panspermia is an idea that originated in the 19th century in opposition to the theory of abiogenesis. It states that life is present in a spore-like form on certain bodies throughout the universe, and that these spores take root when the environment is right. Therefore, life did not originate on Earth, but was deposited here from a collision with a body that did have life. This theory has regained some popularity in recent years, as scientists have had difficulty in figuring out how abiogenesis could have happened. Tests have been done to see whether or not a small microbe present inside a meteor or asteroid could have survived the impact of a crash into Earth, as well as the radioactivity present in space. The results have been somewhat mixed—one test showed that a rock during reentry reached 1700°C, which would likely sterilize even the most robust of hypothermophiles. But the atmosphere is composed much differently now as compared to three billion years ago, and other factors combine to suggest that the idea cannot be ruled out. One extremophile that NASA is studying closely is Deinococcus radiodurans, which has shown that it can tolerate 500 times the amount of radiation that a human can. This finding has certainly

helped back up the idea that some microbes could have survived a trip through space.

A related idea that has gained support is that life could have actually begun on Mars, and through asteroid and comet collisions, could have been transported to Earth. Many astrobiologists like Davies believe that this could have been the case. Some have compared Mars to an older version of Earth that coalesced and cooled earlier due to its slightly smaller size.

Some scientists, like Lynn Margulis, proponent of the groundbreaking Serial Endosymbiosis Theory of evolution, discredit panspermia or exogenesis theories, saying that they tend to just shift the puzzle of the origin of life from Earth to somewhere else in the cosmos without elaborating on how life could have arisen there.

The origin of life is one of the most difficult questions in the universe, and we may be far from knowing an exact answer. But scientists are constantly making new discoveries, and developing new theories that are getting us closer to finding the truth. For instance, extremophiles, when first discovered, were merely a scientific curiosity. However, now that they have been more thoroughly explored and studied, scientists have come to realize the profound significance these organisms possess and the potential they have to help us understand our own past.

- John Jamieson, Chemical Engineering, 2015

Life in Darkness:

How hydrothermal vents create complex biological communities absent from sunlight.

In the traditional view of the food chain, all of life's energy comes from the sun. We hold that the carnivores eat the herbivores and the herbivores eat the plants that derive their mass and energy from sunlight and carbon dioxide through photosynthesis. This classic food chain is indeed the normal hierarchy on landmasses and in shallow seas with which we are so familiar. However, holding the sun as the basis of life raises the question: what, if any, life can exist where sunlight fails to reach?

After about 1000 meters, natural light all but vanishes in the oceans. The majority of our planet's oceans reach far beyond this light barrier, yet still maintain life in their deep-sea environments. Anomalies in ocean floor ecosystems exist that break the traditionally upheld idea of a solar-based food chain. Communities of startling diversity and dense populations, resembling the stunning coral reefs closer to the surface, have been found in ocean depths miles beyond the reach of even the most ambitious sunbeam. These communities boast population densities 10,000 to 100,000 times greater than the other deep sea populations dependant only on the scraps of food that fall to the lower depths. It became overwhelmingly clear to scientists that these diverse ecosystems must derive their energy from a source other than the sun. There must be some other basis for life in these rapidly growing systems. The obvious answer lies in the geologic formation upon which every one of these communities is formed: the hydrothermal vent.

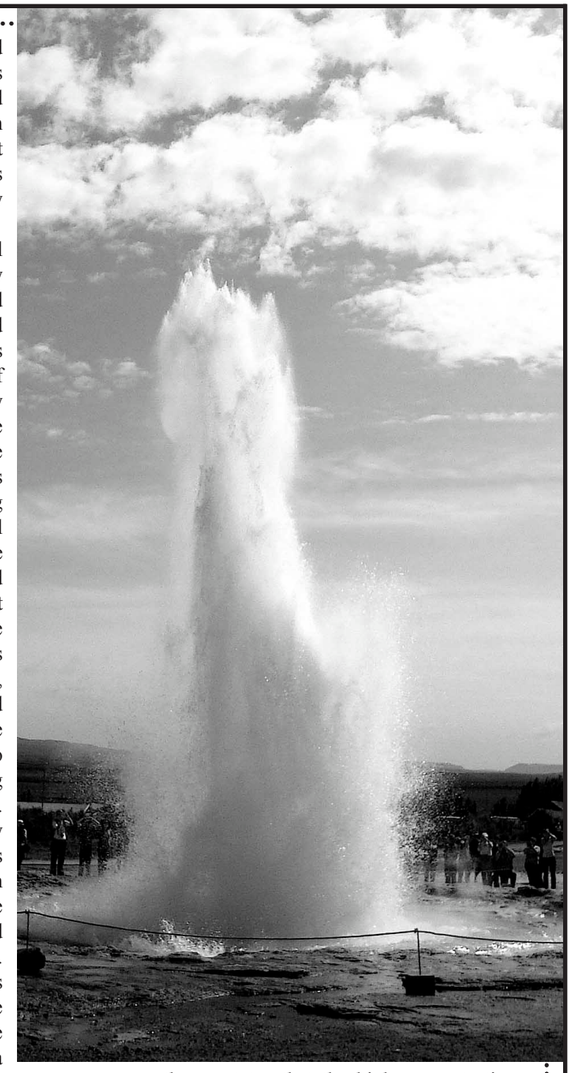
Hydrothermal vents are simply fissures in the earth's crust found mostly in volcanically active regions through which water, heated geothermally deep below the surface, escapes. On land, these hydrothermal vents take the form of hot springs or geysers, such as Yellowstone National Park's Old Faithful. On the deep sea floor, these vents constitute much more than an awe-inspiring attraction. Spewing sulfide and mineral rich water up to 450 degrees Celsius, these deep sea hydrothermal vents are oases of heat and nutrients on the ocean floor. Often appearing as chimneys or smoke stacks spewing black or white smoke, the minerals in the super-heated hydrothermal water almost instantaneously precipitate when contacted by the cold sea water on the ocean floor (averaged at about 2 degrees Celsius). This mineral precipitate takes the form of both the visible "smoke" coming out of the vent, as well as the buildup of the "chimney", a cylindrical column of sedimentary rock surrounding the vent. The minerals dissolved in the geothermal water continue to precipitate and add to the height of the column throughout the life of the vent, causing chimney heights to reach up to sixty meters.

What attracts our scientific attention to these vents is not merely their geologic formation; it is the startling biological communities that thrive around them. The diversity and number of organisms found around the hydrothermal vents had never before been seen so far from sunlight. The immediate question biologists sought to answer was how these organisms can survive without any photosynthetic organisms in their food chain.

The answer lies in the ability of single-celled bacteria to perform a spectacular metabolic process known as chemosynthesis. Perhaps the vent ecosystem's analog to photosynthesis, these bacteria use sulfur compounds and heat released by the vent to create organic matter. Much like the photosynthetic plankton and plants in the traditional ecosystems closer to the sun, these chemosynthetic bacteria form the base of the food chain upon which all other organisms depend. Chemosynthesis is the creation of organic material from small organic compounds (such as methane or carbon dioxide) using either methane or the oxidation of an inorganic (such as ammonia or hydrogen sulfide) as an energy source. With the tons of hydrogen sulfide, ammonia, carbon dioxide and methane deposited by the hydrothermal vents, chemosynthetic organisms can thrive. Mostly, these chemosynthetic bacteria use the readily available heat and hydrogen sulfide, toxic to most other organisms, to create organic material.

The chemosynthetic bacteria often form thick mats on the chimney as well as the immediately surrounding ocean floor upon which millimeter-sized translucent crustaceans known as amphipods and copepods feed. On these small crustaceans, more complex creatures such as snails, clams, shrimp, crabs and octopi feed. What then develops is a complex food chain of predator- prey relationships between these larger organisms that then constitutes a fully developed ecosystem.

One of the more interesting relationships seen in these hydrothermal vent systems is that between the tubeworm and the chemosynthetic bacteria. The tubeworms are immobile, securing themselves to the rock formations surrounding the vents, and appear almost plant-like in nature. The tubeworms, like their parasitic relatives, absorb nutrients directly through their skin. The tube worm also contains hemoglobin streams that allow absorbed hydrogen sulfide to be transported into the interior of the worm, and also give the tubeworm a distinctive red color. In a rare symbiotic relationship, billions of chemosynthetic bacteria live inside the tubeworm, subsisting on the hydrogen sulfide transported by the worm's absorptive capability. In return, the tubeworm feeds solely on the organic material produced by the bacteria. This specialization has caused tubeworms to flourish in hydrothermal vent regions, creating forests on and around the chimney structure.



The hydrothermal vents are home to many strange and specialized creatures adapted specifically to this environment. Species of extremophiles, specifically hyperthermophiles, have been adapted to survive the high temperatures of the water spewing out of the hydrothermal vents. The most notable hyperthermophile found in a hydrothermal vent was shown to reproduce effectively at temperatures of 121 degrees Celsius, and was so dubbed Strain 121. This single celled microbe is also chemosynthetic, surviving by reducing iron chloride. Prior to the discovery of Strain 121, it was common belief that fifteen minutes in a 121 degree Celsius autoclave would kill all living organisms. These hyperthermophiles are thought to be able to withstand these temperatures due to a cellular membrane rich in saturated fatty acids arranged in a compressed monolayer allowing the microbe to maintain its shape.

In addition to resisting the high heat of the hydrothermal vents, many of the organisms close to the vent must also be acidophilic to withstand the acidic water escaping the earth's crust (often having a pH as low as 2.8). Other interesting adaptations include a specific snail, the scaly-footed gastropod (Crysomallon squamiferum), which boasts a foot reinforced with iron sulfides in addition to organic materials.

Hydrothermal vents have indeed been a topic of much study and debate. Some scientists hold that the basis of all life itself could have spawned from these undersea anomalies. The hydrothermal origin of life theory states that the high concentrations of methane and ammonia, not so readily found in earth's primordial atmosphere, formed the first amino acids that the floated to the surface eventually leading to the first single-celled organism. Whether or not this theory proves to be true, scientists continue to study the hydrothermal vents as unique microcosms of evolution. Much like Darwin's Galapagos, the diversity and biological specialization found in hydrothermal vents will no doubt provide insight into evolutionary theory for ecosystems miles above.

- James Peerless, Chemical Engineering, 2011

Name	Living Conditions	Examples (Noted Habitats)	Adaptation
Acidophile	Highly acidic environments with pH values between 1 and 5	Thiobacillus ferrooxidans (concrete sewer pipes)	Pump hydrogen atoms out of the cell at a high rate to maintain a relatively neutral pH compared to the surroundings, thus preserving the intracellular structures
Alkaliphile	Highly basic environments with pH values above 9	Bacillus okhensis (Devil's Golf Course in Death Valley National Park)	Pump hydrogen atoms into the cell cytoplasm to maintain a relatively neutral pH compared to the surroundings
Halophile	Highly saline environments with at least .2M NaCl concentration.	Halobacterium halobium (Owens Lake, California)	Offset the high salt concentration in the environment by storing salts within the cell (such as potassium or sodium) in order to prevent water from flowing outward due to natural osmosis
Osmophile	Environments with very high sugar concentrations	Saccharomyces cerevisiae (skin of grapes)	Synthesize osmoprotectants such as amino acids to protect against the high external sugar concentration that usually limit the growth of microorganisms
Piezophile	Ocean floors where pressure can exceed 380atm	Halomonas salaria (Anmyeondo, Korea)	Cell membranes with an increased concentration of polyunsaturated fatty acids which helps the membrane maintain fluidity and keeps it from becoming waxy or impervious
Psychrophile	Environments with temperatures below 15C (59F)	Chlamydomonas nivalis (Sierra Nevada of California)	Possess enzymes that are able to perform catalysis and function at very low temperatures (become denatured at moderate temperatures)
Radioresistant extremophiles	Environments with high levels of radiation	Deinococcus radiodurans (canned foods)	Many possess some form of a self repair mechanisms that re-pieces together undamaged genetic sequences when exposed to high levels of radiation.
Thermophile	Hot environments 45-80°C (113-176°F)	Thermus aquaticus (Yellowstone National Park's Lower Geyser Basin)	Cell membranes contains high levels of saturated fatty acids in carbon monolayers which allow shape retention at high temperatures
Hyperthermophiles	Extremely hot environments above 60°C (140°F), optimally above 80°C (176°F)	Pyrolobus fumarii (Atlantic hydrothermal vents)	See above

- Brad West, Chemical Engineering, 2013

Has Flipper Finally Met his Match?

How a 50-year industrial error in the production of PCBs could seriously compromise the immune system of bottlenose dolphins.

Since 1987, several mass mortality events have affected dolphins in coastal waters. For instance, in a period between the summer of 1987 and spring of 1988, 740 bottlenose dolphins expired in group strandings along the Atlantic coast. This event decimated 53% of the dolphin population in the region at the time. Contaminant-induced immunosuppression by organochlorines, including PCBs, is a plausible contributing factor to the deaths of tens of thousands of dolphins over the past decades and could continue to significantly impact the 81,600 remaining cetaceans in North American waters. A species-wide deterioration in immune system function may prevent bottlenose dolphins from adapting to the inevitable increase in anthropogenic stressors such as pollution, over-fishing, and the introduction of new pathogens. It is critical to understand the physiological effects of PCBs on the species in order to evaluate the threat to their longevity and survival.

PCB's: Forever yours

Non-coplanar polychlorinated biphenyls (PCBs) are persistent, ubiquitous, anthropogenic chemicals that bioaccumulate and biomagnify in the food web. Over 1.5 billion pounds of PCBs were produced in the United States from 1929 to 1977 to serve as electrical insulating fluids, flame-retardants, and insecticides in a variety of industries. They were recognized as a dangerous carcinogenic toxin in the late 1970's and their production was subsequently halted. Through atmospheric release, agricultural run-off, and improper disposal, PCBs are now widely dispersed and highly prevalent in the marine environment.

Due to their stable chemical structure, PCBs are not readily disposed of. Consisting of linked benzene rings surrounded by one to ten chlorine molecules, the aromatic compound is resistant to natural wearing and gradual degradation. Instead, PCBs are able to linger for generations, working up the food chain from plankton to fish and eventually to higher predators, increasing concentration at each trophic level.

How do they affect dolphins?

Bottlenose dolphins are particularly at risk for the ill-effects of PCB exposure due to their role as an apex predator with copious blubber composition. After entering the dolphin's body from the digestion of toxin-laced fish, residual organochlorines are stored in fatty tissue rather than being excreted. The maximum blubber concentration bottlenose dolphins can tolerate without physiological complications is 17 mg/kg. Specimens in North American waters were found to have exceeded this threshold by 5- to 15-fold. While contaminants stored in the blubber may not have direct effects, they may be accessed during pregnancy, lactation, and stressed disease states. In addition, the mother passes on all contaminants to the developing embryo, causing long-term ecological complications.

209 unique PCB congeners exist. When evaluated individually each congener may not be deleterious. However, in the mixtures and concentrations found in nature, an additive effect was confirmed. Research has indicated a direct correlation between several immunological defects and environmental PCB levels. In a series of experiments on dolphin erythrocytes from controlled environments, noncoplanar PCB congeners 138, 153, and 180 appeared to have three significant physiological effects that could hinder immune function.

I. Decline in phagocytosis

Phagocytosis is an innate defense mechanism whereby cells surround and ingest macromolecule waste or debris. Neutrophils and monocytes are two types of white blood cells that invoke this mechanism to protect the body from viruses and bacteria. Dr. Milton Levin, of the University of Connecticut, found that mixtures of two or more non-coplanar PCBs reduced both neutrophil and monocyte phagocytosis in multiple in vitro assays. He used flow cytometry and compared the fluorescence at a wavelength of 630 nm of dead cells that had incorporated propidium iodide (a chemical that stimulates phagocytosis) and those that were alive (indicating failed phagocytosis). Through analysis of the results it was determined that a mixture of all three noncoplanar PCBS and coplanar 169 reduced monocyte phagocytosis by 80%. The same group reduced neutrophil phagocytosis by 81%. Thus, the efficiency of the blood cells to eliminate foreign waste and function in immune defense was compromised.

II. Induced calcium mobilization

Cytosolic Ca2+ is a vital second messenger in leukocytes that functions in chemotaxis, phagocytosis, phagosome fusion, and the generation of oxygen free radicals. Ca2+ mobilization occurs early in the cell-signaling cascade, thus, alteration in its function could have significant downstream effects. A 2007 study by Dr. Milton suggests an increase in calcium mobilization in leukocytes due to non-coplanar PCB exposure. When dolphin erythrocytes were treated and evaluated each congener had a different potency. PCB 153 induced the greatest increase in calcium mobilization of 131%.

III. Decline in lymphocyte proliferation

T cells are white blood cells that originate in the thymus and become activated by hormones when the immune system is compromised. Multiple studies indicate the presence of three non-coplanar PCB congeners significantly lowered the level of T cell proliferation in bottlenose dolphins. In a 2006 study by Dr. Chi-

haru Mori, the treatment of erythrocytes with the PCB mixture (including coplanar 169) Con-A, induced T cell proliferation declined by 29%.

Continuing complications

As common in many scientific studies, several variables prevent an adequate conclusion and course of action from the assimilation of the above data. First, it should be noted that all evaluated papers involved the testing of erythrocytes sampled from a controlled environment. This does not account for the infusion of PCBs from the natural environment, how much is transferred from the blood to peripheral fatty tissue, or how much contamination is passed to the young. The current method of evaluating contamination in the wild consists of blubber analysis from stranded animals, as large-scale catch and manipulation raises ethical concerns. However, without concise data on the matriculation of PCBs from the blood to the blubber, the in vivo effects are difficult to confirm.

The current method for evaluating organochlorine toxicity in mixture is the employ of toxic equivalency values (TEQ). In multiple tests, non-coplanar PCBs failed to register on the scale, which suggests they operate through an Ah-receptor independent pathway, thereby resisting detection. Thus, much still needs to be learned of their biochemical effects in living organisms. It is clear, however, that the presence of persistent toxins in the marine environment is having a deleterious effect on the immune systems on a critical apex predator. Should stressors such as the recent Deepwater Horizon spill or red algal blooms increase, the effects on dolphins could jeopardize the stability of the coastal ecosystem.

-Kristina Deak, Biochemistry, 2012

GROWING A SUPERBUG

Antibiotic Resistance and its Consequences

The term superbug refers to a rather interesting type of bacterium: one that has, through one of several different mechanisms, become multi-drug resistant. Among the more famous superbugs are MRSA (methicillin-resistant Staphlococcus aureus) and MDR-TB (multi-drug-resistant tuberculosis). In cases of multi-drug resistance, the bacteria in question are able to, as the phrase suggests, resist multiple antibiotic drugs. The consequences of drug-resistant bacterium can range from inconvenient to catastrophic. In the case of MRSA, for example, the infection is able to resist many of the β-lactam family of antibiotics (which is to say any of the penicillins, carbapenems, or cephalosporins). Fortunately, most of these strains can still be treated with glycopeptides. This means that, while difficult to treat, MRSA is not likely to be the source of any doomsday scenarios. However, there has been a worrying appearance of strains that are even resistant to these drugs, requiring the use of some more exotic antibiotic treatments.

More troubling still are the recent appearances of extremely drug-resistant strains of tuberculosis (XDR-TB) and the New Delhi β-metallo-lactamase 1 (NDM-1) enzyme, which both have the potential to exhaust our current knowledge of antibiotic drugs. In lieu of merely lamenting future nightmarish pandemic s, however, it is perhaps more prudent to try to understand how antibiotic resistances even come to be. The principles behind antibiotic resistance are easy enough to understand, and the process can even be demonstrated in a high school biology laboratory using petri dishes, agar, and small amounts of antibiotics. Imagine, if you will, that a colony of bacteria has made their new home somewhere inside of your chest, resulting in some undesirable symptoms. Not content to let these pests take your body hostage, you go to a doctor and receive some antibiotics. After a week or so, 90% of the bacteria have been killed, and you are now symptom-free. Deciding that you're now cured of your infection, you stop taking the antibiotics and go about your business. Herein lays a problem: the 10% of the bacteria that were not killed were resistant to this particular antibiotic due to a phenomenon called spontaneous mutation. Had you finished the course of medication, these bacteria would have been killed by the end. Now that there is no longer any supply of medication to combat them, however, they grow unrestricted. This 10% of resistant bacteria now make up the entire colony, which repopulates. Your symptoms return, but now your remaining antibiotics are useless against the infection. You must use a new antibiotic to treat the infection. This (simplified) outline of the process seems as if it should be easily countered.

When an infection develops a resistance to one drug, you can simply use another one to knock out the resistant bacteria. The problem is easily compounded, though, by horizontal gene transfer, the process by which bacteria can exchange plasmids coding for many traits, including antibiotic resistance. Through this process, bacteria need not ever be exposed to a given antibiotic to acquire a resistance. It is not difficult to imagine, then, that a bacterial strain that was once only considered stubborn could become absolutely lethal. In fact, such a scenario is already playing out, and without intervention, it could spiral dangerously out of control.

Enter the NDM-1 enzyme. First spotted in 2008, the NDM-1 enzyme grants bacteria the ability to resist carbapenems, drugs normally considered one of the "last line of defense" antibiotics. Even more disturbing, however, is the finding that gene coding for NDM-1 (blaNDM-1) is located on a plasmid that can be transferred between bacterial strains. Thus, bacteria that already possess resistances to many antibiotics can acquire this gene, making them, essentially, resistant to nearly all of the antibiotics modern medicine has imagined. Such cases have already been reported in some more severe infections, with only a select few antibiotics (namely colistin and tigecycline) showing any effects.

So the question is raised: what can we do to prevent such resistances from becoming more widespread? Fortunately, it's not tremendously difficult or inconvenient to do this. The resistances in question are often very metabolically expensive. By reducing selective pressures that help propagate these resistances, we will reduce the prevalence of them. Unfortunately, it will require change on a world-wide level, which is very difficult to orchestrate.

Most importantly, prescription of antibiotics should be more heavily regulated. Often, patients will beg their doctors for a round of antibiotics for things like bad colds, sinus infections, and the like. Many general practitioners consider it standard operating procedure to prescribe antibiotics for almost any common illness. These illnesses are caused by viruses, however, not bacteria. So, not only will the treatment be completely useless, but it will also allow any bacteria in the body to develop a resistance to the prescribed antibiotic. By only prescribing antibiotics for true bacterial infections, and by ensuring patients complete their entire course of medication, bacterial resistances will be dramatically reduced.

Antibiotic resistances have the potential to bring about some of the nastiest infections yet seen by humans. But with more responsible use of antibiotic drugs, the risks can be effectively mitigated. In addition, new technologies, such as phage treatments, may one day make antibiotic drugs unnecessary and even the most stubborn infections could potentially be cleaned up with ease. In the mean time, however, it is important to stay smart and vigilant. Don't use antibiotics superfluously. Treat them with respect, and we will be able to successfully avoid a biological nightmare.

-Kyle Deerwester, Behavioral Neuroscience, 2013

SODIUM POLYACRYLATE-WATER-ZEOLITE Y-FORMALDEHYDE

To live in the 21st century is to be inundated with toxic chemicals from conception to death, regardless of precaution and devoid of choice. It is the unfortunate consequence of rapid industrialization and a preoccupation with profits rather than environmental stability and human health considerations. Regardless, toxicologists are working to alleviate complications due to exposure and to develop methods to prevent unnecessary infiltration of toxins into our bodies.

One such case is the prevalence of formaldehyde, a known carcinogen, in the adhesives of approximately 85% of wood products. Since the 1950's, formaldehyde has served as a useful component of the glues that hold particleboard and plywood together. Once produced, vapors can be given off from the finished product and can stimulate an unwanted exposure scenario in domestic settings.

A novel method for reducing such emissions has been discovered. German researchers at the Fraunhofer Institute for Wood Research and the Institute for Silicate Research have discovered that application of modified zeolites can help absorb formaldehyde in the wood. Zeolites are aluminosilicate materials presently used in a variety of industries. They are referred to as "molecular sieves," due to their ability to selectively sort molecules via size exclusion based upon their own microporous structure.

By modifying known zeolites with amino groups to produce zeolite Y, the researchers were able to decrease formaldehyde emissions from particleboard by 40% upon application. No adverse effects on the wood product was noted, leading to a potential solution for the reduction of some indoor air pollution. The scientists are currently seeking a patent for their work and believe zeolites hold promise for the elimination of emissions from other aldehydes as well.

- Kristina Deak, Biochemistry 2012

Quantum Computing:

The Future of Technology?

Few areas of computer science receive as much attention as quantum computing. Its very nature challenges the imagination and draws in great minds, heralding stunning new developments on what often seems like a monthly basis. Many expect that quantum computing will revolutionize the world, ushering in a new era of computing marked by almost unlimited processing power. But what is this exciting new technology, exactly, and long will it be until it finds its way into our lives?

The fundamental difference between a quantum computer and a regular one lies in the quantum bit, called a qubit. Standard machines store information in units called bits, represented by a value of zero or one. A bit can be only one of these values at a time. Qubits, however, work in a different way. While bits are often stored on electrical switches, a qubit's information is kept in the quantum state of a subatomic particle. This particle's state is described as a probability rather than one exact value. This means that the qubit can store the values zero and one simultaneously. Whereas two bits could have one of the values 00, 01, 10, or 11, two qubits are capable of containing all of these at the same time. Theoretically, a quantum computer with n qubits could, at one time, store 2^n different values and operate on all of them independently. A traditional computer with an equal number of bits would be able to express only one of these sets of values at once. Naturally, such a dramatic increase in processing power would be a desirable improvement.

Not surprisingly, Google has been on the cutting edge of practical implementing quantum computing. The company believes that this technology may have the potential to significantly increase their search quality and capabilities. Google's researchers have developed the early version of a process that would allow users to upload an image as the search term. This new search would, in a process impractical with current computers, analyze major features of the image and display results that share these characteristics. The company recently displayed an early version of this technology, although there was disagreement over whether or not the system was a true quantum computer.

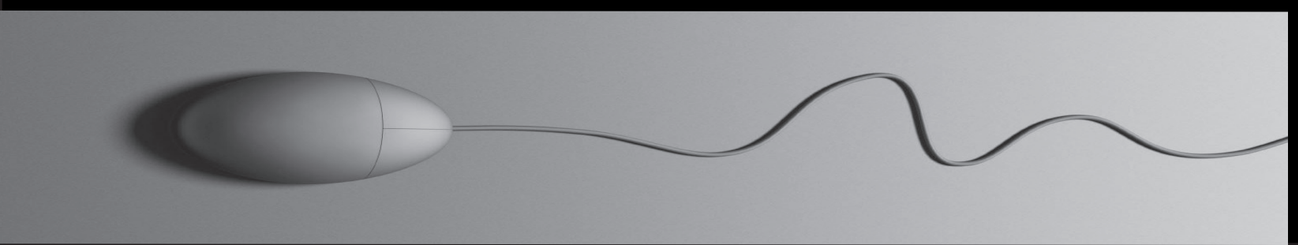
Unfortunately, many technical issues stand in the way. Quantum computers are prone to unacceptably high error rates as the quantum states of qubits become entangled in one another. Given sufficient time, the information will eventually become unintelligible. Once enough information is lost, the machine becomes completely incapable of accurate computation. Major strides have been made in error correction, code that fixes and works around mistakes as they occur, potentially allowing for systems that could continue running from only one of four qubits. However, this technology is still largely theoretical; any practical application is years away.

Another persistent obstacle is the number of qubits that can be incorporated into a single system. So far, scientists have only succeeded in constructing machines with very few, still safely in single digits as recently as 2007. While this has yet to slow theoretical work in the field, any discovery must remain on paper instead of being tested on an actual quantum computer. On example of this is Shor's algorithm. Published in 1994, it would theoretically allow the prime factorization of numbers approximately 10^{200} digits long in seconds, an inexpressibly powerful tool in cryptography. The algorithm swiftly caught the interest of intelligence agencies, given its potential use in breaking RSA, one of the most widely used encryptions. Anticlimactically, the processing power of modern quantum computers have so far limited Shor's algorithm from factoring any number higher than fifteen.

One study, published in the December 2010 issue of the Communications of the Association for Computing Machinery (CACM), suggests that in many areas, traditional computers match the problem solving abilities of quantum computers. Interactive proofs solve problems by a theoretical process in which a "questioner" interrogates an imagined "prover" that has unlimited computational power. With the correct inquiries, the questioner can frequently reach a conclusion faster than with traditional proof systems. Interactive proofs can be applied to a huge number of situations. Many hoped that the power of quantum interactive proofs would be able to tackle problems too complex for regular computers. The CACM article, however, states that all problems solvable by a quantum interactive proof can also be computed by an interactive proof. This means that for many problems, a quantum computer offers no advantage over an optimized traditional computer.

Despite obstacles, scientists continue to make gains towards realizing full quantum computers. Improvements in error correction, qubit control, and quantum algorithms seem to suggest we are moving towards what may be a profound achievement in human history.

-Michael Murray, Computer Science and English, 2014



NU Students Gains New Insight and Perspective in Her Co-op Abroad

If you haven't figured it out already, Northeastern offers hundreds of opportunities during your undergraduate career. As students, we have access to thousands of internships, community initiatives and experiences abroad. Northeastern even offers the option of interning abroad, or what we call "co-oping abroad." This past spring, senior biology major Meghan Cahill took advantage of one of the amazing opportunities that this school offers. She traveled to Costa Rica for a four month co-op where she worked as an emergency medical technician, or EMT, assisting paramedics.

The international co-op advisor works one-on-one with students who wish to go abroad. "The advisors and the projects themselves are extremely flexible. If you would like to get involved and volunteer, you can basically design your own project as long as you follow all the guidelines", said Cahill.

Cahill decided to co-op abroad as a way to gain experience that would make her unique from other medical school applicants. As a pre-medical student in the United States, there is only so much that you are actually allowed to do in a medical setting. As most students who have been on co-op know, it can be difficult to get a position with direct patient contact as part of the job description. Cahill's abroad experience enabled her to engage in more hands on experiences in Costa Rica then she would in the US, especially as an EMT. In Costa Rica, she was able to work directly with patients in an emergency setting. She was told before she left the country that the medical standards between the two countries were considerably similar. However, Cahill observed differences in terms of available supplies and resources. For example, sheets used to cover stretchers or cushions were infrequently changed between patients unless bodily fluids visibly soiled them. She was able to learn firsthand both the similarities and drastic differences between the US and other healthcare systems.

Upon entering the country, Cahill barely spoke Spanish, but after a few Spanish classes and four months of living in a Spanish-speaking country, she quickly learned the basic communication skills. By the end of the four months, she was amazed at the amount of Spanish she could speak. She gained cultural experiences that she never thought possible. Meghan was able to travel around Central America, live with Spanish-speaking families, and meet people from all over the world. "Living in a developing country for four months is truly a life-changing experience," said Meghan. Meghan strongly urges students to participate in the co-op abroad experience. As her third co-op, it was by far her favorite. Cahill said that the most beneficial part of the experience was the confidence she gained in her abilities to be independent and embark on a co-op in a setting so different from anything she's ever known. Many would agree that stepping outside of one's boundaries is life changing. The amazing part is that this is all offered as part of a degree at Northeastern, so why not take advantage?

-Andrea DeDonato, Biology, 2011

Technology: Airport Scanners

Recently, the dangers of newly employed TSA full body scanners have been splashed across the headlines. Across the country, many are asking if the invasion of privacy is really necessary to improve security. However, to understand and make sense of this question, one must learn about how these scanners work and what can be done to ensure privacy.

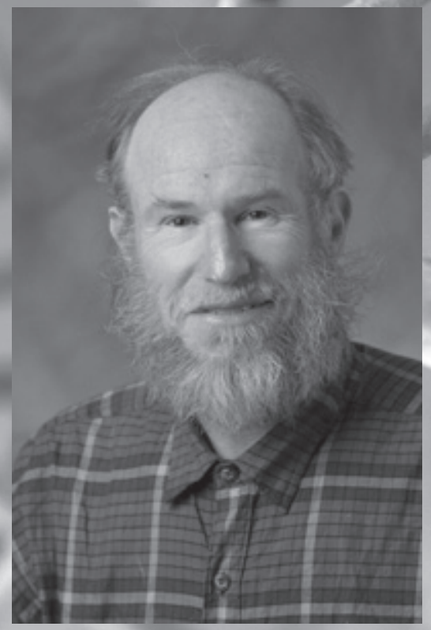
The purpose of whole body imaging technology (WBI) is twofold: to surpass the detection ability of metal detectors and, ideally, become preferential to physical pat-downs, speeding up the security process. Full body imaging can detect metallic and nonmetallic items, such as drugs, underneath the clothing. However, the machines cannot detect objects that may be inside the body. Many feel that the 3D images are too graphic and inappropriate. As a result, WBI technology has revived the debate about the amount of sacrifices in privacy one must make for the sake of security. The images are 3D portrait of what lies under a passenger's clothes, including the individual's genitals. When tested in India in 2006, passengers and technicians alike were uncomfortable and offended with that amount of exposure and the scanners were subsequently taken out of service. In 2008, the European Parliament rejected a proposal to utilize WBI technology in European Union (EU) airports, viewing it as a violation of privacy. The same flack came against the scanners in the United States when they were introduced in certain airports in 2009. As an alternative to pat-downs, this system seemed to be failing. Groups in the US called for boycotting the scans during some of the busiest traveling days in 2010. To address these concerns, privacy filters have been installed that can obstruct the face and genitals of the person being scanned. Also, the images are seen by security officials in an isolated area who never actually meet the passengers.

So, we can see the effects this new technology has had on society, but how does it work? There are two types of scanners. Backscatter technology utilizes x-rays to produce a 2D image. Another type of technology uses radio waves in the millimeter wave spectrum to reflect a 3D image of the body. The latter technology, called Millimeter-Wave scanners, is preferred over the former because of a desire to stray away from x-rays. Some other, more severe, algorithms have been developed to obscure every identifiable feature while still showing if dangerous items are present. Plastics and other non-conducting materials give off a different texture than that of human skin in the presence of millimeter wave frequency. While skin is smooth, other items are granulated. This difference makes it possible to highlight just the threatening objects without enhancing human features. Though technological advances have been made to protect the privacy of individuals, it is unclear how many have actually been implemented. However, it seems that in the near future, WBI will no longer be considered a virtual strip search but a useful tool that protects us while maintaining our privacy.

-Tara Dhingra, Biochemistry, 2012

REVIEWS

nuACM Talks: Prof. John H. Reif, Duke University



The future of numerous scientific fields could be built out of our own DNA. On November 11th, Duke University's Prof. John H. Reif spoke to Northeastern's branch of the Association of Computing Machinery (nuACM) about his work constructing microscopic structures out of DNA chains. His engaging presentation, entitled "DNA-based Autonomous Devices for Molecular-scale Computation, Transport and Sensing," dealt with his research into the development and potential applications of these structures. Reif, a Fellow of the American Association for the Advancement of Science, has studied in this field for the last ten years.

The underlying concept behind Reif's work, which he describes as a fusion of computer science and chemistry, is simple enough. Researchers synthesize single strands of DNA with a customized sequence of bases. Once the process begins, these strands undergo hybridization, the method by which DNA bases bind with their matching pair. Since the strands have been so precisely created, the molecules automatically assemble themselves into the desired structure, typically either a tube or tile made of a lattice of interwoven DNA strands. Once begun, the local hybridization completes in nanoseconds, but can take as long as ten days to cool. Construction on the molecular scale requires self-assembly in order to be precise and efficient.

The applications for this new technology are nearly limitless, as Reif explained, calling it "an example where computer science had a real impact; it impacted a whole discipline." While early research succeeded largely in creating microscopic images, such as the Sierpinski Triangle and a world map, more recent advances have begun to push the boundaries of science. In one such instance, scientists coated small tubes made of approximately twenty DNA helixes in conductive metal to create microscopic wires and circuits, resulting in the creation of crude, almost impossibly small computers. These systems are capable of simple arithmetic, implementing an adder circuit, and even basic search algorithms, although these can often take hours to complete. Another vein of research aims toward creating nucleic nanostructures capable of targeting and destroying cancer cells in the human body. These structures would enter a cell and, should it prove to be cancerous, self-assemble and destroy it. Although these advances remain many years away from everyday use, Reif's presentation offered a fascinating look at the nature of breakthroughs waiting just over the horizon.

nuACM hosts talks every Wednesday in West Village H. Information can be found online at acm.ccs.neu.edu.

-Michael Murray, Computer Science and English, '14

Cortices in Emotional Memory Storage and Retrieval in Rats

Anyone of us can close our eyes and recall an emotionally charged moment in our lives. These bring with them sensory memories. When you smell hot dogs (or stale beer) you might remember the time you caught a fly ball at Fenway, or when you think of a particularly terrifying middle school teacher you might hear an echo of her horribly strident voice.

A recently published study from University of Turin by Tiziana Sacco and Benedetto Sacchetti looks into where those sensory memories might be stored.

They first used excitotoxic lesions to damage the secondary auditory cortex in rats (Te2). Two experiments used different controls: the Te2-lesioned rats were compared to rats with damaged primary auditory cortices, and then compared to rats with lesions in an area of the brain close to both regions, to eliminate general damage as a possible cause. A sound associated with an unpleasant sensation served as the fear-based memory. In both experiments, rats with Te2 damage were found to have long-term auditory memory impairment of emotional memories (fear memories formed one month prior to the lesioning), but not impairment of their recent fear memories, or of their ability to form new fear-associated memories. No emotional memory amnesia was recorded in either of the control groups.

Analogous experiments were then performed on both visual and olfactory cortices. Again, the results showed that rats with damage to their secondary sensory cortices had emotional memory amnesia. Recent memories associated with emotions were unaffected, as was the ability to form new memories.

The researchers then tested modality specificity. Rats were conditioned to have a fear-based response to an auditory stimulus, and then one month later their secondary olfactory cortices were lesioned. The response to the stimulus was unaffected. Several other similar experiments were performed, to ensure that the specific sensory modality held true across the sensory cortices.

A second set of experiments was also performed, designed to track neural activity in the secondary auditory cortex. Rats were conditioned to have a fear response to an auditory stimulus (fear-conditioned), accustomed to the stimulus without an emotional component (recognition memory), or not introduced to the stimulus. All three groups were exposed one month later to the stimulus while the activity of Te2 was monitored. Rats with either no conditioning or recognition memory showed a similar response in Te2 activity, while rats with fear-conditioning showed greater activity in the Te2 when exposed.

Thus, Te2, the secondary auditory cortex, appears to be specifically related to long-term emotional memory storage – but not short-term memory, memory learning, or general memory. The other secondary sensory cortices likely function in a similar manner, due to their comparable responses to lesions and their modality specificity.

This line of research has important applications in humans. If the sensory cortices in humans are found to function in the same way as rats, then it might lead to better understanding of psychiatric conditions such as PTSD, in which emotionally-based memory recall causes a vivid sensory 'flashback' to the conditions under which the memory was formed.

-Cat Ferguson, Behavioral Neuroscience, 2013

The Food Pyramid: Politics vs. Science

It is the beginning of a new year, and of course this means that a lot of us have decided to do things like "start eating healthier." But what exactly does that mean, and how does one even go about it? It's not always easy to sort out everything the media throws at us—between tempting fast food ads, commercials for diet pills, and junk foods being masqueraded as "all natural" and "healthy". It's because of these crazy mixed messages that many of us will turn to what seems to be the most basic truth and the most reliable guide for a true healthy diet: the food pyramid.

Mothers, school boards, and regular folks everywhere have long regarded the food pyramid as the truth, something you could surely rely on for planning a healthy diet when the McDonalds commercials were failing you. But, as Marion Nestle reveals in her book Food Politics, the food pyramid is far from a scientific truth. In fact, it is a product of the highly influential lobbying bodies of the meat and dairy industries using their significant financial and political clout to shape the food pyramid to their own agendas.

Now I know this might sound wildly conspiratorial, but bear with me, because unfortunately, once one turns a more critical eye to the semantics of the food pyramid itself and its changes over time, this becomes the scary truth.

When the US government began distributing nutritional advice in the early 1900s, the top causes of death in the US were infectious diseases like diphtheria and tetanus (made worse by poor nutrition) making it imperative that the people be educated on adequate amounts and sources of important nutrients, vitamins, and minerals. Around the mid-century, however, as the US agricultural system began to take on the big-business form we recognize today and public health had begun to improve, the goals of the governmental nutritional education programs began to shift. The wording, content, and physical shape of what would become the food pyramid was debated for decades, and some aspect of it was changed every few years in a seemingly never-ending battle between the USDA, nutritionists, and trade institutions like the National Dairy Council and the National Cattlemen's Association.

The fight has been a long one, and there have been many major developments over the years, but one of the key themes in the evolution of the food pyramid, and one that demonstrates clearly the blurred line between science and politics, is the "eat more / eat less" paradigm. In a society where two thirds of Americans are considered overweight, one of the simplest and most logical steps to improving our health is to consume fewer calories. Americans' calorie intakes have skyrocketed since the 1970s, as well as consumption of foods high in fat, sugar, and salt, like cheese, soft drinks, and snack foods. However, as demonstrated time after time in the food pyramid debate, the government cannot simply say that people should eat less of these things—because, the food industries argue, this "stigmatizes" certain foods, hurting their profits. The food industries have protested this case since the 1950s, and thus the wording of the food pyramid has evolved from the "eat less" mantra of eat less of x, to the vague but more politically correct avoid too much of x, to the obvious "eat more" philosophy of choose a diet high in x."

One scandal involving the National Academy of Sciences' Food and Nutrition Board is lamentably not the only one of its kind in this debate, but it does provide a revealing example of the unfortunate blurred line between science and politics in the nutrition education arena. In 1980, the Academy released a counter-report to the USDA's annual Dietary Goals, stating that its results showed that "healthy people should not have to restrict intake of fat or cholesterol." It was quickly proven, however, that the Academy scientists who published the report "had demonstrable ties to the meat, dairy, and egg industries," (47). The Academy was "reorganized" soon after once this news came out, but the case stands as a power of these industries, even in what were previously known as reputable institutions of science. It has been said, in cases like these, that the results of scientific studies are not measured—they are bought.

So what does all this mean for your New Year's resolution? I know it might be tempting to run off to fight The Man in an anarchist commune while eating exclusively homegrown arugula and writing government conspiracy theories on your Tumblr, but the good news is that those actions won't be necessary! You don't even have to ditch the food pyramid completely. Although it certainly does not take as hard of a line as it should on the changes that need to be made to the American diet, it can still provide a good basis for a healthy diet. Do you need to eat exactly 3-4 servings of meat every day? Probably not. Do you need to eat exactly 5 servings of vegetables every day? Probably not. Are either of these a good excuse to have a bag of Cheetos for a snack instead of an apple? Definitely not. But you can look to the food pyramid to get an idea of the basics—like that fats, sugars, and oils should make up the smallest part of your diet, while healthy carbohydrates, whole grains, fruits, vegetables, and proteins should make up more significant parts.

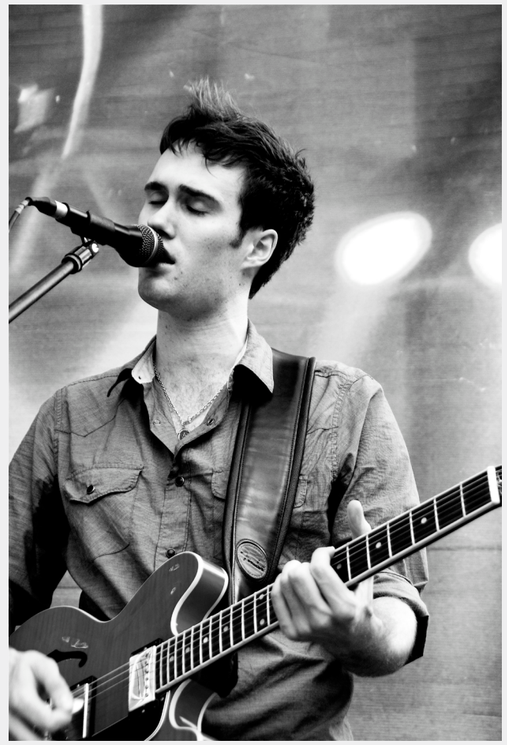
The fact of the matter is, you do know what food is good for you—regardless of what Burger King, the USDA, or the pork industry are screaming in your ears. You know that Domino's cheesy breadsticks don't count as whole grains, and you know that French fries don't count as vegetables. You might even know that protein doesn't necessarily have to be meat! And now you know that the food pyramid doesn't necessarily come from pure, unbiased nutrition science. But you also know that this doesn't mean you have to throw it out entirely—you just have to take it with a grain of salt. Just not too much salt.

-Rebecca Willet, International Affairs and Cultural Anthropology 2013

Music Therapy: Healing with Sound

It plays when the phone rings, when the alarm clock goes off, in stores and restaurants, in a large crowd and in a single person's ear. It has spawned an industry and shaped popular culture. It's music, and it can be more than just a signal or a pastime. Music can heal.

People have used music for healing and spiritual connection for thousands of years, but today music therapy is a scientifically accepted treatment for various illnesses. Music therapy has been found to help people with Alzheimer's, Parkinson's, strokes, chronic pain, and depression, among other mental illnesses, according to the Institute for Music and Neurologic Function.



Research at Stanford University has shown that rhythm can influence neurological function. Music with strong percussion parts in particular stimulates the brain, causing brainwaves to synchronize with the rhythm of a particular song. Music with a slow beat rouses brainwaves normally associated with hypnosis or meditation; music with a fast beat can cause more alert brain function.

When paired with visual stimuli, rhythmic music therapy is even more effective. According to one study, pairing lights and rhythmic sounds can stimulate the brain and encourage greater focus and alertness. In this case, the study practitioner, Harold Russell, a clinical psychologist and University of Texas Medical Branch research professor, used light and rhythm to treat Attention Deficit Disorder (ADD) in 40 elementary and middle school boys. After a period of months undergoing the light and rhythm therapy, the boys performed better on IQ tests and had less reported behavioral problems than the control group. The light and rhythm therapy had worked like conventional ADD medications such as Ritalin and Aderall.

Thomas Budzynski, a University of Washington psychology professor, ran similar experiments on both underachieving college students and elderly people. In both experiments, light and rhythm therapy improved cognition. The college students saw an improvement in their grades; the elderly people's performance on cognitive tests also greatly improved. By using light and rhythm treatments, Budzynski managed to increase blood flow through his subjects' brains. By increasing their brains' blood flow, Budzynski's subjects experienced greater brain function.

Just as fast, strong rhythms can cause greater alertness and concentration, slower music can relax a person and slow his or her brain waves. Slower brain waves cause physiological changes, such as a lowered heart rate and slower breathing. In one University of Utah Health Sciences Center study, 15 cancer outpatients who regularly received analgesics listened to relaxing music two times a day for three days. According to self-reported post-therapy pain levels, 75 percent of the subjects reported some degree of lessened pain as a result of the therapy, and 47 percent reported a moderate or major decrease of pain stemming from the therapy.

Music can relax not only physical pain but also psychological distress. A 2002 study published in Anesthesia & Analgesia found that listening to music before a surgery can reduce a patient's anxiety. Study practitioners told experimental group patients to bring their favorite compact disc of music with them to the hospital. The experimental group was then allowed a half hour prior to operation to listen to their chosen compact disc. The group of patients who listened to music prior to operation reported a reduced level of stress, about 16 percent, when compared with the level of stress before listening to music. The control group, which did not listen to music, showed little to no change in stress level after the same time period. However, physiological measures of anxiety, such as heart rate and blood pressure, showed no difference between anxiety levels of the experimental group subjects before and after listening to a chosen compact disc.

In a Stanford University study, elderly people age 61 to 86 afflicted with depression went through an eight-week music therapy program that coupled relaxing (and sometimes rhythmic) music with other physical or visual stimuli, such as exercise or painting. These depression patients did not engage in any other kind of therapy for the entire period of the experiment. According to this study, the patients who underwent the music therapy treatment showed less symptoms of their depression and reported a greater quality of life when compared to the control group.

Other studies have found music therapy as a possible treatment for schizophrenia and autism. Heavy anecdotal evidence finds listening to or playing music as an accepted from of relaxation and stress relief, even in generally healthy people. Even since ancient times, when societies engaged in rhythmic prayer, music functioned as a way of increasing spirituality and relaxing the mind.

So don't be stressed. Pop in an ear bud, and listen away. Music can heal.

-Jessica Melanson, Journalism 2014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