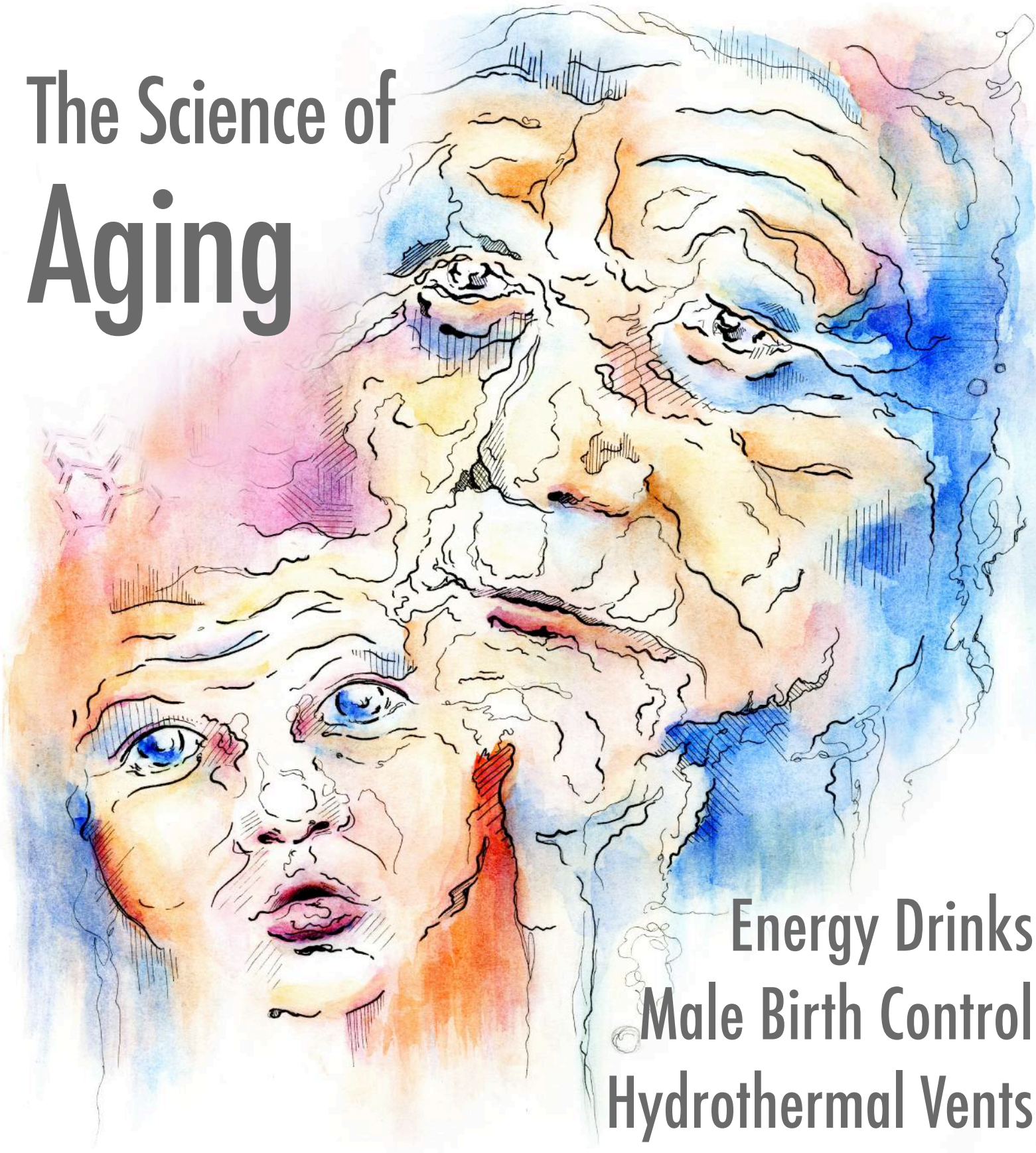
The Synapse

Oberlin College Science Magazine

The Science of Aging



Energy Drinks
Male Birth Control
Hydrothermal Vents

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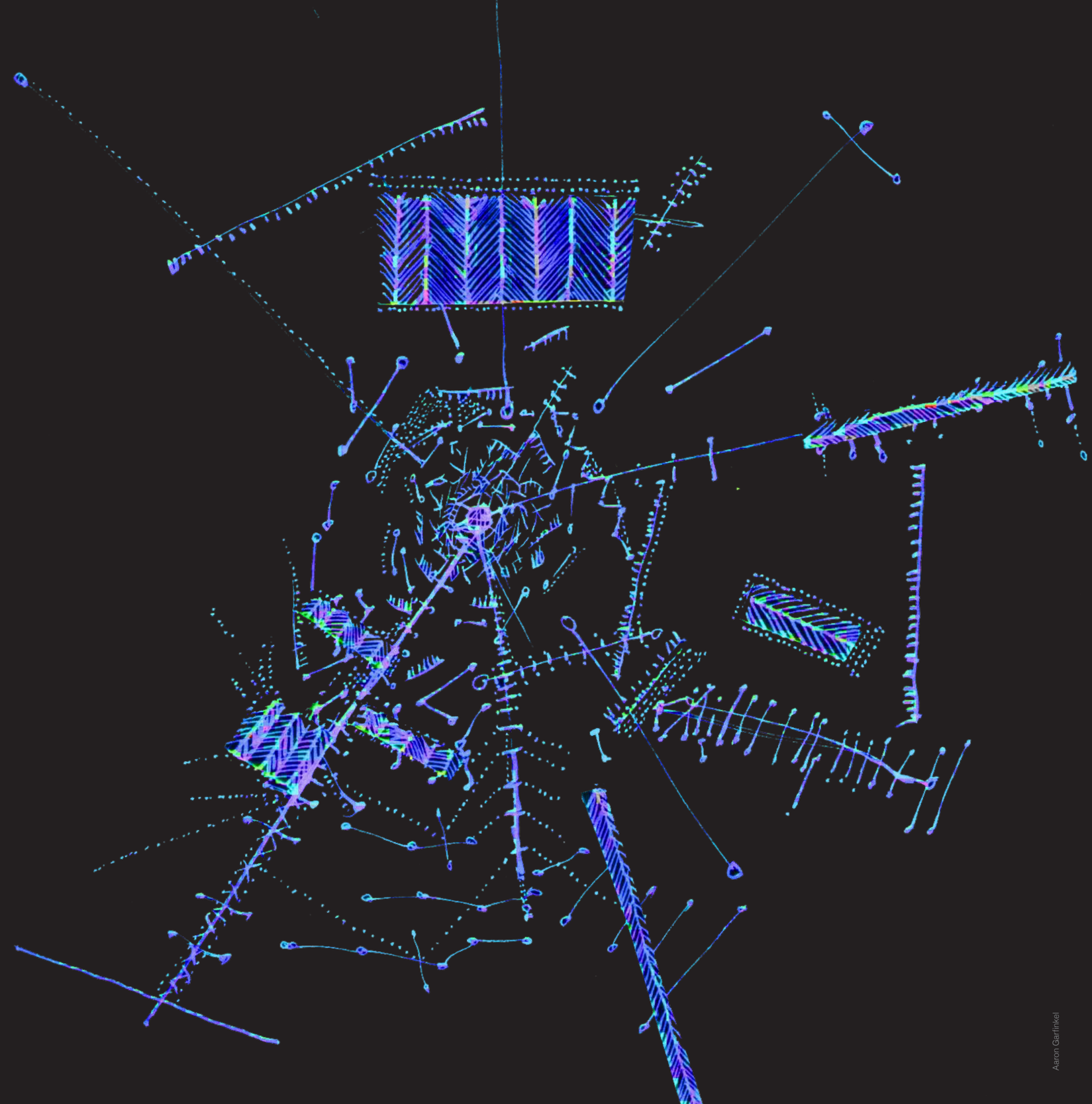

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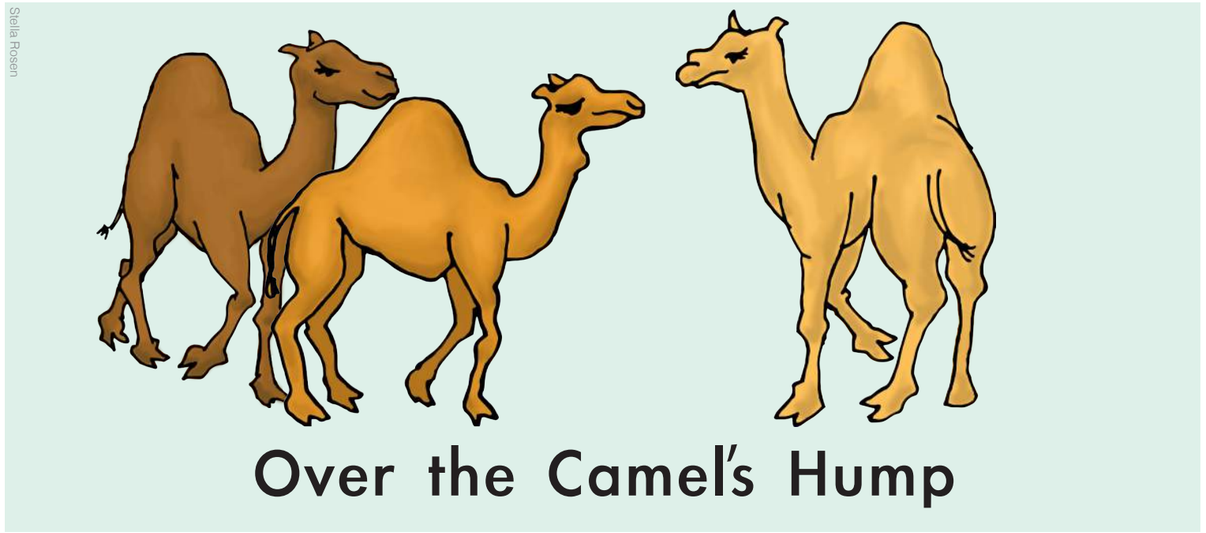


Stella Rosen

By Brett Kingsley

At some point in your childhood you probably learned that camels have the ability to go for long periods of time without taking a sip of water. Logically, people assume that camels can do so because they store water somewhere in their bodies. And what better place than that awkward hump protruding from the middle of their backs?

Yes, camels can survive for long periods of time without water. When the thermometer reads well over 100° F, camels can go from five days to a week without rehydrating. Likewise, during the winter months, camels can survive between six and seven months in the desert without taking a single drink of water. However, if you have ever ridden a camel you know that a camel's hump does not feel like a waterbed. This is because it is not filled with water at all; it is filled with something else entirely.

Fat.

A camel's hump can weigh up to 80 pounds. Arabian camels, otherwise known as dromedary camels, sport a single hump and can be found in North Africa and the Middle East. Bactrian camels, the lesser-known species, have two humps and are native to the steppes of central Asia. Having two humps which serve as fat reserves can be both beneficial and detrimental. Beneficial in the sense that the two-humped cameln now has twice as much stored fat to use as fuel, but detrimental because the extra hump adds another 80 pounds for the camel to carry through the desert, the excess weight forcing the camel to burn more energy to travel the same distance.

It should not be forgotten, however, that camels have the ability to take in large amounts of water in a short period of time. Camels can rehydrate at a faster rate than any other mammal, drinking 30 gallons of water in a mere 13 minutes. So where does all this water go? Mohamed Farid, a former researcher at the Desert Research Institute in Cairo, Egypt, suggested that water stays stored as a fluid in the rumen. The rumen is the large part of the first chamber of the camel's digestive tract. Additionally, some water remains present in the reticulum, the second chamber of its digestive tract. This is the closest thing to a "water reserve" that camels have. Camels can store water in the rumen and use it only when they absolutely need it.

After 12 days of dehydration in hot, desert conditions, Farid found that camels still retained water in their rumen. In this study, they used sheep as a comparison and found that, when raised in the same environmental conditions, camels retained water for 4 times longer than did sheep. Additionally, in 1963, Banerjee et al. conducted an experiment in which they looked at several different animals, including buffaloes, bulls, cows, sheep, goats, horses, and camels. In their experiment, they take a group of camels and cause them to fast, with no food or water, overnight.

At the end of the fast, the researchers took a blood sample from each of the camels and ran tests to determine both the blood volume and the volume of the blood plasma serum (the liquid that the blood cells are suspended in) and compared these levels to the levels of the other animals. The study found that the camels not only had very high volumes of plasma serum and blood, but more importantly, the proportion of serum to blood was found to be greater in camels when compared with the other animals. These two factors lead to a greater total body water volume, as well as a greater intracellular water volume, meaning that camels retain more water in the plasma of their blood!

Two additonal adaptations have also contributed to why camels can survive for extended periods of time without water. One adaptation is the camel's ability to fluctuate their body temperature. As humans, we maintain a relative body temperature of about 98.6° F. The body temperature of camels, on the other hand, fluctuates between 97.9° F and 107.6° F. Another adaptation that allows camels to survive in such extreme temperatures with such little water is their ability to lose a high percentage of their body fluids without introducing a strong, negative effect on their health. Camels can lose up to 40% of their body fluids before there's a risk of fatality, whereas humans become dehydrated after losing only 15%.

The mechanisms that camels have developed to adapt to their extreme desert environments remain unique, making their ability to survive for such prolonged periods of time without water an amazing attribute. Camels may not have large, squishy mounds of water on their backs, but let's get over the hump: camels conserve their resources and survive in the unforgiving desert more spectacularly than any other animal on the planet.

Medicine Through the Ages

Imhotep: Demigod or Doctor?

By Anna Dardick

Long before the era of da Vinci, a Renaissance man emerged in ancient Egypt. Imhotep was an astrologer, priest, architect, engineer, vizier, scribe, and surgeon under four pharaohs of the Third Dynasty (around 2650 BCE). He engineered and supervised the construction of the step-pyramid of Saqqara, and is alleged to have erected the world's first hospital. Hundreds of years after these accomplishments, however, his reputation began transforming from that of a sage to that of a godlike figure. By the 26th Dynasty, Imhotep had undergone an apotheosis in Egyptian lore, becoming a fully-fledged god responsible for star movements, Nile flooding, fertility, protection from poverty, and protection from illness. Eventually, the Romans incorporated Imhotep into their own god of healing: Asclepius.

Time and legend have obscured Imhotep's true life in favor of his characterization as a mystical god—but who was the man behind the deity? Imhotep indelibly changed Egyptian medical history; one does not have to look further than the actual man to find godlike scientific achievements that have resonated throughout time.

As he was both an engineer and a doctor, Imhotep was uniquely qualified to write the first manual on occupational medicine (i.e. how to treat on-the-job injuries), now referred to as the Edwin Smith papyri. The Smith papyri provide examination advice, diagnoses, and treatments for traumas that were common among pyramid construction workers. The text illuminates the Egyptians' astonishingly accurate observations of physiology, anatomy, and pathology. It mentions the use of sutures, cauterization, splints, and antisepsis with copper salts. The latter is especially intriguing due to the relative lack of understanding in the ancient world that cleanliness was integral to halting the spread of infection. Additional progress in antiseptic procedures would not emerge until the United States' Civil War, nearly 5000 years later.

It is unsurprising that the case studies detailed by the papyri are in very specific fields of medicine; in ancient Egypt, doctors were highly specialized. There were two basic types of healers: physicians and priests. Egyptian medicine was based on the precept that there were 36 demons that could infect any of the 36 parts of the body. Priests utilized certain types of herbs and various rites in an attempt to appease the demons.

Physicians, though also influenced by the pervasive metaphysical theory of illness, had a highly intellectual and precise perception of medical problems and their solutions. A doctor would devote his life to studying one area, e.g., teeth, eyes, or rectum. Every malady, from open wounds to breast tumors, had specific prescriptions and courses of treatment. This structure fit in comfortably with the widely accepted theory that the human body was divided into 36 distinct sections, and is also reminiscent of modern medicinal specialization.

Imhotep serves as an excellent representation of the duality present in ancient medicine: his own medical accomplishments show the scientific aspect and his subsequent apotheosis highlights the more metaphysical component of how ancient medical practices were perceived. This duality is has not disappeared from our own society; when struck by illness, many choose to turn to both medicinal treatments and spiritual guidance. Imhotep, considered by many to be the Father of Ancient Medicine, straddled two theories of healing which we continue to balance today.

Sky Kalfus

Animal Advice: Hibernation Habits

By Mia Dawson

I just got back from Fall Break and I can't believe my vacation is over. I just spent a whole week lying on the couch in my pajamas and now I am supposed to act like a sociable, productive human being. What a harsh welcome back! I am not ready to be socializing with this many people and am certainly not ready to be busy every second. Plus, the weather is gross here, adding incentive to laze around and resist facing the world. Please help!

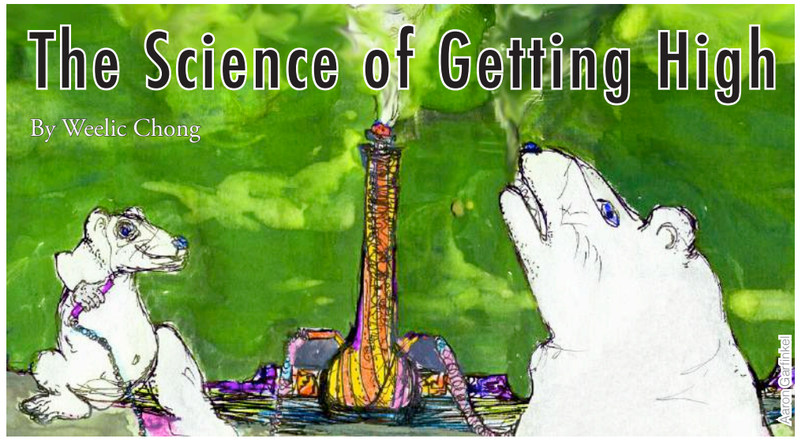
Sincerely,
Faltering in the 440

Dear Faltering -

After exceeding your energy reserves during midterm week, it's no surprise that you needed a period of hibernation. You're in good company — from hedgehogs to black bears, many mammals will take time to kick back, reduce their metabolic rate, and suspend animation for a while. But proceed with caution — the crucial period during which you arouse yourself is a delicate one. Take the Vancouver Island marmot, *Marmota vancouverensis,* for example. After hibernating for 210 days out of the year at a near freezing temperature, the marmot uses its very last stores of energy to heat its heart and restart circulation. Many of them, however, never awake. Those that do, although starving, must then wait at least a week before eating as they rebuild their digestive facilities. So, my advice to you is this - take a slow and easy transition back into action. Have a lunch date, perhaps, and do a couple lines of reading. Don't jump right back into splitchers and all-nighters — the result could be social and mental paralysis.

The Science of Getting High

By Weelic Chong



There are times when I just don't know what to write, so I revert to my standby pile of topics that will always attract both readers and controversy And what better way to celebrate the recent legalization of marijuana possession and sale in Colorado and Washington than with a column on cannabinoids?

Although many readers may be experienced cannabis imbibers, I should still clarify some terms. Cannabinoids refer to a family of psychoactive drugs, the most famous member being THC, which is the active component in marijuana.

Here's a primer in neuroscience: there are cells in our brain called neurons along which little currents of electricity, known as action potentials, travel. Action potentials stop near the border of a neuron at a place we call the axon terminal. There, the message carried by action potentials is converted into chemical form and moves from one cell to another. This chemical is called a neurotransmitter. Once released from the axon terminal, neurotransmitters move across a synapse and bind to receptors dotting the dendrites of post-synaptic neurons. You can also think of it like a van distributing lots of newspapers to many mailboxes in a city. This information flow is thought to be a one-way street.

While this assumption is generally true, sometimes the flow is a two-way street. As early as the 1990s, scientists learned that post-synaptic neurons can produce an in-house version of THC called endocannabinoids. These retroactively bind to pre-synaptic axonal receptors, which then suppress neurotransmitter release, stopping the pre-synaptic neuron from communicating with the post-synaptic neuron.

The main receptor for endocannabinoids is thought to be at the surface of the membrane, just like how a mailbox is found outside the publishing house. Recently, French scientists discovered that the receptors, called CB1, could be found not only on the membrane of a neuron, but also inside of it. Specifically, it can be found in the mitochondria, the energy powerhouses of the cell. To continue the metaphor, it's like finding a mailbox inside the pantry as well. This internal receptor is known as mtCB1.

Scientists were perplexed, but good scientific theories must be able to incorporate unexpected information. Thus, scientists theorized that mtCB1 is probably important for regulating a neuron's energy usage.

They tested their hypothesis by injecting a significant amount of THC into rats and conducting an autopsy on them. They found that there was decreased production of cAMP, a molecule that we think of as an "energy currency". This suggests that THC acts to decrease the production of energy, which is controlled by mitochondrial activity.

To test whether the effects of CB1 receptor mechanism were due to a direct activation of mtCB1 by THC or an indirect stimulation of CB1 receptors on the plasma membrane, they did an in-vitro experiment. Two groups of rats were bred: a "non-druggie" type (rats genetically modified to not express mtCB1 in their mitochondria, and a wild-type (rats that had not been genetically modified). The mitochondria of the neuron cells were then extracted from each type of rat and placed in test tubes, and cannabinoids (or saline, used as a control) were added. Finally, oxygen consumption was measured for each type of mitochondria. It was hypothesized that cannabinoids added to the wild-type tube would bind to mtCB1 and inhibit a pathway, resulting in less respiration (breakdown of sugars to create energy) and therefore less oxygen consumption. Conversely, the scientists predicted that when cannabinoids were added to the non-druggie tube, there would be no mtCB1 to bind to, the pathway would not be inhibited, and respiration would proceed as normal. These hypotheses were both supported: this is exactly what they found to occur.

To ensure that the results had nothing to do with the innate structure or performance of THC, the scientists found another drug that also bound to CB1 but had a completely different structure. This synthetic drug is called WIN. WIN was found to have the same effects as THC, and thus gave the scientists similar results.

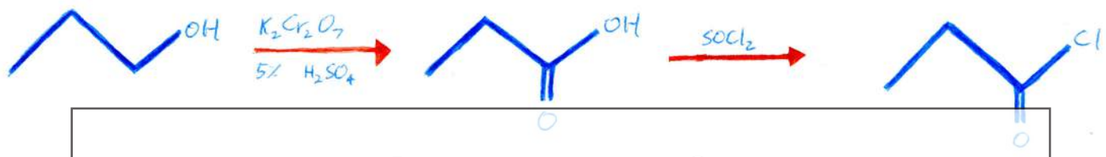
Scientists often want to double-check their results with different techniques. To conclusively prove that the reduction of energy production in neurons has something to do with the mtCB1 receptor specifically and not an unexpected side effect of creating a genetically modified mouse, they employed the use of a retrovirus. A retrovirus is a virus which inserts its own genetic material into the DNA genome of whatever cell it infects. This has proved to be an extremely useful tool for scientists, as it allows them to insert genes they wish to study into very specific cells. In this study, researchers injected the non-druggie rats' hippocampal neurons with a virus containing the genes for mtCB1. They then extracted the mitochondria, and found that with mtCB1 now present on the mitochondrial membrane, WIN bound to the receptor and reduced cAMP levels.

So what exactly might lowering available energy do to a cell? It seems like inhibiting mitochondrial activity might contribute to DSI, the depolarization-induced suppression of inhibition. Let me explain this long, complex phrase. I previously described action potentials as a flow of electricity in a neuron. Action potentials are actually a specific kind of depolarization. Think of it like a battery that only comes in one voltage rating. Depolarization is a broader category, which you can think of like static electricity, which can vary from mild to extremely shocking. We don't know how exactly, but depolarization triggers the release of endocannabinoids in some neurons.

Now, different neurons in your brain release different types of neurotransmitter. There's a highly common type of neuron that releases GABA, an inhibitory neurotransmitter which (usually) dampens activities of neurons that receives it. Thus we call GABA-producing neurons "inhibitory neurons".

Now we can try to tackle the acronym DSI. Endocannabinoids are released whenever there is a depolarization, and the released endocannabinoids bind to mtCB1, suppressing respiration in a GABAergic neuron. This is DSI - depolarized-induced suppression of inhibition. Through another series of experiments with other synthetic drugs, scientists have been able to show that mtCB1 contributes to DSI.

What does this all mean? Well, it means that there is now another way of explaining how weed works. It is like a secret agent that enters the insides of a party-pooper cell in order to switch off some power stations in there. This then gives other neurons more excitement, allowing the brain a chance to have a rave party. Dear readers, if you made it this far, congratulations! I hope I have not damaged your brain with this article, but I am sure that a few years at Oberlin might have already done that anyway!



For the Love of Orgo

By Holden Lai

I remember sitting in the science library, so excited about what I was doing that my hands were shaking. Earlier that day, my professor had shown us the final step of the N-methyl-1-phenylpropan-2-amine synthesis. However, I was not content with knowing only the final step. Determined to elucidate a total synthesis of the compound, I looked through all the reactions that we had learned over the course of the semester. After much scribbling of hexagons and arrows, I sketched out the eight- to nine-step synthetic pathway. That was one of the greatest experiences that any class has ever given me.The class that made my hands shake from excitement and gave me the knowledge to develop a theoretically possible pathway for the synthesis of a compound FDA approved for the treatment of ADHD and obesity was Principles of Organic Chemistry.

Aside from that triumphant moment, however, my experience with organic chemistry has not always been great. At first, it took me awhile to learn my way around the laboratory. I didn't even know what a stir bar was. The material for the class was both challenging and abundant, especially because, as a conservatory student turned double-degree, organic chemistry was one of the first college classes I took at Oberlin. But I never stoped loving the reactions and mechanisms.

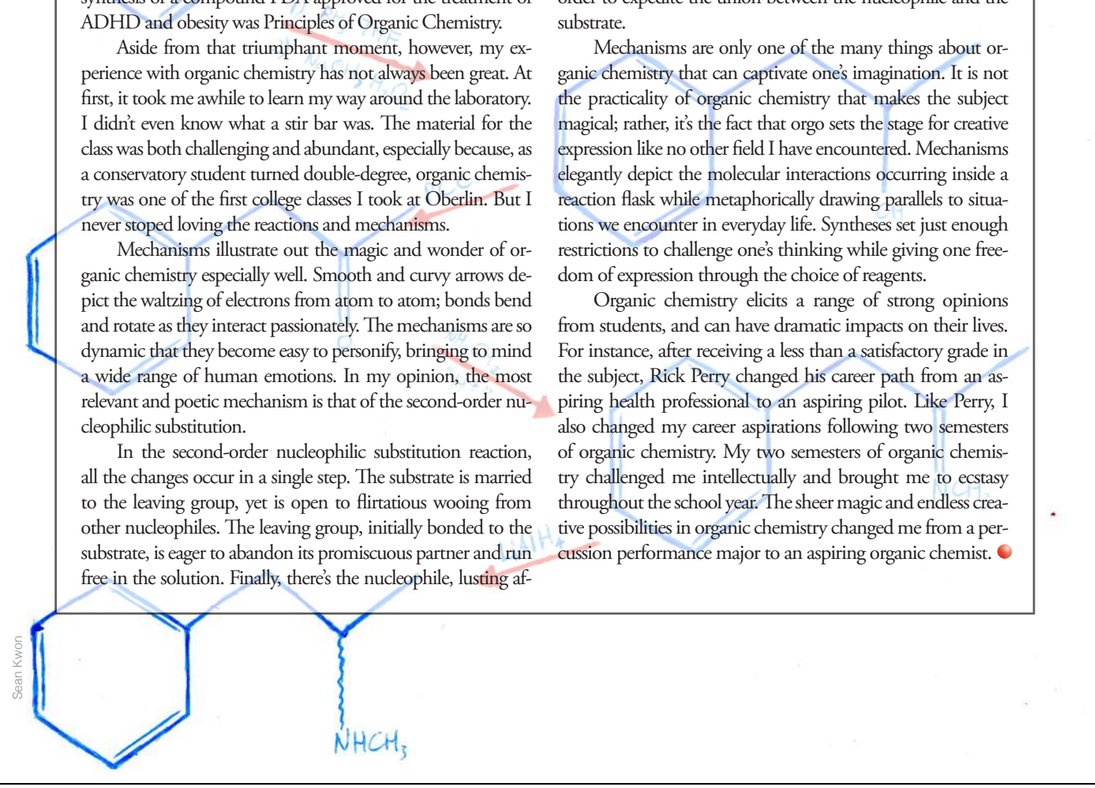
Mechanisms illustrate out the magic and wonder of organic chemistry especially well. Smooth and curvy arrows depict the waltzing of electrons from atom to atom; bonds bend and rotate as they interact passionately. The mechanisms are so dynamic that they become easy to personify, bringing to mind a wide range of human emotions. In my opinion, the most relevant and poetic mechanism is that of the second-order nucleophilic substitution.

In the second-order nucleophilic substitution reaction, all the changes occur in a single step. The substrate is married to the leaving group, yet is open to flirtatious wooing from other nucleophiles. The leaving group, initially bonded to the substrate, is eager to abandon its promiscuous partner and run free in the solution. Finally, there's the nucleophile, lusting after a reaction with the substrate and endowed with enough nucleophilic charm to rock the substrate's world. In one foul swoop, the nucleophile charms the substrate and kicks out the treacherous leaving group, which happily cozies up to a new nucleophile.

But the eloping of the substrate and the nucleophile could be hindered if the environment were not right. Were the solvent of the reaction polar protic, the nucleophile's nucleophilicity — its desire to attach itself to the substrate — could be suppressed; it wouldn't be able to fully express its affections. Only in a polar non-protic solvent would the nucleophile be completely free to seduce the substrate from behind, inverting its configuration and thus completely winning over the substrate's heart. Ultimately, the chemistry has to be perfect in order to expedite the union between the nucleophile and the substrate.

Mechanisms are only one of the many things about organic chemistry that can captivate one's imagination. It is not the practicality of organic chemistry that makes the subject magical; rather, it's the fact that orgo sets the stage for creative expression like no other field I have encountered. Mechanisms elegantly depict the molecular interactions occurring inside a reaction flask while metaphorically drawing parallels to situations we encounter in everyday life. Syntheses set just enough restrictions to challenge one's thinking while giving one freedom of expression through the choice of reagents.

Organic chemistry elicits a range of strong opinions from students, and can have dramatic impacts on their lives. For instance, after receiving a less than a satisfactory grade in the subject, Rick Perry changed his career path from an aspiring health professional to an aspiring pilot. Like Perry, I also changed my career aspirations following two semesters of organic chemistry. My two semesters of organic chemistry challenged me intellectually and brought me to ecstasy throughout the school year. The sheer magic and endless creative possibilities in organic chemistry changed me from a percussion performance major to an aspiring organic chemist.



Kinship Between the Kingdoms

Hydrothermal Vents

By Darrin Schultz

Life has adapted to live in strange places. On land, humans have spread to the most barren of deserts and mountains, but are bested by plants and animals that can survive Antarctic winters, Saharan dunes, and the Himalayan massif. In the oceans, life flourishes even in the most extreme climate – around hydrothermal vents. Living in this aquatic Hades is akin to bathing in a pressure cooker full of boiling brimstone and caustic brine.

Monolithic spires rise up to 200 feet from the sea floor and disgorge dense jets of smoky, scalding black water, up to 750°F. At the base of these underwater volcanos, dense forests of tube worms host a bevy of other creatures: iron-mineral-scaled snails, giant clams, crabs, octopi, fish, squid, and more. These organisms have adapted to spectacular acidic and boiling conditions, but what do they eat? Light does not penetrate to hydrothermal vent depths of 3,000 meters, so there are no photosynthetic plankton to support the food chain, like in surface communities. Instead, these larger organisms feed on lush bacterial mats that grow like a watery grey mold on rocks and the backs of larger creatures.

But what do the bacteria eat? While there are not enough nutrients in normal seawater to support dense bacterial blooms, these bacteria feast on the dissolved sulfurous metals expelled by the "black smoker" hydrothermal vents. Many extremophiles, or organisms that live in extreme environments, synthesize carbohydrates using sulfur compounds as the driving energy source. This chemosynthetic process is comparable to photosynthesis, in which plants instead use the sun to make carbohydrates. Chemosynthetic bacteria make all other life possible around the torrid hydrothermal vents!

Living around the vents presents unique challenges to these bacteria. First, they must produce enzymes and proteins that are active and stable at soaringly high temperatures, and at a dangerously low pH. These conditions would quickly denature, or 'cook' most other organisms. Because the bacteria are so well adapted for these extreme conditions, other creatures like the Pompeii worm have symbiotically employed them as a buffer to the harsh waters. The bacteria live on the backs of the worms in large, hair-like colonies and feed on secreted worm mucus. In return they provide the worm with food and thermal insulation from the extremely hot water.

These chemosynthetic bacteria sometimes even inhabit the guts of their host organisms. Giant tubeworms' red plumes are similar to our lungs; they use hemoglobin to carry hydrogen sulfide to the bacteria who use it to make food for both the bacterial colony and the host worm.

Unlike on land, where plants are ubiquitous, every region of hydrothermal vent has a different form of chemosynthetic bacteria – each with a unique way to synthesize food. Hydrogen sulfide, iron, manganese, it does not matter what substrate is available: there is a chemosynthetic microorganism that is specially adapted to thrive. What is more, chemosynthetic bacteria have even been found kilometers into the earth's crust (piezophiles), inside of rocks (cryptoendoliths), or frozen in millennia-old ice (psychrophiles). Someday, we may find that life on barren planets resembles chemosynthetic extremophiles! Life takes seemingly unlimited forms, and through the slow creep of time, is able to adapt to even the most barren environments.

By Ben Garfinkel

Slivering amongst the flora and fauna of its hydrothermal home, the Pompeii Worm (Alvinella pompejana) is a sight to behold. Far derived from your backyard earthworm, A. pompejana's gills extend from its head like feathers from a fancy hat to soak up oxygen from the deep ocean waters while its ribbed body usually stays within its thin colonized tube. Despite being tucked away from predators, the worm quite a daredevil—A. pompejana is believed to be able to withstand temperatures in its tube of up to 176° F, making it one of the most heat-resistant animals on earth and a worthy namesake of the scorched Roman city of Pompeii. But how can A. pompejana manage to live in such a scorching environment? According to researchers, the only thing keeping A. pompejana alive are its grey tendrils hanging off its back like the roots of a sapling. Though they may look like mere decoration, these strands are in reality a multi-species consortium of Epsilonproteobacteria. These bacteria have specially adapted heat-resistant proteins, thus providing protection for the bacteria, as well as its worm host, against the searing temperatures of the vent.

While A. pompejana is much larger than its bacterial symbiotes, the bacteria are not hitching a ride. So why do they have such an affinity for the worm's back? Like an underwater slug (which is not a type of worm, it is worth noting), A. pompejana secretes mucus full of all the nutrients vital to bacterial survival on the ocean floor. Thus, the bacteria and the worm are entered into a symbiotic relationship, a partnership where two organisms aid in one another's survival. The bacterial assemblage provides A. pompejana with essential protection from the blazing temperature, and in return they receive room and board as long as the worm is living.

The armor of A. pompejana offers invaluable protection, but it only covers so much of the worm's body. The head of the worm is left unprotected, which means that it must avoid entering its tube head-first. While most of its time is spent in the tube, feeding is nonetheless essential to keep up mucus production for its bacteria, growth, and the production of reproductive cells. The worm primarily feeds on microbes that live on the vents; anything else would put up too much of a fight.

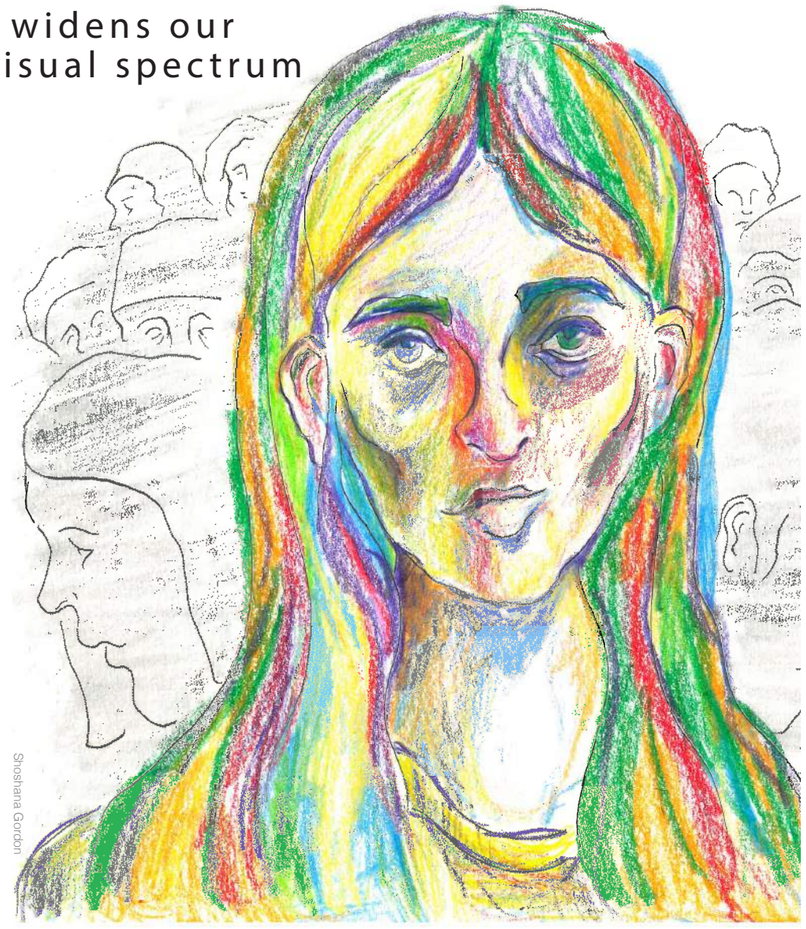
Unfortunately, no A. pompejana has never been brought to the surface alive, since it is only adapted to deep underwater pressure conditions. Undoubtedly, future research will help illuminate more details about A. pompejana and its amazing tolerance to such extreme conditions.

All Paintings by Hannah Daneshvar

Beyond RGB

a genetic mutation widens our perception of the visual spectrum

By Marisa Aikans



Shoshana Gordon

As children, we all wished that we had super powers. They could range from summoning a book with your thoughts to having lasers shoot out of your fingertips. This idea of super powers originally came from comic books, movies, and stories about genetically altered people whose powers went beyond normal human capabilities. In the modern age, it's possible that these abilities could be mimicked by technology. However, real super powers are the ones that don't need to be enabled by a gadget or gizmo. Tetrachromacy, for example, is an amazing ability recently discovered in some women that allows them to see a range of color 100 times greater than the average person.

Vision is made possible by two types of cells in the retinae of the eyes: cone cells and rod cells. Cone cells allow an organism to see colors; rod cells allow an organism to see at night and are crucial for peripheral vision. The majority of humans have trichromatic color vision, which means their retinae contain three types of cone cells activated by three different spectrums of visible light (red, green, blue). An organism is tetrachromatic if it has an extra type of cone cell that is activated by a different spectrum of light than the other three—usually somewhere in the orange-yellow spectrum. Interestingly, only females are capable of inheriting this rare genetic gift. The genes coding for the red and green cone cells are located on the X chromosome (the blue cone code is coiled up in chromosome 7, a non-sex chromosome). In a trichromatic female, each chromosome contains an identical copy of the normal red (R) and green (G) cone cells: RG, RG. In a tetrachromatic female, however, one of genes for the the red or green cones has mutated so that the cell will now activate under an orange-yellow (O) spectrum of light. The chromosomes now contain non-identical copies of the cone cell genes: RG, OG or RG, RO. The reason why men can't be tetrachromats is because they only have one X chromosome. Therefore, even if their red or green cone genes are mutated, they are still only able to produce three distinct varieties of cones.

A tetrachromatic woman can develop the ability to distinguish between colors with more precision than trichromatic individuals. Each type of cone can perceive approximately 100 different graduations of color in its given activation spectrum. Because those 100 shades are mixed and combined, trichromatic women are able to see approximately 1,000,000 distinct colors. A tetrachromatic woman, on the other hand, can see approximately 100,000,000 distinct colors. There are many other organisms that possess similar capabilities: zebra fish, mantis shrimp, and birds are all tetrachromatic organisms whose fourth cone cell can perceive ultraviolet light. UV light is 10nm to 400nm and is not visible to the human eye; scientists have always assumed that no mammal is able to perceive UV light because it is damaging to the eyes.

Actually, it turns out that there is one tetrachromatic mammal able to see UV light: the reindeer. Reindeer live in the Arctic tundra, which is completely covered with snow at all times. The sun's UV rays bear down from the sky and reflect off the snowy ground; the animal can't escape them. Reindeer's eyes have therefore adapted to safely perceive UV light, indicating that reindeer must have developed some form of retinal protection.

If researchers could identify a similarity between human tetrachromats and reindeer retinae, they could potentially find a way to genetically modify the human eyeball and make us able to safely see UV light. How cool would it be to be like Argus from DC Comics, able to see both the infrared and ultraviolet parts of the spectrum? Even if we never develop the technology to give super-vision to the general population, its still amazing to think that there are people alive in the world today who have the power to see a world 100 times more nuanced in color than anything most of us can imagine.

Solenn Morvan-Donohoe

Raeftus: Procreate or Perish

By Mia Dawson

We college students are getting to the age at which our parents may start asking loaded questions. "So, is there a special someone these days? Anyone new in your life we should know about?" What once may have seemed like an innocent inquiry is now a purposeful probe, a pointed accusation. Sure, you're doing well in environmental systems modeling, but are you taking the necessary steps toward one day creating a brand new human life that will bring meaning to your days and joy to the hearts of its loving, devoted grandparents?

If you are ever feeling unwanted pressure to reproduce, I invite you to consider the plight of a very singular captive turtle at the Suzhou Zoo in China. At least 80 years old, she is the last known female of the species Rafetus swinhoei. Commonly known as the Yangtze giant softshell, she has a worldwide fleet of herpetologists -- or zoologists interested in amphibians and reptiles -- eagerly watching and waiting for her to procreate.

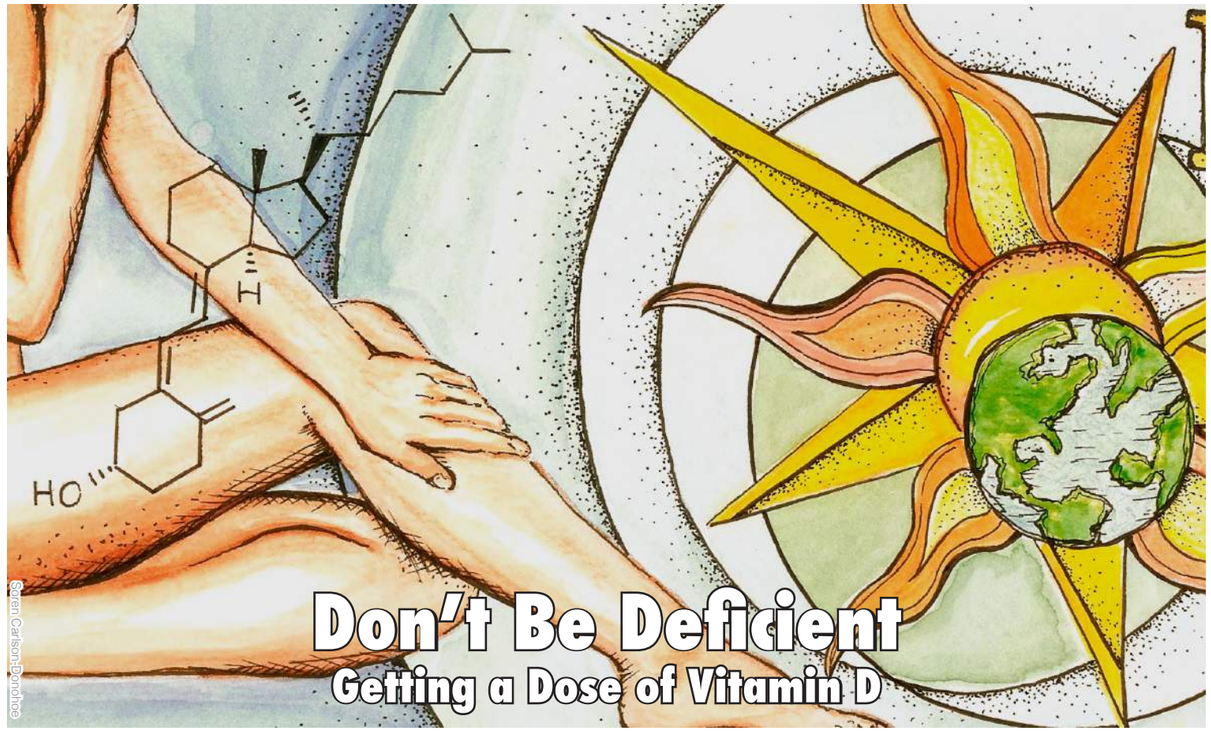
For this large, quiet, and rather shapeless animal, the attention is altogether new. The Changsa Zoo bought her from a traveling circus half a century ago, and she had spent many years there, unidentified, largely unnoticed, and alone in a man-made pond. When the U.S.-based Wildlife Conservation Society identified her as a Rafetus in 2008, the herpetologist community was overjoyed. Previously, herpetologists had only known of three living specimens, all of which were males – two wild and one captive. One resided in a lake east of Hanoi on private property. Another, living in Lake Hoan Kiem in Hanoi, was a hero of local folklore. The captive male Rafetus was a 100-year-old resident of the Suzhou Zoo in China.

Clearly, the discovery of a female was a game-changer. In an international collaboration, Chinese and American herpetologists decided that the female should be transported 600 miles to unite her with the captive male. Turtle biologist Peter Pritchard was one of the experts involved in the discussion.

"These turtles only get more fertile as they get older," Pritchard said, "and as long as nothing bad happens, they can live a very, very long time." So the prospects of mating an 80-year-old female with a 100-year-old male aren't as bleak as they sound. However, neither animal had seen another of its own kind in decades, and nobody was sure how the two would react to one another.

But, undaunted by their inexperience, the two turtles began to copulate almost immediately, and they have continued to do so since they were brought together in 2008. The female has laid several clutches of over 100 eggs. So far, however, none of them have hatched. Many of the eggs have had weak or cracked shells, perhaps resulting from a calcium-deficient diet in her years at the Changsa zoo. Now, she is being given calcium supplement, and being fed delicacies such as whole fish, crayfish, gutted quail, and chicken with bones .

Even if the female does produce offspring, the species is still in grave danger. After such a severe bottleneck event, any new population of Rafetus swinhoei will have virtually no genetic variation. Dr. Pritchard is hopeful, however, pointing to species such as the cheetah, Acinonyx jubatus, which survives despite its species genetic homogeneity. Furthermore, he thinks there is a chance that another female lurks somewhere in the lakes or rivers of Vietnam. Fishermen have told him of Rafetus swinhoei they've caught and killed as recently as five years ago, giving him hope that there are more in the wild. But for now, all hope rides on the back of one ancient and placid female; her ability to procreate could be a matter of life or death for her species.



Soren Carlson-Dundee

Don't Be Deficient

Getting a Dose of Vitamin D

By Sesha Nandyal

In the dark winter of 1791, after partially composing his Requiem Mass in D minor, Wolfgang Amadeus Mozart drew his last breath. Mozart's daily routine of practice, performance, and composition took place almost entirely indoors. Six months of each of his thirty-five years were spent in the dark Austrian winter, rendering his body completely unable to synthesize vitamin D from the sun's interaction with his skin. Many scientists speculate that his chronic deficiency in the vitamin caused his unidentified terminal illness.

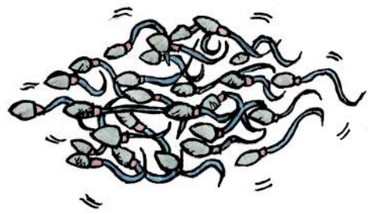
Vitamin D is a critical nutrient for the healthy functioning of our bodies. It is a modulator of cell growth and immune function, an anti-inflammatory agent, and a part-time regulator of apoptosis. Deficiency has been linked to breast cancer, prostate cancer, diabetes, rheumatoid arthritis, multiple sclerosis, and rickets. Our bodies, through a stroke of evolutionary genius, produce vitamin D when exposed to sunlight. Several recent studies, however, have brought to light a severe and pervasive worldwide deficiency in the crucial nutrient.

Many populations are vitamin D deficient because they live in high latitude regions, putting them farther from the equator and subjecting them to lower intensities of sunshine. In a recent Chicago-based study of 492 men, ages 40 to 79, 93% of African-American men and 70% of white males had vitamin D levels below the minimum concentration that meets basic health standards (30 nanograms per milliliter of blood). However, even in countries like Jordan that receive a lot of sun, 73% of young men and women in a 316 person survey were found to have less than 15 ng/mL of Vitamin D present in their blood. What could be preventing them from absorbing enough of that plentiful sunshine?

The answer may lie in the skin. The biological compound melanin is found in the skin and is responsible for pigmentation. Not only does it increase in concentration as skin color gets darker, it also inhibits our skin's ability to absorb sunlight. The more melanin present in one's skin, the less sun can be absorbed and the less the body is able to produce vitamin D. Evidence in the aforementioned studies supports this hypothesis; the African-American men in the Chicago study had Vitamin D levels significantly lower than those of the white males. In Boston, MA, another high latitude city, researchers found 73% of elderly black subjects to have insufficient vitamin D, while only 35% of comparable elderly white subjects were deficient. Elderly Hispanic subjects fell somewhere between the two.

Since it can be difficult to produce enough vitamin D through purely biological means, the IOM and the FDA make the general recommendation that all North Americans take in 400 International Units (IU) of Vitamin D supplements daily. The majority of Americans, however, are still Vitamin D deficient. This disparity may be partially attributed to the fact that people of different skin colors need to be taking different doses of supplementary vitamin D. The IOM is responsible for providing reputable health advice to a geographically and racially diverse society. Although race has no biological basis, melanin does; it cannot be ignored in addressing the health of people of color.

How can you make sure you're getting an appropriate daily dosage? Fortified milk contains only 100 IU of Vitamin D per cup, but a teaspoon of Cod liver oil, a piece of salmon, a gallon of orange juice, or one supplementary pill of 1,000-5,000 IU should help do the trick. When the sun comes out, put on a low strength sunscreen and catch some rays (those who are pale-skinned need not subject themselves to periods of exposure longer than an hour). Vitamin D deficiency is something that goes unnoticed in many parts of the US and the world, but it is crucial that people take it to be a serious component of their health and that the IOM guidelines treat a diverse patient base. Otherwise, we may end up composing our own funeral mass in D deficiency.



Lizzie Roberts

The Future of Male Birth Control

By Joe Dawson

Half a century ago, the advent of the birth control pill empowered women with the ability to control conception. Now, scientists worldwide are racing to develop a simple, effective birth control method, one that would enable male responsibility. By some accounts, a male 'pill' may be widely available in five years.

The difference between male and female chemical contraception comes down to biology. During the menstrual cycle, hormonal pathways lead the ovaries to release an egg that later implant themselves in the uterine lining. Once sperm fertilizes the egg, and thus the woman impregnated, the ovulation cycles halts. Female birth control may prevent one of those crucial events (e.g.prevents an egg from leaving the ovary) or may simulate a physiological condition (e.g. tricks the body into falsely 'thinking' that an egg is implanted). These birth control methods have limited side effects.

Male birth control is more difficult. Young males are always naturally capable of impregnating a female, whereas prepubescent girls and postmenopausal women are incapable of pregnancy. Thus, scientists have no natural condition to mimic when designing a male contraceptive. The most obvious hormonal pathway that can be manipulated in men is the spermatogenesis (sperm creation) cycle. At the beginning of the process,, the hypothalamus sends a hormonal signal to the pituitary gland. Hormones called gonadotropins in the pituitary gland travel to the gonads to start sperm production. Then, the testes produce testosterone, a hormone that stops the hypothalamus from sending its signal to the pituitary gland. A shot of testosterone to the hypothalamus, even in the absence of sperm would stop sperm production for the extent that the testosterone signal remains.

However, continually pumping testosterone into the body results in a number of undesirable side effects, including weight gain, prostate growth, liver dysfunction, and acne. Researchers counteract these side effects by incorporating progesterone, an active ingredient of many female birth control pills, into male contraceptives. Results have been mixed but promising in clinical trials of these formulations.

Some researchers focus on other ways to affect sperm production. In 2005, studies at the University of Massachusetts in 2005 found that sperm coming out to the testes have tails but cannot use them to swim until they have passed through the epididymis. The Cs protein works to turn on the swimming motion, so inhibiting the Cs protein could immobilize the sperm and work as an effective birth control method. One of the most promising therapies, currently the subject of clinical trials in India is Reversible Inhibition of Sperm under Guidance (RISUG). RISUG involves an injection of long-lasting gel that creates a plug in the vas deferens, stopping sperm on their pathway out of the penis. The chemical makeup of the gel also works as a spermicide, disrupting sperm membranes and further disrupting possible fertilization. The gel almost instantly renders men sterile, and has been shown to last at least ten years in tested subjects. The gel is less permanent and less invasive than a vasectomy, and can be reversed with a second injection that completely dissolves the plug. Clinical tests in India show success with the gel, resulting in no unwanted pregnancies and resulting in few side effects.

Scientific breakthroughs alone will not ensure a male contraceptive in the pharmaceutical market. Although RISUG was developed in India nearly thirty years ago, it is not yet available on the market because American drug companies refuse to fund the research; some even purport that it would be an economically defunct method of male birth control. Drug companies in America seem to want to produce a pill similar to the female birth control pill, both for familiarity and the idea of Americans repeatedly buying pills instead of one-time gel injections. Despite these complications, scientific progress is impossible to ignore, and the advent of the internet means that more American citizens will have access to information about new male birth control technologies. Knowledge is empowerment, and if informed American citizens lobby for male contraceptives, commercially available male birth control could appear on the market within the next decade.

Climate Change Quarrels

scientists sweat to make climate change research accessible

By Duncan Reilly

Climate change deniers have a mantra. It's a simple phrase they enjoy repeating, and for good reason: it's gotten them through many a rough spot without having to recant their claims. This mantra asserts: "there is no scientific consensus on issues of climate change." Between August of 2006 and October of 2009, a poll by the Pew Research Center found a fourteen percent decrease in number of people who believe in climate change, mostly swayed by those casting doubt on the science behind it. Unfortunately, for both informed discourse and the people making these statements, this particular mantra is blatantly false.

There has been very little doubt in the past few decades regarding the existence of a major climate shift that is clearly caused at least in part by humans. Much of the research, far from being the product of a few rogue scientists, has been conducted via simulations called global climate models, or GCMs. Hundreds of GCMs running on supercomputers around the globe are fed information about the current climate which they can compare to patterns in the past to produce predictions about future climates. By analyzing how accurately these results predict short term changes, scientists can then refine their algorithms to predict climates further on in the future with much more accuracy. These programs have been running since the early nineties, and by now are able to calculate average future temperatures with impressive precision. The data becomes still more accurate when one takes a combined average of the different models in use. This has been enough for the vast majority of the scientific community to endorse the idea of climate change, despite the efforts of a few to cast doubt on it.

One might be tempted to ask: who is promoting this belief, then, if not scientists? But the better question might be: who is paying the bills for the scientists writing on behalf of climate change denial?

The Cato Institute gives a singular, yet representative example of how denial research is produced. A Libertarian think tank, the institute has harbored critics of climate change science as a matter of course. Through funding research and promoting results, they have made climate change denial an institutional priority. Naturally, some of their researchers take more extreme positions than others on this matter. Most of their researchers, however, assert that the danger of climate change has been overstated, and that any attempt to counteract it would be a waste of money. The Institute, of course, has its own reasons for asserting this. Being a Libertarian institution, excessive public spending projects—such as those that will likely be required to counteract climate change—are an anathema to its members.

Furthermore, the institute is both founded and funded by Koch Industries. This corporation, established on oil money, still makes the majority of its profits through petroleum related industries. Given that their survival depends so heavily on that of the oil industry, it should come as no surprise that their interests preclude accepting climate science. Other groups, such as Americans for Prosperity, the Heritage Foundation, and the Manhattan Institute, have also received Koch money, along with 41 other groups that promote climate change denial. The vast majority of the research produced is shaped almost entirely by financial interest, and is of no use to the scientific community or the climate change debate as a whole.

A little more than a month ago, the scientific journal Climatic Change published an article by Robert J. Brulle, Jason Carmichael, and J. Craig Jenkins. In this article, the three researchers explored the extent to which different factors influence public opinion on climate change, and concluded that using information-based tactics to inform the public had a negligible effect.

Though the research currently being performed on climate change is important, it means very little to those with the real power to do anything about it: the American people. And after all, why should it? Only a small percentage of the public has access to the journals in which such research appears, and an even smaller percentage choose to read them. Popular media presents another option, but comes with problems of its own. Many newspapers are currently reducing circulation (in which case fewer people will see the science section), taking funding away from less popular divisions (which reduces the number of quality articles the science section is able to produce), or pushing content online (where readers must actively search for science-based articles instead of finding them displayed in a neat section). Television becomes more sensationalized every day, in part to keep up with dwindling attentiveness of its own viewers. What remains does not lend itself particularly well to impartial scientific coverage. The problems of modern media, however, are compounded by science's general inability to capture public interest the way it once did. This leaves scientists with the problem of how to effectively present climate change to the public. While any sort of fact-based approach to the climate change problem generally meets a lukewarm reception, the support of public figures has been found to be the most effective call to action.

Most readers will remember Al Gore's film An Inconvenient Truth, in which the former Vice President laid out, over the course of the film, a case for action to prevent catastrophic climate change. Perhaps Mr. Gore would be disenchanted with the American public were he to learn that seeing the trailer for his film was about as convincing as the film itself. The most disturbing aspect of this fact, however, is the susceptibility of the public to misinformation if it is delivered by a seemingly reliable source. Maybe in a perfect world every authority figure could be completely trustworthy, but the one in which we live is extremely imperfect. As cynical as it may sound, the future of our planet's climate may rest on which side can hire the best PR people. While moneyed interests levy firmly in favor of denial (preventing a worldwide catastrophe is, let's face it, quite expensive), research institutions will have to turn to other tactics. Here too, however, interest must be raised before any meaningful action can be taken. Few Senators have won elections by demonstrating an understanding of basic thermodynamics, and still fewer will should public interest sway more strongly against climate science. Both members of Congress and laypeople will need special appeals targeted at their own interests if they are to be of any help. Scientists might balk at making their findings simpler and presenting it to a more pedestrian audience. Some will likely talk of having to "dumb down" their research. Perhaps this word choice is completely appropriate, which makes it all the scarier that it might be the only tenable option left.propriate, which makes it all the scarier that it might be the only tenable option left.

Cleaning Kenya's Rivers

By Anna Dardick

Last semester, I conducted a four-week field research project in the Amboseli region of Kenya, focused on the decreasing water quality and quantity of the Noolturesh river system. Much of the problem can be attributed to changes in land usage. The local Maasai people, traditionally nomadic, have recently begun settling and farming just meters from the river. Agrichemical runoff, pumping for irrigation, and human waste runoff pollute the water. Locals drink, bathe in, and cook with water directly from the river – water that has never been boiled or chemically treated.

My research team assessed trends in land use changes, water status, and health through field-based assessment, local community interviews, and interviews with key informants including Maasai elders, clinicians, public health officials, a Water Resources Management Authority (WRMA) representative, and an agrochemical dealer. The field assessment had three components: assessment of human encroachment (farms and homesteads), characterization of soil erosion, and measurement of water turbidity (sediment load) along the river. Household interviews, conducted in three towns of varying distances from the source, focused mostly on trends in river quality, water quantity, water use, waterborne diseases, and agrochemical usage.

Most of the study area was comprised of farmland, not natural vegetation. Most plots featured rill and sheet erosion, likely from declining amounts of vegetation due to deforestation by farmers. Fittingly, higher turbidity corresponded with further distance downstream.

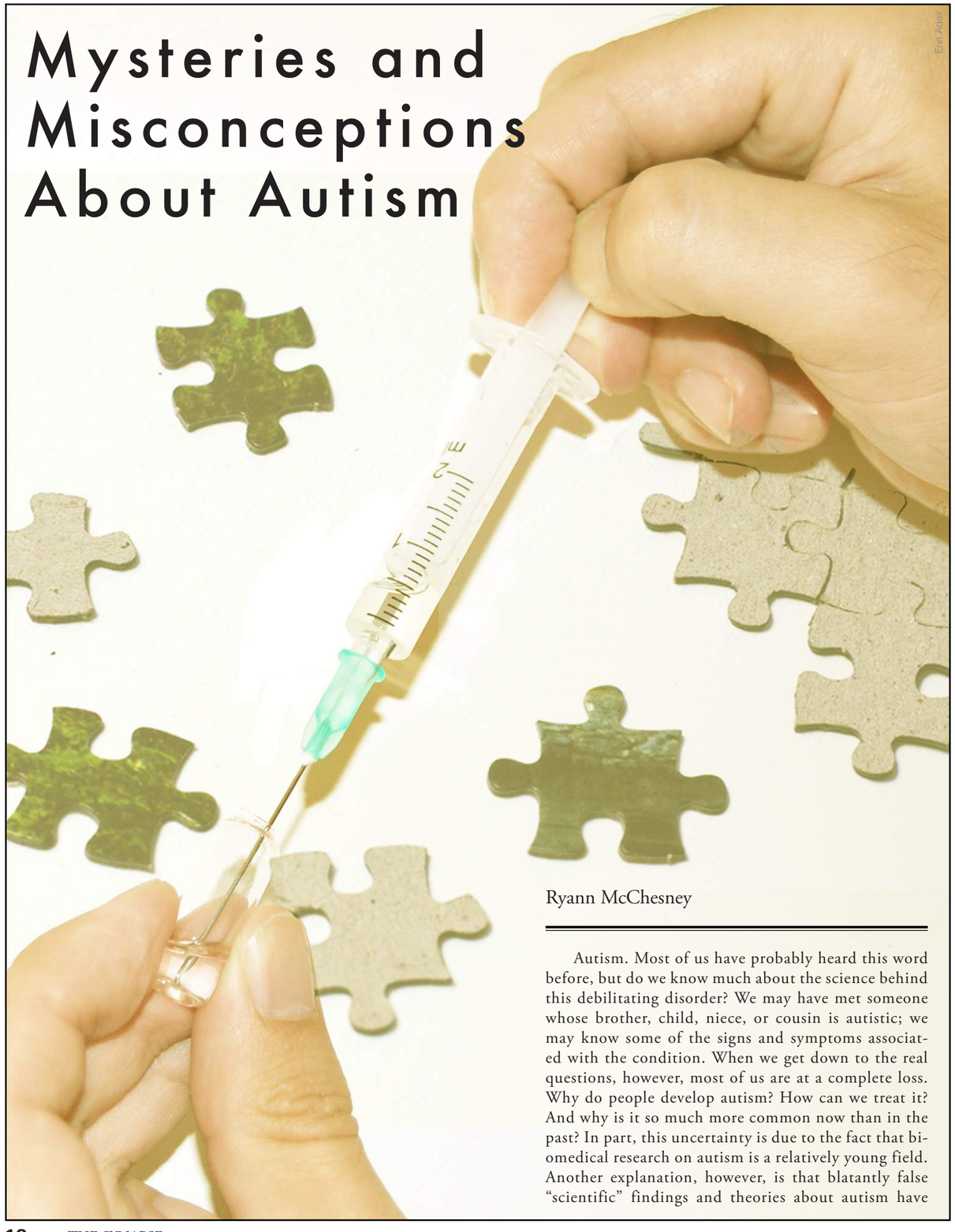
There is a significant and obvious trend in terms of water quantity – the further downstream a person lives, the less water there is for him to use. Approximately one pump was spotted every 1.5 kilometers along the river. From any one point, the quantity of water 20 kilometers downstream will be much less than the quantity 5 kilometers downstream, because there will be an estimated 10 pumps in between those two locations. The same pattern was true of water insufficiency, as it was more prominent in downstream towns. People in Olorika and Elang'atankimam, two downstream towns, were significantly more likely to have recently changed their water usage than those upstream, whether by lessening the acres irrigated or prioritizing domestic usages. As quantity suffers from the pipeline, increasing pumping, increased agriculture, and climate change, the people downstream will be the first to experience life-threatening dearth of water, perhaps to the point of obligatory relocation. In addition, downstream communities were significantly more likely to report instances of sickness, especially typhoid, from the water.

Interviews showed that most pastoralists water their livestock in the river, which poses serious health concerns to humans who drink and bathe in the water. Few of the homesteads in the study area had a nearby toilet (only 3 out of 46), which is indicative of the lack of sanitary facilities around the Noolturesh. Most people utilize the bush, and any waste the animals have stepped in on the way to the river is washed off into the water that people will then drink. Rains also wash human waste into the river. According to Maasai elders and a public health official, and corroborated by personal observation, the animals themselves also defecate into the river, adding even more fecal matter. Additionally, Maasai elders identified both solid and liquid human waste as concerns, especially since human settlements and farms are upslope from the river on both sides.

While collecting data, I observed a man measure pesticides using his bare hands. He stirred them with a stick, splashing the mixture onto his shoeless feet before pouring it into a spraying machine he would wear on his back. He washed the bucket in the river, filled it up with water, and washed his hands in it. Acute sickness from agrochemicals appeared to be minimal but chronic illnesses stemming from pesticide exposure had not yet been assessed. On hot days, farmers inhale the pesticides and pass out in the fields.

Declining quality and quantity of the river are likely due to human activities, such as a government-run pipeline to Nairobi that diverts most of the water from the source, removal of natural herbaceous vegetation resulting in increased erosion and sedimentation, pumps which extract water for irrigated farming, and agrochemical and human waste runoff. Unless locals are empowered with knowledge about sustainable farming practices, sanitation, and water-borne diseases, declining water status will continue to devastate local health.

Mysteries and Misconceptions About Autism



Ryann McChesney

Autism. Most of us have probably heard this word before, but do we know much about the science behind this debilitating disorder? We may have met someone whose brother, child, niece, or cousin is autistic; we may know some of the signs and symptoms associated with the condition. When we get down to the real questions, however, most of us are at a complete loss. Why do people develop autism? How can we treat it? And why is it so much more common now than in the past? In part, this uncertainty is due to the fact that biomedical research on autism is a relatively young field. Another explanation, however, is that blatantly false "scientific" findings and theories about autism have been common and well publicized since the 1960s. Some of the most devastating of these false claims have been in regards to the causes of autism and the success of novel "miracle" treatments.

> " While some arguments may seem ridiculous to us now, at the time very little had been uncovered about autism, and people were desperate for an explanation for their child's unusual behavior. "

Let's begin with some facts. Autism falls under the category of a pervasive developmental disorder: disorders that begin early in life and lead to severe impairments in relationships, communication, and various behavior. There is currently no known cause or cure for autism, although much research is being conducted in hopes of finding answers for both.

The etiology of autism is an area shrouded in mystery. There have been many different causes suggested in both the scientific world and the general media, but so far none have been shown to have a high level of reliability. In the 1960s, it was proposed that autism was a childhood form of schizophrenia, which resulted from poor or negligent parenting. Some experts believed that autism was the result of an infant's defense against maternal coldness while others believed that blame fell on parents who inadvertently reinforced outbursts by repeatedly ignoring their child's requests. While these arguments may seem ridiculous to us now, at the time these theories were published, very little had been uncovered about this disorder and parents were desperate to find an explanation for their child's unusual behavior. The second wave of media outburst on autism followed the 1988 publication of Andrew Wakefield's article in *Science*, in which he 'exposed' the measles-mumps-rubella vaccine as a cause of autism. Although his findings could not be replicated in subsequent studies and his article was later retracted, vaccinations are still wrongly cited as a cause of autism, and even today some parents continue to harbor fears about vaccinating their children.

Questions of increasing rates of diagnosis further enhance this sense of public confusion and paranoia regarding autism. With prevalence rates increasing from 5 per 1000 in 1998 to current rates of 1 in 110, it is not surprising that parents are searching for information on how to keep their kids safe. It is important to keep in mind, however, that the reasons for this increase may include factors such as an increased awareness of the disorder and more clearly defined diagnostic criteria. It is therefore quite likely that the spike in number of persons diagnosed with autism has nothing to do with an actual increase in number of people developing the condition, and merely improved diagnostic capabilities.

As of yet, there is very little we can definitively say about the causes of autism. There have been certain abnormal characteristics of brain growth and development which appear to correlate with autism, but no specific abnormalities in brain structure have been discovered. Twin studies conducted by multiple different groups also suggest that genetics do play a role in the development of autism, but no specific risk genes have been identified. New theories, however, are being continually proposed and tested, rapidly expanding our understanding of this complicated disorder.

Treatment of autism has also been an arena laden with false claims. The treatments proposed have varied immensely, but none so far has proven effective at eliminating all symptoms of the disorder. One treatment that gained popularity in the 1990s was a supposed method of enhancing the communication skills of autistics, in which a facilitator aided a subject to move their arm and type messages on a keyboard. This "treatment" was called facilitated communication and was hailed as a way to give nonverbal autistics a way to communicate with the outside world. It was hugely popular until controlled scientific studies began to test the efficacy of this treatment and discovered that the the well-meaning facilitators were unintentionally manipulating the typed messages to express their own desires. Another phony treatment once popularized was the medicinal use of the hormone secretin. Reported by Horvath et al. to improve language and social behavior in a few autistic children, it was briefly considered a miracle drug. Subsequent research, however, was unable to find any evidence that this drug led to improvements in either domain, and today this drug is no longer prescribed for treatment of autistic symptoms.

Although there is still no "miracle drug" for autism, there are many empirically studied treatment options that do help alleviate some of the symptoms. Currently, the most popular treatments are medications, most of which target behavioral symptoms such as aggression. These include antipsychotics such as Risperdal and antiepileptics such as Depakote. Other medications such as the SSRI (selective serotonin reuptake inhibitors) category of antidepressants are commonly prescribed to minimize repetitive behaviors. Furthermore, a number of therapies, including an intensive behavior modification technique known as applied behavior analysis, have shown extremely positive results for those treated early in life. Research on these therapies and behavioral treatments are gaining a great deal of attention and popularity, which will hopefully lead to more financial support and subsequent improvement in treatment efficacy.

There is still much to be learned about autism. Research in this field is becoming increasingly popular, and one can only hope that soon we will see the answers to some of our questions about autism answered. In the meantime, however, it is extremely important to remain critical of plugs for miracle drugs and emerging theories about causes. If there is no valid research to back them, such "discoveries" are likely to do little more than provide false hope.

Population Growth, Biofuels, and the Meat of the Future

By Duncan Reilly

How to Feed the 21st Century

There is not a problem facing society today that wouldn't be at least somewhat alleviated by ending world hunger, or that wouldn't be exacerbated by a failure to deal with it. With the population steadily climbing, climate change looming, and a corn industry turning an ever-growing percentage of its crop into fuel, the problems that stand in the way of a dependable food supply are social, political, and economic all at once. It will be the job of scientists, politicians, and laypeople to arrive at realistic solutions to them.

Population Growth

The United Nations' Department of Social and Economic Affairs reported in 2008 that the years leading up to 2050 would see the world's population increase to seven billion in late 2011, and to nine billion by 2050, with the vast majority of those new people being born in the developing world. Simply put, there won't be enough food for all of them. With climate change threatening to destabilize an already shaky system of food production, and no sign of a miracle cure to the problem coming soon, the ability to produce enough food for everyone will be one of the major factors in making sure that the population can continue to grow.

Improving the planet's food output might be difficult, but imagine the alternative: trying to control the rate of population growth. Spreading access to contraception will only do so much, and it is hard to believe that citizens of a democratic nation would accept a one-child policy like the one China has implemented. Barring some major depopulation event — say, a nuclear war, or a large-scale outbreak of antibiotic-resistant disease — the best bet is to shift the focus towards the food supply.

Climate Change

When considering the future, it is essential to think about not only how many people will need feeding, but also about the resources that will be available to produce the food. Climate change poses the most serious threat to agriculture; even if everything possible is done to decrease carbon emissions, it is likely that humans have already done substantial damage to the environment. A joint study by the International Centre for Trade and Sustainable Development and the International Policy Council considered the massive damage that climate change could do to agriculture around the world. Sub-Saharan Africa, for instance, is projected to lose an average of 12% of its grain farming capacity by 2080. Adapting globally, the study says, might require an excess of $170 billion a year, taking into account basic agricultural needs, finding clean water in increasingly dry climates, providing for public health, and infrastructure, among other things. Until climate change becomes impossible to ignore, this will be as big of a political problem as an economic one, especially in the U.S. where skepticism still prevails over climate science.

Corn

This past summer had more record high temperatures than any other recorded in the U.S., and few groups felt it more acutely than the corn farmers. It couldn't have happened to a more important crop — most foods in the average American kitchen have at least some sort of corn by-product in them, whether it's starch, corn syrup, or cooking oil. Also, most livestock is fed on a diet of corn and soybeans. All told, only about 12% of the corn grown in the U.S. is sold for direct consumption. If the summer of 2012 is indicative of future summers, massive and permanent increases in food prices all over the world would occur. People in the developing world would feel the strain the most. Though agriculture is heavily subsidized in the U.S., American agriculture still accounts for more than half of the world's grain supply. Any severe corn shortage could lead to food shortages of a global scale.

Compounding the problem, corn's use as biofuel has meant converting more farmland to a fuel source. Corn ethanol is much cheaper to produce than gasoline, and produces less carbon emissions. On the other hand, every acre of corn grown that's used for fuel is an acre of corn that cannot be eaten. Although recent studies by the World Bank, the Organization for Economic Co-operation and Development, and other organizations show that biofuels have not affected food prices as much as previous research has claimed, having to make the decision between food and fuel sets up two indispensable industries to be dependent on each other. If global industry reaches the point where it can no longer depend on fossil fuels, it will be necessary to convert an unsustainable amount of corn into fuel. Likewise, if the corn crops fail in large volumes, fuel prices could jump astronomically. Either one of these outcomes would be devastating to the global economy by itself; tying one to the other is simply too great of a risk. In the short term, corn ethanol has been an effective way to decrease gas prices, but given rising food demands the costs might outweigh the benefits in the long run.

The Meat of Tomorrow

Even more in need of an overhaul than the corn farming industry is the meat industry. A 1997 report by the Department of Agriculture found that livestock take up 80% of farmlands, and consume 70% of all grain, 80% of all corn, and 90% of all soy grown in the U.S. A study done around the same time by Cornell University revealed that the grain consumed by livestock could feed 800 million people. U.S. consumption of meat is about 5 billion pounds per year higher than it was in 1997, although fortunately it is dropping after peaking in 2007. Solutions here can be tricky. Those with the option to eat meat will continue to do so, and it is doubtful that public service announcements will stop people from ordering hamburgers.

However, some scientists think they have an answer. Using research originally done by NASA, dozens of labs are now working on creating in vitro meat. Instead of raising an animal for its meat, this research aims to grow tissue in a laboratory setting. A few stem cells are taken from an animal. They are placed in a protein-rich environment, and from there, are allowed to grow and divide into muscle cells. There is no theoretical limit to how much meat could be produced this way, and as any of the cells produced could themselves be used as cultures, an actual animal would only be necessary at the very beginning of the process. The process has yet to be perfected. No complex structures can be made (most experiments with in-vitro meat have looked more like bologna than steak), but someday, the process might produce meat more cheaply than factory farms do. The corn, soybeans, and grain fed to animals could largely go back to being used for human consumption. It offers other benefits, too, including cruelty-free meats that might appeal to ethical vegetarians.

Still, in vitro meat faces a few challenges. Nobody has proved that it could be done on a large scale. All the experiments that have happened up to this point have been too slow and expensive to make in vitro meat economically feasible. Currently, a single steak's worth of in vitro meat costs approximately a million dollars. Furthermore, most investors will wait until it seems likely to be profitable. Even if it can be done, consumers will have to accept it on a large scale for it to work. All of its benefits will come to nothing if people can't get used to the idea of eating meat grown in a petri dish.

Giving the People What they Want

Perhaps the greatest challenge of the next century will be getting used to the food of the future. People will eat what tastes good and what they feel comfortable with when given a choice, regardless of what it means to the future of the world. It is important to realize that there is much more than personal comfort at stake here, and as such, people will have to get used to eating foods that may be more and more removed from nature.

Generally, this is the easiest when people don't have to think about it. The vast majority of soybeans, for example, are genetically modified, but tofu still remains popular amongst organic food enthusiasts. Milk produced by cows injected with bovine growth hormones still sells well, mainly because it is not labeled prominently as such and is generally understood to be safe. Bread with preservatives sells well because, to the few customers that read ingredient lists, benzoic acid could be any number of things. The point here is not that consumers are ignorant, but that they are willing to put up with a great number of things they would consider unnatural in their food if their attention is not drawn to them. When the foods of the future are developed, scientists will need to ensure that they are safe, sustainable, and that they avoid any obvious ethical dilemmas. But above all, they have to be things that people will want to eat.

Decorative Deterioration

the science of fall colors

In the summertime, chlorophyll pigments in leaves absorb energy from sunlight for use in the synthesis of sugars. Since the pigments absorb blue and red light, the green light is reflected to our eyes, giving the leaves their characteristic green appearance. The sugar produced by the leaves is transported all over the tree, destined to be broken down for energy or incorporated into sugar based structures, such as cell walls.

As the nights grow longer and the days shorten, the lack of sunlight triggers the plants to cease production of chlorophyll, as the energy return diminishes. Simultaneously, the cold nights restrict the flow of fluids into and out of the leaves, leading to a local build up of sugars. The excess sugar is used to synthesize anthocyanins, pigment molecules that give leaves a deep red or purple hue.

Some species of trees do not produce anthocyanins, or produce only a small amount. For these plants, the dwindling presence of chlorophyll reveals other pigments called carotenoids that are always present in the leaves. Orange and yellow in color, carotenoids are found in many foods, namely carrots.

As the leaf dries out and dies, it becomes brown and crunchy. Most pigments have broken down, and the cell husk remains. As the cell dies, it begins a process in which many molecules, anthocyanins included, are linked together to make melanin - a long polymer that is brown in color. This process is identical to that of fruits, such as apples, that turn brown when left exposed to oxygen.

Ben Garfinkel & Daniel Slater-Stoy

Ben Garfinkel

Energy Drinks

Calling Bull on Taurine

By Connor McCleskey

Loaded with caffeine and taglines — "It gives you wings!" — energy drinks have rapidly emerged from relative obscurity into a $9 billion dollar industry that sponsors everything from soccer teams to space missions. These so called "dietary supplements" promise unlimited energy, weight loss, and even improved athletic performance, all while existing in a legal gray area unregulated by the FDA Since their rise to popularity in the late '90s, energy drinks have been plagued by negative publicity, yet a mix of savvy marketing and celebrity endorsements have allowed the industry to experience constant growth. In fact, many companies seem to capitalize on the danger surrounding their product, cultivating an "extreme" image with brand names like "Monster" or "Cocaine", appealing to risk-takers. News reports frequently cite the blend of unusual and imposingly scientific-sounding ingredients in energy drinks, such as taurine and glucuronolactone, as evidence of their danger. Although recent studies and media outlets have proclaimed these substances hazardous, the small amounts contained in each vibrantly-colored can have virtually no effect on the human body.

A British study conducted in 2001 found that drinking one can of Red Bull actually does improve aerobic endurance, memory, alertness, and reaction time when compared to placebos. The researchers concluded that "these consistent and wide ranging improvements in performance are interpreted as reflecting the effects of the combination of ingredients [found in Red Bull]." The manufacturers of Red Bull cite this study, among others, as evidence to support their claim that Red Bull "vitalizes the body and the mind."

Although each company claims to have a unique combination of ingredients, the composition of energy drinks rarely varies from brand to brand. Diverse taglines, brand names, and serving sizes aside, all energy drinks are composed of essentially the same four active ingredients in large quantity: taurine, caffeine, guarana and ginseng. For instance, a can of Rockstar contains 2000 mg of taurine, 160 mg of caffeine, 400 mg of guarana and 50 mg of ginseng — concentrations typically found in any other energy drink. Although the makers of Red Bull may try to convince you that each one of these ingredients serves a vital role in its effect, in reality many of these ingredients offer no tangible benefit.

Taurine, for instance, is an amino acid used by the body to maintain skeletal muscles and remove fatty liver deposits, which, in theory, could lead to greater endurance. However, to get even a slight effect from taurine — positive or negative — you would need to ingest at least several thousand milligrams, equivalent to drinking three or four cans of Rockstar in quick succession, which would also mean taking in a dangerously high dose of caffeine. Ginseng, included to increase immune function and stamina, is no better. Studies suggest at least 200-2000 mg of ginseng a day would be the minimum quantity needed to yield any effect, adverse or otherwise. As a typical energy drink contains 50 mg, the ginseng does not likely confer its advertised benefits. Guarana, an herb that is frequently peddled as an "all natural energy supplement," is actually just a small source of caffeine, insignificant when compared to the amount that is already artificially added.

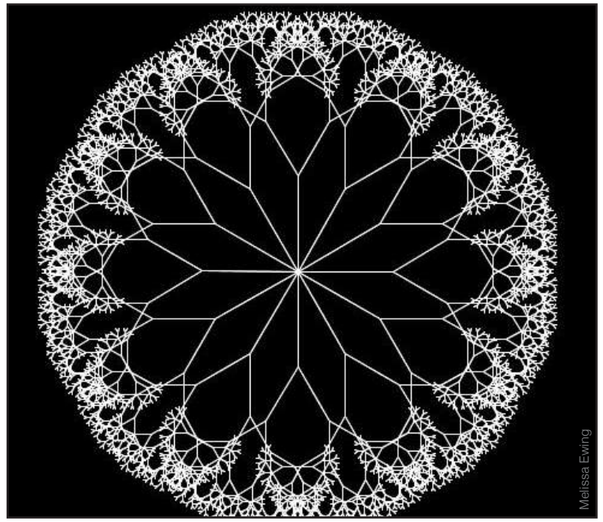
For all intents and purposes, caffeine is the only active ingredient in any energy drink. An 8-ounce Red Bull has as much caffeine as two cups of coffee, but squeezed into a much smaller package. So yes, it may give you wings, but the wings are made of caffeine, not some ingenious secret formula. Caffeine has long been known to lower heart rates, increase endurance, and improve cognitive functions when consumed in moderate amounts — the exact same effects that the British researchers attributed to Red Bull's "combination of ingredients." The other ingredients found in energy drinks, although you've never heard of them, are just a clever marketing ploy: an attempt to convince you to buy their product.

Though the more unusual chemicals in energy drinks may be harmless, caffeine can pose a big health risk. Though it increases memory and mental performance, caffeine also may cause insomnia, anxiety and heart palpitations, as anyone who's ever had a coffee-fueled study session can tell you. Caffeine is also an extremely strong diuretic, meaning it can easily lead to dehydration, sometimes with fatal results. Energy drink manufacturers have recently begun to target athletes as a consumer base, claiming that their product enhances performance and reaction times. This marketing practice was banned in certain countries, following the death of several adolescent athletes after they consumed many cans of Red Bull before their sports events.

Even without intense physical activity, energy drinks have the potential to be dangerous. Reading a list of the side effects associated with the drinks calls to mind those prescription drug commercials on television. You can almost hear the narrator hastily reading aloud: "Frequently reported side effects include seizures, birth complications, heart palpitations, and severe tooth decay." Drugs that have adverse effects like these would ordinarily undergo years of testing, be regulated by the FDA, and require a doctor's prescription, but anyone can buy a Red Bull at their local gas station. These dangers are very real, yet since the FDA have classified these chemicals as dietary supplements, energy drinks are not required to list them on the can. As hospitalizations related to the drinks among adolescents have been rising (there were more than 16,000 reported cases in 2008), this classification is likely to change soon. As more than half of these cases involve males ages 18-30, researchers have highlighted the risks these drinks pose to adolescents, particularly boys drawn in by the drinks' "extreme" image.

Despite these dangers, no one can deny that if you're in need of a quick burst of productivity, energy drinks get the job done. Yet, as the risks associated with frequent consumption become more and more apparent, the cost of this productivity must be considered. Personally, even knowing the side effects, I still find myself reaching for a can of Rockstar during finals season, simply because nothing else works as effectively.

"It may give you wings, but the wings are made of caffeine, not some ingenious secret formula."



Nature's Algorithms

By Veronica Burnham

Close your eyes.

Think about the veins under your skin. Picture a branching tree stretching towards the sky. Imagine the surface of a pinecone. What can similarities can you observe in the patterns of these images?

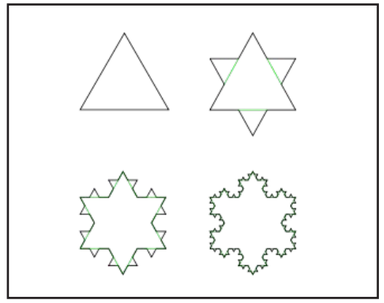
Go back to your mental image of the tree; start at the base of the trunk and work your way up until you reach the first branching point. Follow any one of the branches, and you'll notice that it, too, will eventually split apart. This branching continues until the limbs become too thin to support the weight of the tree's leaves. This sort of pattern is known as a fractal. Pinecones, veins, and tree branches, along with snowflakes and spiraled sea-shells, all feature distinct patterns of conformational repetition.

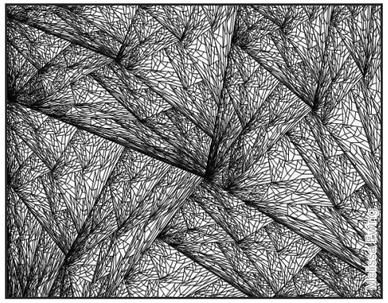
The tree's pattern of branching is recursive; that is, the branching is self-similar and follows the same basic rules at every level as each one becomes smaller and smaller, from trunk to bough to twig. Theoretically, in addition to being recursive and self-similar, fractals are also never-ending. Mandelbrot's set, one of the more popular visual fractals, is a pattern that goes on forever, its stopping point only determined by the artist or programmer's limitations. A video on YouTube, which currently claims to be the deepest zoom yet, magnifies the original image 2.1 x 10^275 times. As the video zooms, you begin to see repetition — within the larger shape are many smaller versions of the whole. Modeled by complex equations, fractals are continuous everywhere, but differentiable nowhere — a fun fact which can probably only be appreciated by someone who has taken a calculus class.

Fractals are not just abstract constructions of the mathematical world; they are found nearly everywhere in nature. Beyond tree branches and veins, fractal-like patterns can be found everywhere from lightning bolts to animal coloration patterns, from heartbeats to some types of broccoli. They are even present in certain animal behaviors. Recently, a study conducted by David Sims of the Marine Biological Association revealed that a number of predatory fish, including multiple types of sharks, use fractals to hunt. More specifically, they use a fractal pattern of movement known as the Lévy flight, in which the animal rapidly changes direction a set number of times, then swims in a straight line for one long period of time, and then returns to moving jerkily. This pattern repeats indefinitely. The movement is self-similar in the sense that the pattern would look the same at any scale, whether the animal is moving through 10 square feet or 1,000. Interestingly, there is a strong correlation between scarcity of food and a predator's adherence to the pattern: less food, more fractals. This suggests that this fractalline system of hunting is programmed into the behavior of these animals, and has arisen because it increases efficiency in hunting — especially in times of prey scarcity when conserving energy is a priority.

Another peculiar aspect of fractals comes from a 1967 study by Benoit Mandelbrot, the mathematician who first coined the term fractal. Mandelbrot created the famous Mandelbrot set (an intricate recursive pattern which is often used in fractal art), and was an integral figure in the early study of fractals. The paper, entitled How Long Is the Coast of Britain? Statistical Self-Similarity and Fractional Dimension, tackled this seemingly simple question and got a surprising answer. In his paper, Mandelbrot first explains the fractal qualities of the coastline's shape. First, it is statistically likely that any given part of the coast is a miniature replica of the entire coastline. This is true at any level of magnification. Second, Mandelbrot declared the coastline of Britain to be of infinite length.

The latter sounds like a highly improbable claim. How can a land mass which we can physically observe and measure in its entirety have an infinite perimeter? This strange observation is due in part to the intricate shape of the coastline. Let's say we start by measuring the coast in miles; we have a huge measuring stick that is exactly one mile long. We take that stick and place it end to end all the way around the island. A problem with accuracy immediately arises. If we are measuring with a straight stick, then each mile-long chunk of coast loses all the length it would gain from curvature. As we reduce our measuring stick — a yard, a foot, an inch, one tenth of an inch — our measurements get increasingly more accurate. However, since we





can theoretically shrink our measurement stick infinitely (via division) without ever reaching zero, our measurement of the coast will get infinitely more accurate. Thus, the coastline of Britain is infinite and can never be measured accurately with a measuring stick of any discernible length.

This phenomenon can be similarly observed in a common fractal known as the Koch snowflake. The Koch snowflake begins with an equilateral triangle. For every iteration, each discernable side is divided in thirds. The middle third is taken and copied twice, forming a small equilateral triangle latched onto the side of the original triangle. Now there are three mini triangles budding from each side of the original triangle (see image above for clarification on this process).

At first the image looks like a triangle, starts to become a star, and then begins to resemble a snowflake. With each iteration you increase the length of the perimeter, but once you get to a certain point, this increase is so small it makes no visible change in conformation and no discernible increase in area. With infinite iterations, however, you could magnify the shape continuously, resulting in an endless number of teeny-tiny sides. Thus, just like the coastline of Britain, this shape has an infinite length simply due to the fact that no matter how small of a unit you use to measure it, there will always be a littler one which could measure it more accurately.

Theoretical mathematicians are not the only party who have capitalized on the unique nature of a fractal's perimeter; engineers, too, have exploited the unique utilities of certain fractal patterns. One of the most striking examples of this is the use of fractalization to augment the function of antennas, especially portable ones like those found in cell phones and GPS.

Antennas serve to convert electricity into radio waves and vice versa. They are used to both send and receive radio waves by either radiating electromagnetic waves at a certain frequency or by intercepting these waves. Antennas transmit and receive information for everything from radios to televisions, wifi devices to cell phones. Each of these devices operates at a different frequency, which must be reflected in the length of each antenna. For example, a typical radio receiving both AM and FM information has two antennas. AM radio waves typically have a frequency of 100 kHz while FM waves vibrate at around 100,000 kHz. Because all radio waves travel at the speed of light, higher frequency indicates shorter wavelength. The length of the antenna you need is thus inversely dependent on the frequency – the lower the frequency of the wave, the larger your antenna would have to be. Typically, the length of the antenna has to be approximately half the wavelength of the radio waves—FM radio waves are typically about ten feet long, so about five feet of antenna would have to be coiled inside the metal sheath you see sticking out of many radios in order for you to listen to WOBC.

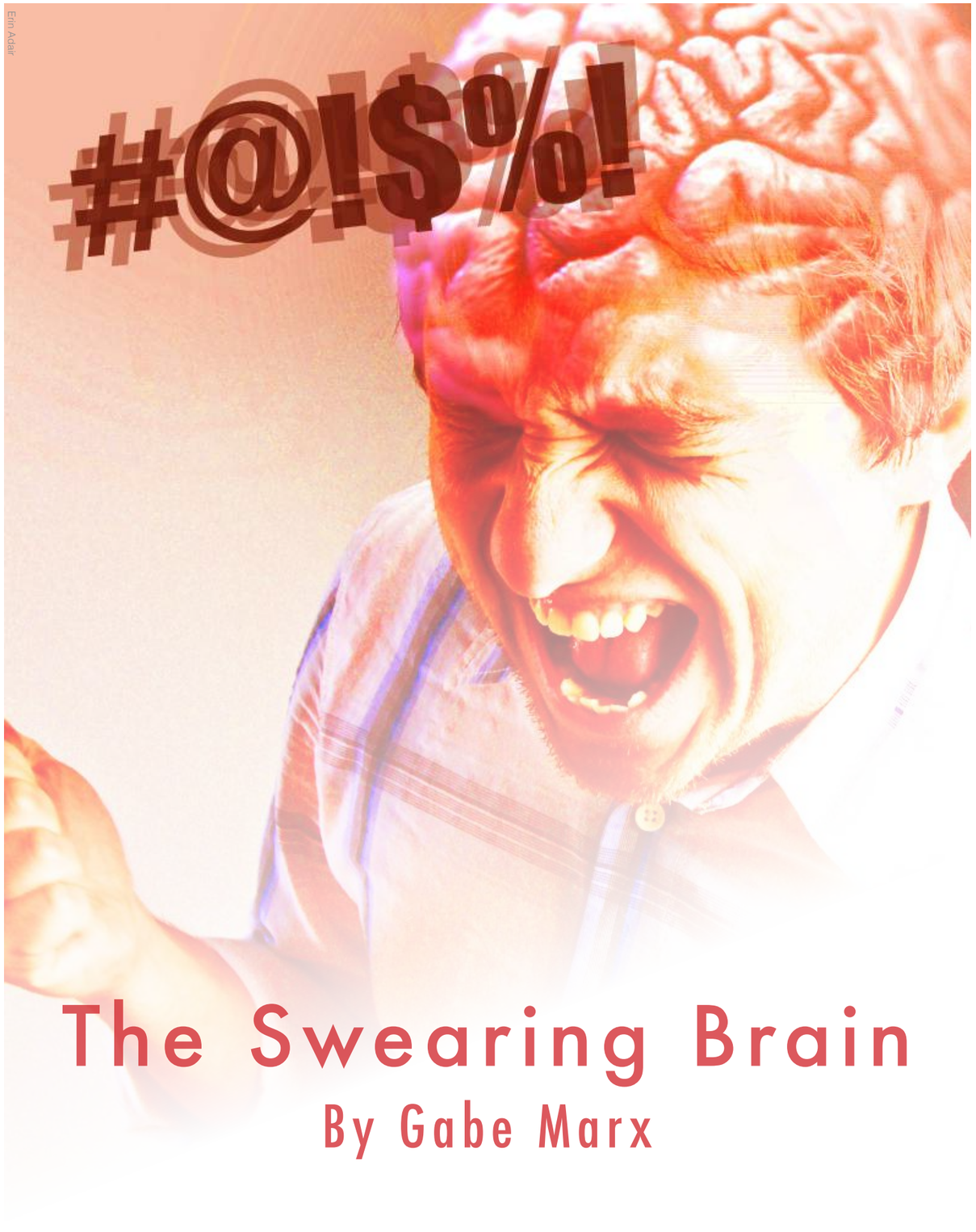
This phenomenon becomes a problem when an antenna needs to be extremely compact and when a device needs to receive waves at a number of different frequencies. As was the case with the Koch snowflake, fractal patterns allow shapes to greatly increase their perimeter while only slightly increasing their area. In the antenna world, this allows for tight packing of an extremely long antenna into a very confined space. Additionally, researchers have recently shown that fractal antennas allow for sensitivity to several different frequencies. It's like having multiple antennas all wrapped up into one.

Beyond being practical, efficient, and found nearly ubiquitously throughout our natural world, fractals have even managed to invade the human psyche. In particular, fractals have recently been found to dictate our preferences for certain visual aesthetics. This finding comes from a study conducted by a physicist, Richard Taylor, and was found while he was taking a sabbatical in the mid-1990s to pursue a master's degree in art history. Taylor's focus of study was one which made full use of his unique education – studying the mathematical nature of Jackson Pollack's modernist drip-paintings. He studied over twenty of Pollack's canvases, dating from 1943 to 1952, quantifying their fractal dimension. The fractal dimension is a measure used by mathematicians to determine how strictly a shape or pattern adheres to the classical definition of a fractal. For one-dimensional fractals (2D shapes, i.e. a branching line or Sierpinski triangle), the fractal dimension rating ranges from 0.1 to 0.9, while two-dimensional fractals (shapes in a 3D plane, i.e. tree branches) are rated between 1.1 and 1.9, with a greater number in a given dimension indicating closer adherence to classical fractal qualities. Most fractalline shapes observed in nature are rated between 1.2 and 1.6.

Using this information, Taylor analyzed each canvas at numerous locations and magnifications – ranging from 1/10 of an inch to the whole canvas – to see if fractal patterns were present on multiple scales. Not only did Taylor find fractal dimensions, but his findings also seem to support the idea that Pollack knowingly implemented these self-similar patterns. His earlier works display fractal dimensions similar to shapes found in nature. Jack the Dripper's later paintings, however, involved more intricate patterns which gave rise to even higher fractal dimensions than normally seen in a one-dimensional fraction.

Taylor then took a look at how people reacted to Pollock's work in relation to its fractal qualities. After making a number of mock-Pollocks – some with a fractal pattern, some without – Taylor surveyed 120 people on which paintings they preferred. A whopping 113 out of 120 preferred the paintings made with a fractals in mind. A study later conducted in collaboration with the University of Oregon revealed that people are most aesthetically pleased by fractal images with dimensions between 1.3 and 1.5, nearly the same fractal dimension observed in nature.

At first, the idea that our world is filled with complicated, recursive mathematical shapes does not seem intuitive. However, on closer examination, it doesn't make sense for the world to exist any other way. The principle of Occam's razor states that "simpler explanations are, other things being equal, generally better than more complex ones". This philosophical approach has proven itself veritable time and time again in explaining the innermost workings of our universe. It would seem to fit in perfectly with the world of fractals: incredibly complex visual shapes and behavioral phenomena that can be boiled down to a set of simple rules.



Erin Adair

The Swearing Brain

By Gabe Marx

> “ Over time, a society’s fluctuations of values, morals, and beliefs are reflected in the content of its profanity. Historically, we can see clean words turning dirty and dirty words turning clean. ”

Profanity is a linguistic universal. Every culture seems to have some grouping of words that are deemed inappropriate or taboo. Ever since we were children, these words have been a forbidden fruit; their use is naughty and tempting, fun and wrong. Children will memorize an illicit catalogue of profanity long before they are even able to grasp its meaning. From a neurological perspective, research has found that taboo words activate the amygdala, an evolutionarily ancient brain structure that gives organisms their emotional stress response in high-stakes situations. This activation accounts for the emotional jolt that swear words tend to elicit when heard or read. As a result, swear words are much more salient to us than everyday words.

Swear words have an anomalous relationship with the brain. A study published in Neuroreport by Dr. Richard Stephens at Keele University found that subjects who repeated swear words were able to tolerate painful stimuli for an average of 40 seconds longer than subjects repeating a control word. If that doesn’t seem weird, consider this strange observation made about patients suffering from aphasia, a neurological disorder caused by damage to the brain’s left hemisphere language cortices. Aphasia patients, despite having lost the ability to coherently produce or comprehend language, still retain the ability to yell “shit!” when they stub their toe. No one is suggesting that there is some ‘profanity cortex’ in the brain; however, it is plausible that profane words are mentally organized in a manner that is distinct from the rest of the lexicon.

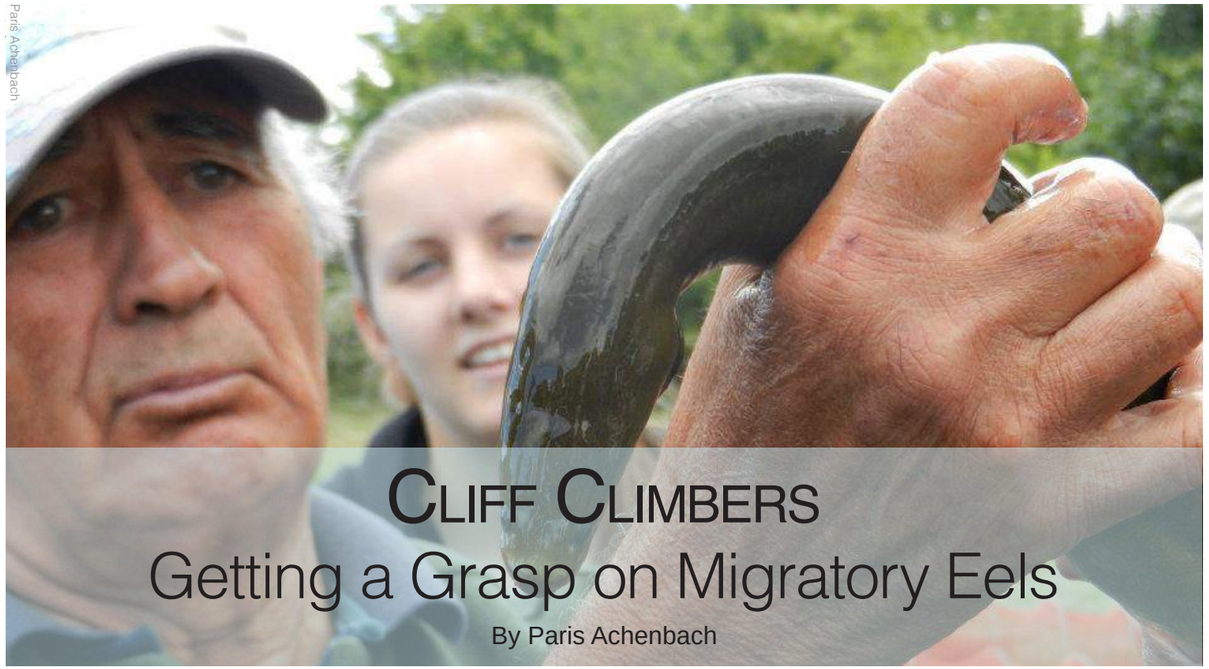
The greatest insight into the neurobiology of swearing comes from coprolalia. Coprolalia, or the pathological and uncontrollable urge to yell profanity, occurs in roughly 8 to 30 percent of Tourette’s Syndrome patients. For individuals with Tourette’s, these vocal tics are a response to an overpowering urge—similar to a mounting desire to scratch an itch or yawn, but much more intense. Tourette’s is a disorder caused by misfiring neurons in a region of the brain called the basal ganglia. The purpose of the basal ganglia is to coordinate voluntary motor control and regulate the way animals learn routine behaviors or habits. Popular theories suggest that the basal ganglia is critical for helping the brain decide which of several actions to execute at a given moment. Furthermore, it is also the responsibility of the basal ganglia to inhibit the execution of these actions.

Ordinarily the basal ganglia can keep us from acting on our ‘bad’ compulsions, but in patients with Tourette’s, the floodgates are open and the impulses that are normally kept quiet are able to assert their presence. As a result, patients may begin shouting words that lie in the off-limits category. However, there is nothing intrinsically bad about these words; it is society that deems them inappropriate. Coprolalia tics reflect a culture’s values - the content of our swearing is societally determined by what makes us uncomfortable. In more religious cultures, individuals with Tourette’s tend to have more religious tics than those that live in more secular cultures. Tourette’s patients in more sexually repressed cultures tend to have sexually vulgar tics; those in cultures with high racial or homophobic tension tend to have tics that are racist or queer slurs.

Over time, a society’s fluctuations of values, morals, and beliefs are reflected in the content of its profanity. Historically, we can see clean words turning dirty and dirty words turning clean. Modern English speakers would be appalled to read, “In women, the bladder is short and is made fast to the cunt.” However, this description would have occurred regularly in a 15th century medical textbook. Words have a habit of shedding their taboos as well. In 19th century America, phrases such as “drat”, “shucks”, and “Gee willikers” (defined today, respectively, as God rot, darn, and Jesus) were considered appalling and indecent. The fact that these words wouldn’t trigger a flinch if muttered over tea with your neo-conservative grandmother is a reflection of the incredible secularization society has undergone in the past 200 years.

There do appear to be some semantic categories of swear words that are prevalent in every culture. For example, words concerning the evacuation of bodily waste appear to be universal offenders. Some scientists believe that this is due to a biologically innate disgust with our bodily functions. In 2001, biologists Valerie Curtis and Adam Biran conducted a widespread survey throughout Europe, India, and Africa, and found that bodily secretions were the most widely reported elicitors of the disgust response in individuals. Feces, urine, and ejaculate ranked top on the list. Curtis and Biran contended that it is not a coincidence that these substances are also the most dangerous mediums for disease. As the strongest component of the biological disgust reaction is a refusal to eat or touch the offending substance, they postulated that the evolutionary reason for it is to make us less likely to spread fatal infections. The disgust reaction doesn’t even require the physical presence of the substances; the mere thought of them is enough to summon repulsion, which is why it is unpleasant to hear the words describing them.

As much as the FCC would beg to differ, profanity is an innate, effective, and important functional tool of language. It relieves us of stress and pain, and allows us to diffuse aggression through nonviolent means. Expletives provide a fascinating window into the moral values of our society by representing concepts or objects that make us uncomfortable. Perhaps by embracing that which makes us ill-at-ease, we can come to be more understanding when someone’s actions violate our cultural taboos.



Paris Achenbach

Cliff Climbers
Getting a Grasp on Migratory Eels

By Paris Achenbach

It was the purest water I had ever seen: crisp, clean, and not a piece of sediment or grain to taint it. We followed this tranquil river upstream, as it wound its way through the North Island of New Zealand, until we began to hear a rushing sound. The noise became louder and louder, and right before I deemed myself crazy, there it was: At a 600-foot vertical drop, the Tarawera River came crashing over volcanic rocks into a glassy pool below.

The waterfall was awesome in every sense of the word, silencing every member in our party. Then, one of our study abroad program's instructors said something even more astounding:

"The eels can crawl up that, you know," he told us. "They migrate up and over that waterfall before they're even six inches long."

When people ask me how I – an Oberlin student, a geology major, etc – possibly wound up studying eel migration for five months in New Zealand, I think back to this moment: Standing at the base of the most epic waterfall I'd ever seen and trying to conceive how an organism could sliver and crawl its way up six hundred feet of gushing water. The scientific side of my brain (and the imaginative side as well) exploded with questions: How did they do that? Why did they do that? Eels migrate?? How is New Zealand so full of mysteries?!

Apparently, I wasn't the only one to wonder about the oddities of this species; I soon became exposed to a whole world of research, myths, and beliefs about the migration of "freshwater" eels. The term "freshwater" is perhaps misleading, because New Zealand eels are actually born in the ocean, thousands of miles away from any river or estuary, and migrate as wormy babies through some of the fastest ocean currents in the world. Once they reach New Zealand, they migrate up the rivers, over waterfalls, and into the cold mountainous lakes where they stay for approximately 40 to 100 years (preposterous, I know) and grow to be eight or nine feet long (also preposterous, and somewhat terrifying). Then, when they've reached maturity, they head back down the river, out to the Pacific Ocean, and all the way to Tonga, where they each have approximately one million offspring and subsequently die.

> Eels are bizarre, enigmatic creatures, especially in New Zealand, which itself supports a fascinating array of biological taxa.

It's quite the existence, to say the least. Eels are bizarre, enigmatic creatures, especially in New Zealand, which itself supports a fascinating array of biological taxa. There are three different species of freshwater eel in New Zealand, but nineteen worldwide; all of them make migratory journeys that could humble Chris Columbus.

The day after we hiked to the waterfall, my study abroad group had the chance to see migrating baby eels in action, with the help of an old Maori man named Billy. He led us down a little path on the river to the base of a hydroelectric dam and into a clearing that had a white, plastered tank and several buckets.

I peered over the tank's edge. Inside were approximately 1,000 baby eels, swimming and squirming and slithering over each other in the clear water. If I hadn't known any better, I would have thought the tub was full of lively ramen noodles. I stuck my hand into the water, and they all swam away; some of them climbed up the side of the tub, risking the lack of water in an attempt to escape to freedom. What the eels didn't know was that Billy was saving their lives.

Billy, a sun-kissed and crinkly man in his seventies, has carted baby eels in buckets over this hydroelectric dam once or twice a day, every day, for nearly half a century. Without him, all those eels would never make it to the lakes, and perhaps never grow to be much bigger than a noodle-y teenager, barricaded from their migrational destination by the dams.

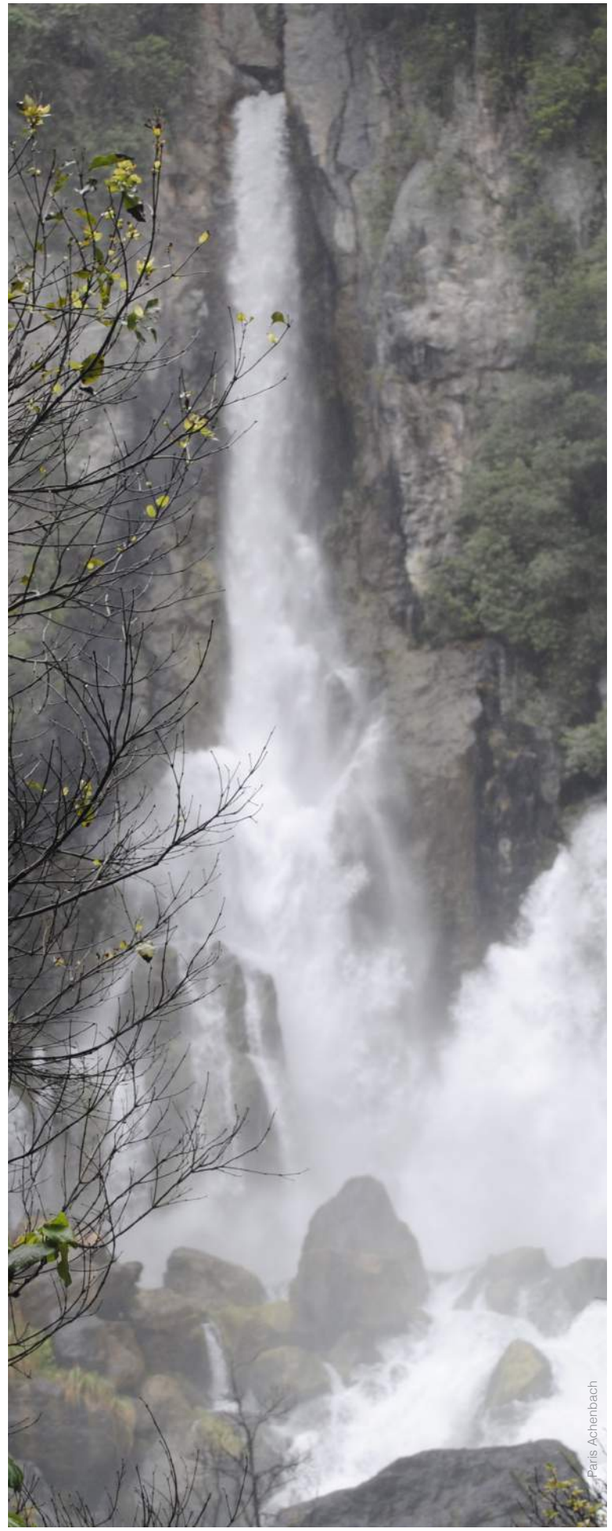
Despite Billy's daily heroic efforts, the eel population has been rapidly declining over the past few decades, in New Zealand and in the rest of the world. Billy has witnessed it himself; eels trapped and killed in hydroelectric dam turbines, with fewer and fewer turning up each year from the ocean. There's the additional problem of overfishing, and perhaps the changes in weather patterns associated with climate change, which could throw off the eel's migratory cues. No one knows for sure, though, not even scientists who have been studying eels for decades.

One positive in the otherwise dismal situation? The eels that get trapped in the turbines provide a great resource for scientists, who otherwise have a difficult time capturing and studying the evasive fish. There's a unique story that's imprinted in the bones of every eel – specifically in their otoliths, or ear bones. As an eel ages and travels through the oceans and rivers, it deposits a growth ring in its otolith; in that ring lies a specific combination of elements that reflects the environment in which the eel inhabited at the time. If there is a higher ratio of strontium to calcium, for example, then at the time the growth ring was made, the eel was probably still migrating through the ocean, because fish incorporate more strontium into their bones in saltwater than in freshwater.

For the rest of the semester in New Zealand, I dedicated my research project to this: eels, otoliths, migration, and the growth rings the eels deposit. I had two pairs of otoliths, one from a longfin and one from a shortfin eel, both of which died in a turbine in the Tarawera river. By counting their growth rings under a Scanning Electron Microscope (SEM), I was able to make estimates for how long they lived. Inevitably, I also found things I hadn't known I was looking for: strange pores in the shortfin's otolith, and distinct rings within rings – perhaps showing seasonal, or even daily, deposits in the bone.

Either way, my project proved to be challenging, and by the end, I seemed to be left with more questions than I had started with. How do we know that one ring is a "growth" ring, and not just a reflection of starvation, or a measure of the water temperature and pressure of the eel's environment? How do eels know where to go when they migrate? Are their migratory routes and timing determined by lunar cycles, climatological cues, or the Earth's magnetic field? And what if human actions -- through climate change, hydroelectric dam construction, or overfishing -- are causing their extinction? The eels left me conflicted: I was convinced that they were somehow performing magic and yet, clearly, as a scientist, I also know there has to be an explanation.

I left New Zealand to migrate back to Ohio with most of my questions still unanswered. Looking back, I sometimes wonder if it was even real – the pure water, the exhilarating landscape, the research of a nine-foot long slimy animal that so captured my interest. New Zealand and the eels seemed almost too mystical to be true, something that I must have made up. Yet they exist, continent and creature, as not just a reality, but a product of nature's vast and beautiful possibilities.



Paris Achenbach

MDMA

The Clinical Benefits of the Party Drug

By Cynthia McKelvey

In Europe and the United States, the drug known as ecstasy is a magic bullet that loosens the inhibitions of many dancers at all-night dance parties known as "raves." Ecstasy—or "Molly" in its allegedly purer form—is a psychedelic drug with a signature high that produces an intense sensory experience coupled with feelings of euphoria and closeness with others. However, ecstasy's tendency to raise body temperatures and dehydrate users in over-packed, sweltering clubs creates a dangerous situation that troubles parents and politicians alike.

Though ecstasy has been the culprit behind some tragic deaths since its popularization in the mid-eighties, death and injury from ecstasy are relatively rare compared to other drugs deemed schedule I or II controlled substances by the DEA. The number of emergency room visits per year resulting from the use of ecstasy are tens of thousands fewer than those due to the use of cocaine, heroin, and marijuana. Every year, the number of deaths from ecstasy are miniscule relative to tobacco- and alcohol-related deaths. Some experts believe that MDMA (3,4-methylenedioxy-N-methylamphetamine), the primary chemical constituent behind the ecstasy high, isn't the real danger of ecstasy. Instead, they believe that it is the crowded, hot dance floors combined with the effects of the many other substances ecstasy is famously cut or mixed with that puts users in danger.

Despite the risks, MDMA's signature high has not only entranced party-goers. The drug has also intrigued many scientists with its potential therapeutic benefits. In hushed sessions behind closed doors, therapists in the seventies and eighties began to explore the drug's ability to release patients from painful emotions attached to traumatic experiences and to strengthen the therapist-patient alliance. Although the anecdotal evidence was in favor of MDMA as a therapeutic drug, no placebo-controlled clinical trials had been performed by 1985, which was when MDMA was on the table for scheduling by the DEA. Due to the lack of clinical data, and MDMA's perceived dangers in the club scene, the drug was labeled as Schedule 1: a harmful drug with no medical benefits. All research on the therapeutic effects of ecstasy were halted for the next two and a half decades.

Nevertheless, MDMA has only become more ubiquitous among young people since 1985, and the cries to research the actual effects of MDMA on the human body have gradually swelled to a dull roar. However, the US and British governments have little to no precedent for funding studies on MDMA in humans. In 2010, Channel Four Television Company, a publicly-owned media company in London, endowed Professors David Nutt and Val Curran with funding to begin the first fMRI study of MDMA's effects in the human brain. David Nutt and Val Curran, Professors of Neuropharmacology at the Imperial College London and University College London respectively, are both well-known in the scientific community for their work on the cognitive effects of MDMA. The results of their study were broadcast live late last September in a TV special called Drugs Live: The Ecstasy Trial.

In the trials, conducted in September 2011, 25 volunteers came in for testing twice. Each time a volunteer came in, they received either an 83 milligram dose of MDMA or a placebo. The study was double-blind, so neither the researchers nor the subjects knew which drug each participant received. Thirty minutes after they took the pill, the volunteers entered an fMRI scanner, where they were monitored for 90 minutes while answering questions about their subjective experiences. Throughout this process, volunteers were also asked to recall positive and negative memories from their lives. After the volunteers came out of the scanner, they performed a task in which they rated the trustworthiness of various faces, testing their feelings of closeness with others.

Drugs Live features the experiences of five volunteers: an ordained priest, an ex-soldier, a journalist, an actor, and a former member of Parliament. The show itself consists of clips of the five volunteers' trials on ecstasy, interviews with them and members of the audience, a debate between David Nutt and his loudest dissenter, Swansea University's Professor of Psychology Andrew Parrott, short videos of recreational MDMA users out dancing or just enjoying a night in with friends, and a video of an illegal therapy session with MDMA. The program is punctuated by fleeting explanations of the results of the study, described by Nutt and host Jon Snow with the aid of a giant, plastic brain with flashing lights indicative of the various structures within.

The first major discovery presented in episode 1 is MDMA's effects on the neural circuit between the posterior cingulate cortex and the prefrontal cortex. This circuit is known to become overactive in people suffering from anxiety disorders and depression, and is believed to lead to the excessive rumination characteristic of mood disorders. Normally, the two nuclei fire in sync with one another, but MDMA releases a deluge of serotonin and causes the two nuclei to start firing out of line, hushing the circuit between them and alleviating anxiety, which leads to the characteristic euphoria of the drug.

After a clip showing a therapy session, in which a woman talks through her feelings towards her recently deceased, abusive father, Nutt walks toward the giant brain to explain how MDMA is helping this woman work through her traumatic memories. When a person recalls a traumatic memory, there is an activation of the amygdala and the prefrontal cortical region. According to Nutt, the prefrontal cortical region modulates the emotions associated with a particular memory, and MDMA works to dampen the firing of that region. Without the chatter of the emotional overlay, patients are better equipped to engage with and process those memories, making MDMA a particularly exciting potential therapy for post-traumatic stress disorder.

Effects of MDMA on Serotonin Levels

Neurons communicate with one another via chemical messengers called neurotransmitters that travel the space between two neurons called the synapse. Serotonin is an important and ubiquitous neurotransmitter that plays a role in diseases such as depression and schizophrenia. Many of MDMA's psychological effects are thought to be a result of MDMA's effect on serotonin. The first main way MDMA affects serotonin is by binding to serotonin transporters on neurons that release the neurotransmitter. The binding of MDMA causes the transporter to change shape and allow MDMA to enter the cell. The new configuration of the transporter makes it receptive to serotonin molecules inside the cell, whereas before the transporter was closed off to internal serotonin. MDMA then pops off the transporter and serotonin hops on and is released out into the synapse where it can land on receptors on the surface of the other neuron. However, MDMA does not stop there. After it enters the serotonin-releasing cell it also finds sacs storing serotonin and breaks them up, allowing more of the neurotransmitter to bind to transporter proteins and be released into the synapse. While MDMA causes the flooding of serotonin into the synapse, it also inactivates an important enzyme involved in the synthesis of serotonin. It is thought that because it both enacts the release of serotonin and prevents its further synthesis, that MDMA causes serotonin depletion in neurons which may lead to the "midweek blues," or the infamous "crash" many people experience after taking MDMA.

Though the program opened with a claim of being politics-free, "unvarnished science," many viewers felt that Drugs Live was more of a "pro-drugs" circus than a lucid exposition of the science behind MDMA. Indeed, there was little discussion of the negative aspects of MDMA, including the "Tuesday blues" experienced by one volunteer in the study and the overall negative experience the ex-soldier had during the trials. There was also little air time for the debate between Nutt and Parrott, which some viewers with a scientific background were particularly interested in.

Perhaps the positive bias in Drugs Live is unsurprising to those who know David Nutt for famously suggesting that drugs like cannabis, ecstasy, and LSD were less dangerous than alcohol and tobacco while a member of the Advisory Council on the Misuse of Drugs. His comments were largely responsible for his subsequent firing from the Council.

Regardless of Nutt's personal opinions on illicit substances, the study performed in Drugs Live is still an exciting contribution to a sparse body of research on the effects of MDMA in humans. Many other studies on MDMA are funded by government agencies such as the National Institute on Drug Abuse (NIDA). These studies tend to be performed on animals with the intention of finding the harmful neurological effects of MDMA affecting human users. Such studies have shown significant depletion of neurons that produce serotonin that lasts for years after a single round of MDMA administration. However, these single doses are given intravenously over the course of three or four days. Critics say such dosages are not representative of how the drug would be administered in therapy (a low dose taken orally once or twice in a patient's lifetime), nor do they reflect how most recreational users take ecstasy (taken orally once or twice a month.)

Studies on humans are often relegated to surveying cognitive faculties in recreational users of ecstasy, using hair and urine drug tests to determine what sorts of drugs subjects have been taking. There are many criticisms of these studies as well, many citing poor controls for subjects who have taken ecstasy in combination with other drugs or alcohol. However, these studies still show many deficits in memory, as well as higher levels of anxiety in current and former ecstasy users, and foster skepticism for the therapeutic benefits of MDMA.

A viewer watching Drugs Live likely wouldn't catch the troublesome findings of such research on MDMA just from watching the few short minutes where Andrew Parrott attempted to explain it. This was one of many issues that commenters brought up about Drugs Live after it aired. Some criticized Channel 4 for not giving enough credit to its viewers for being able to hold their attention on scientific facts for more than a few seconds. It seemed as though the content of Drugs Live wasn't much different from that of ecstasy found on the street: very little thorough potent science adulterated with an abundance of questionable filler.

All Illustrations by Hannah Daneshvar

The Science of Aging

By Daniel Starer-Stor

There is no more universal human experience than ageing. All individuals who avoid freak accidents and medical catastrophes will one day grow old, become feeble, and die. For some, ageing is a grim march towards an inevitable death. Others view the process as natural – even necessary – and therefore not to be feared or despised. No matter your point of view, however, there are unambiguous ills that come with the ageing process; cancer, diabetes, dementia, osteoporosis, arthritis and cardiovascular diseases are just a few of the many disorders that await us in old age. In order to extend healthy living and to develop a better fundamental understanding of cell biology, researchers tackle the difficult questions of life, death and degeneration. However, science has only recently developed an understanding of the many pathways involved, and there is much work yet to be done.

In the late 1950s, Leonard Hayflick landed on a paradigm-shifting discovery – normal human cells only replicate a fixed number of times before they stop growth and eventually die. This number, now known as the Hayflick Limit, represents the first observance of ageing at the cellular level. Further research into the Hayflick Limit and attempts to find a molecular explanation led to an explosion of research into cellular ageing. From this, the first grand theory of ageing emerged, positing that ageing is caused by the gradual shortening of chromosomal DNA as a cell divides.

This gradual shortening occurs in a region of DNA known as the telomere. Telomeres are short, repeating sequences of non-coding DNA that are found at the ends of the chromosomes. With each division, the cell fails to replicate the very ends of the chromosomes, meaning that the telomeres get shorter as the cell persists. Cells that are at their Hayflick limits have extremely short telomeres, which cause cellular defense mechanisms to activate, eventually leading to cell death. Some cells, however, such as cancer cells, have been shown to have no Hayflick limit - they possess biological immortality, and can continue to replicate forever. This immortality comes from telomerase, a protein-RNA complex that elongates the telomeres and prevents cell death. The discovery of telomerase has brought about a new hope for life extension – the possibility of maintaining telomere length, possibly mitigating the disorders of ageing.

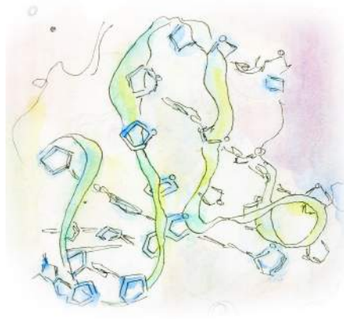
Telomere length and telomerase continue to play central roles in ageing science. A recent study by researchers at the Dana-Farber Cancer Institute showed that telomerase activity could rejuvenate mice that had exhibited signs of ageing. Mice without any telomere lengthening via telomerase experienced premature signs of ageing, including decreased cognition, smaller brains, and infertility. However, after increasing the activity of telomerase, these signs began to reverse, and the mice became significantly healthier. Such studies imply the possibility of telomerase activation as a human therapy to counteract ageing and age-related disorders, even after some damage has already taken place.

Not all scientists are convinced that ageing is caused by telomeres, however. Although telomeres reduce in size with age, the length of telomeres has not been found to correlate well with many age-related disorders, such as diabetes or Alzheimer's. Moreover, the theory fails to explain ageing in non-replicating cells, such as neurons or the smooth muscle cells of the heart, which are tissues that seem to be most affected by age. Incidentally, these cell types have more in common than the inability to divide. They also share a high need for energy and a corresponding high rate of metabolism. This is the basis for another school of thought, which holds that ageing is caused by the accumulation of damage due to metabolic dysfunction.

Metabolic dysfunction with age is implicated in a number of disorders, including obesity, diabetes, and atherosclerosis. On the cellular level, mitochondria drive our metabolic process by burning food to give us usable energy. A critical step in this process is the very favorable reduction of oxygen gas to make water, which provides a huge amount of the energy. Mitochondria can control this reaction, and use the energy to produce molecules that would otherwise be unfavorable. This is the basis for our metabolism, and the reason that oxygen is so crucial to our survival.

Every so often an error in the metabolic process leads to the production of a superoxide ion or other dangerously reactive oxygen species. Superoxide causes many problems for the cell, one of which is the mutation of mitochondrial DNA. If the right mutation is made, superoxide can start a vicious cycle in which the mitochondria produce more superoxide, leading to even more mutations. The mitochondria eventually become so damaged that they signal for the cell to begin apoptosis, the process of cell death.

For many years, nutritionists have advocated antioxidants as a method of extending healthy living. Antioxidants react with molecules like superoxide, neutralizing it and mitigating the damage that can be done. However, many antioxidants cannot get access the mitochondria. While they can stop damage from the reactive oxygen species that escape the mitochondria, they cannot stop



the vicious cycle within the mitochondria that will eventually destroy the entire cell. Cytoplasmic antioxidants may even be harmful, as they mask the presence of failing mitochondria, preventing signals that lead to the destruction of the old mitochondria and the creation of new ones

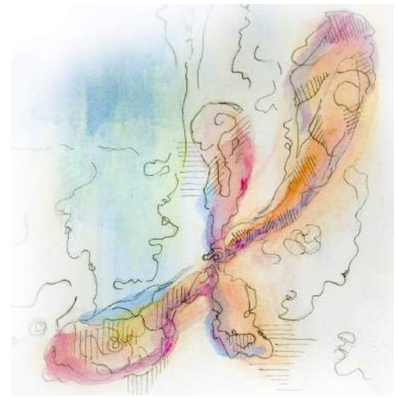
But not all is lost for antioxidants. MitoQ is a novel antioxidant that is designed to be preferentially taken up by the mitochondria. Current studies show promising effects on models of Alzheimer's disease, diabetes, and even Parkinson's disease. Clinical trials in humans, however, have shown mixed results, leading many researchers to focus their research on the tried and true methods of age extension.

The most publicized and universally accepted method for extending life spans is caloric restriction. Caloric restriction is not a simple diet; it involves at least a full 25% decrease in calorie intake, without any malnutrition. For humans, this would mean a 1500 calorie per day diet, still including adequate amounts of protein and vitamins. Although its efficacy in primates is debated, caloric restriction has been shown to extend lifespan in a wide variety of organisms, from yeast to mice. Many scientists believe that this phenomenon evolved due to the selective pressure to postpone breeding during times of famine. During these times, any new offspring will most likely die of malnourishment, and possibly kill the mother as well. If instead the organism maintains its youth and fertility throughout the famine, it will have the ability to pass on its genetic material when nourishment becomes readily available. Some scientists believe that the main health benefits associated with exercise come from the caloric restriction experienced during those periods.

Biologically, many mechanisms underlie the caloric restriction effect. The most notable of these is the sirtuin pathway, first discovered in experiments on yeast. Sirtuins are proteins which play a crucial role in the cell by detecting the oxidation levels in the cell, and changing gene expression to respond. Sirtuins can lead to expression of the genes required for the formation of new mitochondria. The cell then breaks down old and damaged mitochondria, leading to a healthier mitochondrial population. Since sirtuins rely on oxidation for signaling, antioxidants may actually 'trick' the sirtuins into staying inactive despite the failing mitochondria that surround them. Antioxidants may actually prevent the cell's natural mechanism to repair the root of the problem. This is one of the reasons that antioxidants may actually cause damage to the cell, if they are not targeted to the mitochondria.

The discovery of resveratrol, a sirtuin activator, has made a giant splash in the scientific community and in popular culture, as it mimics many of the effects of caloric restriction. Resveratrol is found in high concentrations in red wine, and may be responsible for some of the health benefits associated with it. Resveratrol is believed to be a plant defense compound, produced when the plant encounters pathogens or poor conditions. Some scientists believe that we evolved to recognize these stress molecules in plants as a signal of impending famine, and that we have developed pathways to recognize them so that we may get a head start on preparing ourselves. Although there are many studies in favor of the health benefits of resveratrol, some have come out in opposition, raising conflicting evidence regarding life extension in higher organisms.

Another major component of the caloric restriction pathway is the mammalian target of rapamycin (mTOR), a protein responsible for integrating nutrient, growth, and stress signals. mTOR is a potent inhibitor of autophagy, a process by which the cell digests its own components and salvages them for parts. By breaking down damaged mitochondria, the cell can prevent the vicious cycle that will eventually lead to cell death. Studies have shown that mTOR activity is inhibited during caloric restriction, which leads to an increased rate of autophagy and mitochondrial recycling. Many researchers believe that discovering mTOR inhibitors is the key to slowing the ageing process.



The first and foremost inhibitor of mTOR is rapamycin, the compound for which mTOR was named. First discovered as an antibiotic, rapamycin has been in use for some years as an immunosuppressant. Researchers studying rapamycin have noted that it leads to dramatic increases in the lifespan of a variety of organisms, including yeast, worms, flies, and mice. However, rapamycin itself is not a viable treatment – not only does it suppress the immune system, but it is also toxic to the lungs. While it is still unclear if these effects are related to the inhibition of mTOR, many researchers search for alternative inhibitors, in order to more safely mimic the effects of caloric restriction.

Therapies such as these might one day provide an escape from ageing, and an extension of healthy living. Counteracting the effects of ageing, however, will require a multifaceted approach. While more theories of ageing exist beyond that of telomeres and mitochondrial dysfunction, all of the theories fall into one of two broad categories: a programmed death, or an accumulation of damage. As researchers argue over which category predominates, an important evolutionary concept lies in the balance. Have we evolved to die, or is it just the byproduct of a complex system slowly falling apart?

Quantum Quilts and Mechanics Myths

An Interview With

Daniel Styer

John & Marianne Schiffer Professor of Physics

Daniel Styer is the John and Marianne Schiffer Professor of Physics at Oberlin College. Professor Styer teaches a number of courses in the Physics and Astronomy Departments, including Einstein and Relativity, Quantum Mechanics, and Electrodynamics. He is the author of a number of books, including Relativity for the Questioning Mind *and* The Strange World of Quantum Mechanics. *Professor Styer's research interests include: statistical mechanics, chaos in quantum mechanics and quantum mechanical time revivals.*

I feel I should preface this interview by saying I don't know much about physics.

I have to disagree with that statement. Strongly. If you know how to watch the world around you, you know quite a bit about physics.

Alright, let me rephrase – I don't have much classroom knowledge about physics.

Now there, there I'm happy to say that's true for many people. But I am upset when people say, "Oh I don't know much about physics. This is all way beyond me." It's not way beyond you, it's just day-to-day life except it's examined and pieced together so carefully that we find all sorts of things hidden just in day-to-day life. It's the greatest jigsaw puzzle ever invented.

You focus a lot on quantum mechanics, from what I've seen on your resume. Can you explain what quantum mechanics is?

Quantum mechanics is the framework of the science of very small things. I say framework in this way: when we talk about classical mechanics, we talk about the kinds of problems where you throw a ball or use a magnet or an electrical spark. Classical mechanics is not particularly concerned with what the force *is* — the idea is whatever the force is, classical mechanics will tell you what the motion is. So it's the framework, not the details, of what these forces are. Well, you would think that these rules of classical mechanics were developed to explain ordinary-sized things, and then it was applied to big things, like planets and moons. And it worked beautifully, though there was some who believed it would break down at the very large scale. I don't know if you know this story, but Newtonian mechanics were used to predict where the planets would be at a specific time, where you had to point your telescope to find Jupiter or Saturn or Uranus. Except, Uranus was not exactly where the calculations said it would be.

Does it have a different orbit?

No, it was just moving a little bit away from where everyone thought it would be. Many people, including the head astronomer in England, said, "Well that's because Newton's Laws do not apply over very large distances." So it was very good fortune that it worked for something the size of the moon, but it wouldn't for something as large as the orbit of Uranus. Other scientists said, "I bet there's another reason for this – it's not that Newton's Laws are breaking down, it's that there is another planet beyond Uranus." [John Couch] Adams in England and [Urbain] Le Verrier in France actually calculated the properties of this unknown planet, and told the other astronomers that, "If you point your telescope at this point in space at this time, you will discover a new planet." And they discovered a new planet. So what people thought was a breakdown of classical mechanics was actually a triumph – that you could, with nothing more than pen and paper, you could discover a planet.

Just from the gravitational pull.

Yes. They knew how Uranus deviated, and they calculated the location of this assumed planet, and it was there. And indeed, classical mechanics has been applied to larger and larger lengths, out to Uranus and Neptune, double stars and the rotations of galaxy beyond the Milky Way. And it could be that classical mechanics only works for human-sized things, but no one has been able to find the length at which it breaks down. So, to answer your initial question – you would think it would go the other way around, that it would work for dust motes and cells. It works very well for cells and large molecules like DNA. But it doesn't work for atoms or small molecules. Classical mechanics, when applied to things like atoms, gives results that simply cannot be right. And, just as before, the scientists thought, well maybe classical mechanics is right, there's just something like Neptune there. People tried all sorts of things. You know, if you have a system of science that works all the way from DNA to galaxies, you're not going to want to abandon it readily. But in fact, it was abandoned and we know this classical framework does not work for very small things.

And does anyone know why it doesn't work?

Ah! Well, the first thing is, why do you think classical mechanics should work for very small things?

Because it works for very large things.

I think it's a gift of unimaginable generosity that classical mechanics work so well for things ordinary size to such large objects. To expect it to work in the other direction is asking too much. The fact is it doesn't work. And I worried about the question you asked for a very long time before I realized, really, it's the other way around. As far as we understand, quantum mechanics works for things on all scales. Classical mechanics is a good approximation for quantum mechanics when you apply quantum mechanics to big things. But as far as we know, quantum mechanics is the fundamental idea and classical mechanics is the approximation, not the other way around, which is what I think you were getting at.

How does one go about conducting research on quantum mechanics?

There are a number of different and interesting questions, and they all have their own appropriate tools. I am particularly interested in time development in quantum mechanics, or how things change with time. Many people are just interested in the energies. I can understand that, because most of the time, it's difficult to come up with an experiment where you can actually probe how things are changing over time in quantum mechanics. You can't watch how an electron changes over time through a microscope. Nowadays, people are beginning to answer these questions experimentally, but for a long time, the questions were not accessible to experiment and people weren't interested. But I was interested in these questions even back in the day when they weren't accessible experimentally because I like to understand what's going on and not just be able to calculate to produce the answers. *[Styer pulls out a sheet of paper and writes an equation on it.]* There you go.

I don't know what any of that means.

You're not supposed to. This describes a single particle moving only in one-dimension with no forces acting upon it. So, I'm not talking about something as complicated as throwing a ball, or even throwing a football, where you would have to account for rotation. This is really the simplest problem you can imagine, but the solution has all of these parts. You can look at this in two ways. First, you could say, this is so messy and complicated, it's so yucky. Or, you could say, it's so rich, there's so much phenomena here. It's so simple in classical mechanics, and here there's just so much more to it. This situation, which in classical mechanics seems like a dot, in quantum mechanics is a richly embroidered cloth, with all sorts of intricate patterns and things you can explore and look at in more detail. So it's up to you if you want to take one attitude or another. I choose to look at it and say, "Yes, I want to explore this rich world of quantum mechanics." There are all sorts of phenomena that appear in quantum mechanics that simply do not appear in the day-to day world of baseballs and cars and trucks. My research has been focused on trying to pull out the qualitative character of quantum mechanics and looking at not just coming up with equations, but trying to come up with what these equations are trying to tell us.

> "As far as we know, quantum mechanics is the fundamental idea and classical mechanics is the approximation, not the other way around."

So, what research methods do you use?

Yes, you asked me that a long time ago. I'm a theorist. I'm afraid I really wanted to become an experimentalist, but I kept on breaking equipment and giving myself shocks and so forth. So I figured I was better off sticking to pens, pencils, and computers. I enjoy solving equations, but if you try to study anything more complicated than free particles, you have to use computers. I never like using computers by themselves, I like using them in conjunction with other arguments. So, I do use computer techniques. I don't imagine that my research is ever going to cure cancer or make better washing machines or whatever. But to me, it's the thing I least understand about physics and I would just like to understand it better. And I am fortunate that I am not paid by a large corporation, so even though I don't think it will ever have much practical application, I'm really excited about pursuing this

How did you come to teach at Oberlin?

I had always envisioned myself teaching at a large research university where I would have graduate students, because I am so excited about developing new knowledge and pushing the frontiers of knowledge. And when I was offered a job at Oberlin, I was disappointed. I had hoped to go to another, larger university, where there was more research going on and also lots of places to go hiking. That was my dream job, and had I been offered one there, I would have taken it. And I am very fortunate that I wasn't offered a job there, that I was offered a job at Oberlin. I loved then and I love now to teach. I look back on my life now, and I realize that [getting a job at Oberlin] was a very fortunate thing because the other universities are very big on getting research grants, bringing in graduate students and getting them out the door quickly. They are much more interested in productivity, and as I said, I am interested in problems that I want to understand. There is much less of a market for that in the world of earning grants and getting graduate students. So I am very fortunate that my dreams didn't come true because Oberlin is much better suited [to] the kind of person that I am and want to be. You want to know

Continued on Page 41

The Future Of Nuclear Energy

An Interview with **Kennette Benedict** OC '69

In addition to being an Oberlin graduate (OC '69), Kenette Benedict is the Executive Director and Publisher of the Bulletin of the Atomic Scientists*, an online magazine which seeks to bring news about global security and nuclear policy debates to a lay audience. Before heading The Bulletin, Benedict served as Director of International Peace and Security at the MacArthur Foundation. Benedict is also a member of the Oberlin College Board of Trustees and visited Oberlin last spring to participate in symposium "Fukushima: Lessons Learned?"*

What would you say is the Bulletin's main aim today, and how has it changed over the course of its existence?

Its main aim is to inform policy leaders and the public about the most powerful and dangerous technologies that we've invented. And I think it's changed a little bit since its early days, since it was set up to inform people about nuclear science and nuclear technologies. And since then, we've now discovered that there are other technologies that can change the planet, namely fossil fuel burning technologies, which, through scientific documentation, we've now seen can really change the planet.

You talked a little bit about some of the dangers of nuclear science. Do you think these are as significant as portrayed in the media? There's been a lot of misinformation after Fukushima.

In terms of the nuclear power industry? I think after fifty, sixty years, it's disheartening that we haven't been able to make these technologies safer. We've now had three accidents in about forty years, and when nuclear power was first introduced, people thought … there shouldn't be an accident in ten thousand years. Clearly we haven't gotten the safety part right. Some of it has to do with cost, some of it has to do with design, and some of it has to do with figuring out how to manage very complex systems, and we still haven't quite figured that out yet.

Can you talk a little bit about how we can make these systems safer? It seems, from the point of view of an outsider, that we're at the point where we simply wait for something to go wrong and then prevent it from going wrong again, but I'm sure it's much more complicated than that.

Yeah, we do kind of tend to fight the last war, or look at the last accident. There are different designs, newer designs, that could be put in place, that are what some engineers call passive safety designs, so that human intervention doesn't need to be applied to prevent a meltdown. And some of these designs have been on the books for a long time; in the pages of the bulletin, you'll find designs, or talk about designs for traveling wave reactors, which are now being developed by a company called TerraPower. The [designs] are different, but the idea is that you would prevent a meltdown from happening even if you lost the coolant. And the other idea is to put these underground … so if there were some kind of a release, the radiation would be released underground, which may bring other problems with it, but at least not the ones we've got now. Many of the ideas that have been talked about, though, are generally more costly than what is in place now, so one of the issues is how much are we willing to pay, and for what level of safety?

Is it only the cost issue that is preventing these designs from being put into place or are there other, more political factors at work as well?

Well, it may end up that we just don't know how to deal with this very dangerous technology. We haven't really tried hard enough to ensure that this is as safe as it can be. And other people will say well, coal-fired plants aren't as safe as they could be either. There are accidents in coal mines. In all other kinds of fuel sources, we have similar kinds of safety issues. I think the issue that's so difficult for nuclear fission is that we have to take care of this material, this spent fuel, for over ten thousand years. And the radiation is not something you can easily see, but it can have devastating effects. The problems are not just cost, but they have to do with … the length of time we need to protect and safeguard and make sure this deadly material doesn't cause damage to human society. So that's a major problem.

There was a lot of talk recently about fusion, more specifically cold fusion, when NASA released a video that some thought confirmed that they had seen a cold nuclear reaction. It's pretty clear at this point that that didn't happen, but do you see progress being made on that?

From what I understand from physicists who've worked in that area, cold fusion has been just around the corner for the last forty years. It's always been "there will be breakthroughs in the next five years" for forty years now. It seems, theoretically, to be a terrific idea, but it's been very hard to figure out how to actually initiate it. I don't think it's something we can count on for the near term. There are other things that could be, as power sources, put in place now that are more safe and less problematic than nuclear, like solar or wind; we already know how to do those.

And what would you say the future of nuclear energy looks like? It seems a bit unclear, what with it being, along with solar or wind, one of the few technologies we can count on for the long term.

Yeah, there are positive things about nuclear energy. After the initial construction the carbon emissions are nonexistent, and they do provide, as you say, base load electricity, which we need for economic development, not only in the States, but in China, in India, and the new emerging developing countries, and there are some advantages; that's clearly the case. But we have to weigh that against the disadvantages. The one most people worry about is the proliferation of nuclear weapons, which is truly a very dangerous thing. Another is the possibility of accidents, and now we've had several; we've experienced one even in a very mature nuclear industry such as Japan's. This does give people pause. And the cost, which for other countries besides the United States is not such a critical issue, because most of the nuclear industries there are publicly funded by the government. In the United States there are some subsidies, but really it's up to private industry, private capital, and they're finding it much too costly in terms of return on investments. And the final issue is what to do with the spent fuel and the waste. Nobody, except the Swedes now, has any practical plan for storing all of this, for until the sun goes cold, essentially.

Can you talk about their plans?

Well, they have now conducted, across Sweden, a number of discussions across municipalities. And they had a competition, and one of the cities won the contract for the depository. It's a process which involved the public, which I think has been missing in a lot of the discussion about safely storing nuclear power, especially in the United States. Settling on Yucca Mountain, at one point without getting the buy-in from the state and from the people who were living there was probably a mistake, and I think people understand that now you really need to get all sorts of folks involved, and that's what happened in Sweden. And so they now will put in place a repository that will store their nuclear waste material.

What's currently being done to prevent nuclear proliferation? What are some strategies that could be followed that aren't at this point?

The strategies I don't think are particularly well developed. The problem that we're facing now is not so much that countries are intentionally sending weapons, although North Korea has been involved in some stuff, working with Syria and some others. And of course, Pakistan was involved in getting weapons to North Korea. But the big focus now is on, and has been for years, this centrifuge technology, which as you know can enrich uranium to 3% for civilian nuclear power, but once you've got that, it's fairly simple to enrich it to 90%, which is what you need for a weapon. And in the Nuclear Non-Proliferation Treaty, there is a clause that says countries have the right to enrich uranium. An inalienable right to enrich uranium. But we don't have a very good way of regulating that. The International Atomic Energy Agency does quite a bit in overseeing that, but they can only do so much. They don't have a military force that will help them propose rules. So that's the main problem we're facing now, and that's the case in Iran and North Korea, that they're able to use the civilian-enriched uranium that we think Iran may be using for weapons. There are now in place two ideas. The first is to provide nuclear fuel to the nation in question; that's happening in the United Arab Emirates. In other words, the UAE is willing to take the fuel, have it put in their reactor, and have it taken out. They don't want centrifuges, they say, they don't want to enrich the uranium, they just want to take the fully enriched fuel and use it. The other is to have a multilateral, international fuel bank, where countries can come together and have a pool of fuel that can be called upon by a country. They don't have to enrich their own fuel, they can simply get it from this international agency, so there's oversight. Those are the two ideas. They haven't been fully tested, but there's at least some thought about a strategy.

At this time, there seems to be the need for a bridge between science and policy. How well do you think the Bulletin bridges this gap, and where do you see the need for other institutions like the Bulletin?

This is a time when science in the United States is not being as honored as it has in the past. Although if you look at public surveys, I think scientific institutions still get something like a 73% trust rating from the public, a little below the military and much above Congress. And yet, as we know, science hasn't been playing that much of a role in some policy areas, like on questions of climate change, for instance. But it's a very good question. I think the Bulletin has over the years, and still does, provide a credible, authoritative information analysis, and we know that congressional members read what we publish. The executive branch does, all the major agencies, the Department of Defense, the Department of Energy, the CIA, and the Intelligence Community all subscribe and actually look at the articles in the Bulletin. And we know that congressional staff members, John Kyl's office, Ron Paul, for instance, as well as Rush Holt and Harold Markey all at some points go to the Bulletin for information. John Kerry used the Bulletin's nuclear notebook to talk about the estimates of how many nuclear weapons Russia has, so the Bulletin does seem to be a trustworthy source of information, and we do try to bridge that gap, but it takes more than a small organization to do that. I think there are a few others who have been trying to do it, and they've had more or less success. The American [Association] for the Advancement of Science has had a center on science, technology, and security policy. The Federation of American Scientists, which was founded at the same time as the Bulletin, also tries to provide that kind of information. But these are relatively small centers, and to have a really major impact, we need to understand more about how congressional members want to see the information come to them and figure out how to make that bridge smoother and easier for them.

Interview by Duncan Reilly

Obie Alums: LIFE IN THE SCIENCES AFTER OBERLIN

Chelsea Martinez '02

By Anna Dardick

Chelsea Martinez has managed to capture, distill, and employ the essence of the Oberlin experience since graduating. While at Oberlin, she majored in Chemistry and minored in History and Math, but the jack-of-all-trades theme continued post-graduation. She has taught pre-algebra and chemistry at a boarding school in Virginia, switched to a public school in California, attained a PhD in Chemistry from University of Texas at Austin, interned at the LA Times Health section, and worked at the Office of Science and Technology Policy in Washington, D.C. She has now come full circle and currently works as a Visiting Assistant Professor at Oberlin.

Martinez did not ever think that she would come back to Oberlin to teach, although she acknowledges that many of her graduate school peers are envious of her Oberlin professorship. Martinez concedes that there are some differences between her student and faculty years at Oberlin, but "things are more the same than I thought they would be." She now works with professors who used to be her own teachers, markedly Michael Nee, with whom she took Organic Chemistry and Organic Mechanism and Synthesis.

Martinez's doctoral thesis focused on synthetic peptides: for example, construction of novel enzymes with made-to-order functions to catalyze a specific reaction. Although she researched in a lab that had a dual focus in organic chemistry and molecular biology, she favored the former for her experiments. She enjoys organic chemistry because "you have to do everything for yourself" – you synthesize your own compounds, set up and break down your own experiments, and you don't send away a compound to be analyzed at another facility.

Now, as a professor, Martinez revels in "watching people work out basic concepts" and "look at things from different perspectives." There's one hitch, though – "I hate lecturing," she says, smiling at the irony. Ideally, she would lead a class with "more conversations and more collaborative work."

Any advice for current students? "Take advantage of more things," she says, "Be as broad as you can." As a student, Martinez worked at WOBC, taught an ExCo about producing a children's radio show, and researched in four different labs, at Oberlin and around the country. Now, she encourages students to attend concerts and join clubs that are out of their comfort zones. "Take advantage of the people," she says, noting that she keeps in touch more regularly with her Oberlin friends than those from her other various exploits and studies. True to the Oberlin education and mindset, Chelsea Martinez has dabbled in a variety of fields and followed her passions in education, public policy, and organic chemistry. The only question left is: what's next?

Bruce McEwen '59

By Veronica Burnham

Before he was a prolific researcher with over 700 publications, numerous awards, and a picture of his smiling face on display in the glass case in the science center's Bent corridor, Bruce McEwen was a once a young, passionate Obie, traipsing through Tappan Square. McEwen, who is currently the Alfred E. Mirsky Professor of Neuroscience at Rockefeller University, is head of the the Harold and Margaret Milliken Hatch Laboratory of Neuroendocrinology. The research in McEwen's lab is focused on studying the effects of hormones on the mammalian brain, both physiologically and behaviorally. He is best known for his research on the actions of estrogen and glucocorticoids (stress hormones) in the brain, in conjunction with the modulation of memory, emotion, and neuroplasticity.

McEwen attended Oberlin in the late 1950s, and his story is steeped in Oberlin history. He credits his decision to pursue chemistry major to current Chemistry Professor Emeritus Norman Craig, who was then in his first couple years of teaching at Oberlin. McEwen's interest in the inner workings of the brain was sparked when he took a psychology class in his sophomore year. "I took a psychology course with Celeste McCollough, a young visual system psychophysiologist," explains McEwen, "who planted the seeds that led me ultimately to behavioral neuroscience." McCollough, Oberlin's first full-time female faculty member of the Psychology Department, is most well-known for her characterization of the "McCollough Effect", a now-widely explored oddity of human visual perception. McEwen began to explore research at Oberlin, under Professor Peter Jack Hawkins, on a project he describes as "an organic chemistry project that was distantly related to biochemistry".

When asked about his favorite part of receiving an undergraduate education at Oberlin, McEwen explains, " Besides the serious academic atmosphere, exposure to diversity of cultures … and the music and arts scene were very stimulating, and I acquired a strong social conscience that has guided my current interest in how deprivation affects the brain and body and what needs to be done about it in our society." This consciousness of human deprivation was to greatly color the rest of McEwen's career. After graduating from Oberlin in 1959, Bruce McEwen went on to receive his Ph.D from Rockefeller University. While at Rockefeller, he worked in the lab of Alfred Mirsky and Vincent Allfrey on the regulation of gene expression through protein-DNA interactions. McEwen himself was involved in studying "how cell nuclei get energy to make nucleic acids." McEwen received his Ph.D. in cell biology in 1964 and went on to complete a postdoc in Sweden, where he was first introduced to the study of the brain through a project involving neural proteins. Following a brief stint at the University of Minnesota, he moved back to Rockefeller University to join the lab of psychologist Neil Miller. In Miller's lab, McEwen began exploring the effect of hormones on behavior and gene expression, and the rest, as they say, is modern neuroscience.

Aaron Levin '68

By Lizzie Roberts

Careers in science writing don't necessarily begin with careers in scientific research. Aaron Levin is a self-described "writer specializing in science and medicine but interested in pretty much everything" who graduated from Oberlin in 1968 with a B.A. in history. From there he went on to pursue graduate study in classical archaeology and an M.A. in publications design.

Before plunging into the world of science journalism, Mr. Levin spent many years working as a professional photographer. Among his other assignments, he documented archeological research at several Mediterranean sites. His earliest excavations took place in Tel Anafa, Israel. He spent one summer working in Tunisia as a supervisor with the Oberlin Art Department's very own Susan Kane. He later spent several seasons as the excavation photographer at Pompeii and Paestum in Italy, and Caesarea in Israel.

His years working in Israel led to an extended photographic project documenting Israelis who took part in the country's struggle for independence in 1948. In 1998, he published a compilation of those black and white portraits and interviews entitled Testament: At the Creation of the State of Israel.

His launch into journalism occurred after earning his masters degree in publication design from the University of Baltimore in 1991. After being commissioned to write a few articles on cardiology and oncology, he discovered his bent for medicine and science. Mr. Levin has since contributed to a number of publications, from Journal of the National Cancer Institute and Drug Topics to Archaeology and Weight Watchers. After thirteen years working as a freelance journalist, he joined the staff of Psychiatric News.

Presently, Mr. Levin works as a senior staff writer, drawing most of his inspiration for articles from science meetings or reading journals. His beats include child psychiatry, military mental health, and disaster psychiatry, but he is also enthralled by neuroscience and genetics. "It's the future of psychiatry to understand what goes on in people's brains, beginning at the cellular and molecular level," he explains. "I try to cover them as much as I can."

Mr. Levin emphasizes that you don't need to come from a scientific research background to successfully pursue a career as a science writer. He knows some writers who have gotten their PhD's and said, 'I can't work at a lab bench anymore.' Others, like him, took a slower and more circuitous route into the profession. Not having an advanced degree in the sciences by no means held him back in his career: he is an active member of the National Association of Science Writers, the Association of Health Care Journalists, and a past president of the Washington DC Science Writers Association.

Interview: Styer

Continued from Page 37

why I came to Oberlin – it was dumb luck, but really good luck. And I have found all sorts of beautiful places to hike here.

So, hiking is one of your activities outside of teaching and researching?

Yes. Last summer, I hiked the span of Pennsylvania from Maryland to New York. And the summer coming up, I am planning on hiking the Colorado trail from Denver to Dorango. The summer after that, I want to hike the span of Idaho. By then, I'll be sixty and maybe ready to slow down.

Last question – what would your advice to students interested in graduate school and research be?

Well, the first thing is to make sure you are interested. You know, when you were five years old, you went to kindergarten. It was the natural thing to do. And then first grade through twelfth, and then the next thing was to go to college. And you're probably at a point now where you go, I don't know what to do, and it's tempting to keep on doing the same thing. Graduate school is very rewarding, but it's extremely hard. If you're not sure that's what you're interested in, I recommend you take a while to become interested. I spent two years between undergraduate and graduate school because I wasn't sure what direction I wanted to go. Even if you are sure, it might make sense to take some time off – how long have you been in a classroom? What percentage of your life is that? There is life outside of the classroom. I don't say that everybody should go to graduate school. The first thing is to make sure that is really what you want to do, because it is a lot of work and a lot of money. If you really want to, you can learn so much. You will be surrounded by very bright people who are very intense and on the cutting edge of their field. All of the students around you will be very sharp and all of the professors around you will be very sharp, and if you are motivated, you can lap up knowledge like no other. And the time, I spent in graduate school, boy, I learned a lot and it was a great experience. But it was a great experience because I was sure this was what I wanted to do and I was willing to work like a demon, which I did and was expected to. It was great, but if you're not certain, it can be very grinding down. There is a lot of work. And if you're not willing to see that work as fun, and if it isn't fun to you it will be very grinding.

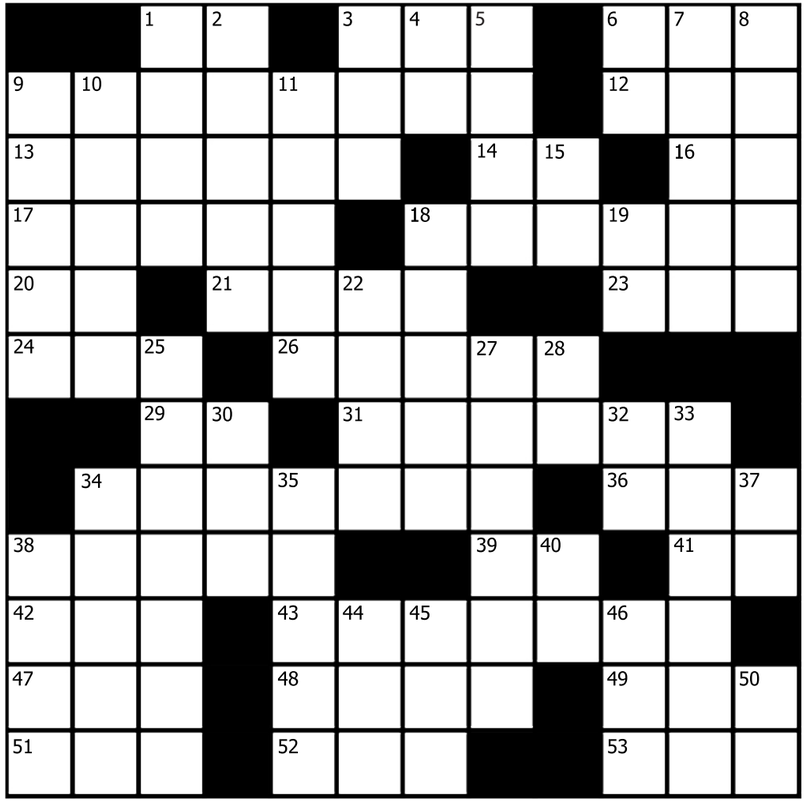
J: That's so fascinating. Thank you ftaking the time to let me interview you.

S: It was very nice talking to you.

Interview by Jessica Lam

Brain Benders

By Daniel Starer-Stor



ACROSS

1. Famous subject for memory studies
3. ___-Ray, DVD competitor
6. Detergent used with PAGE, abbr.
9. Enzymes, transporters, e.g.
12. "___ it in the bud"
13. An evolutionary concept introduced by Dawkins, or an image seen multiple times on imgur, e.g.
14. Direct, as opposed to alternating, abbr.
16. Molybdenum or Missouri
17. Noble, as a gas
18. Last name of the Oberlin Bio/CS professor duo
20. A quantification of bacterial growth, or to take a harmful amount of drugs, abbr.
21. A highly regarded scientific journal for biology
23. Wrath
24. National grant-giving science agency
26. Surfactants that are products of base-catalyzed lipid hydrolysis
29. What astrobiologists search for
31. Proteins involved in sensing light
34. Connection between two neurons
36. A program on your phone, or an alternative way to write ADP
38. Smallest ones in a litter
39. Northern part of MI
41. With 37-down, half of the day
42. Species of tree devastated by a Dutch disease
43. Of or pertaining to the heart
47. Graduate degree for a Creative Writing major
48. Prefix in dictating binding to iodine
49. Ball player from the Big Apple
51. _____ Andreas Fault
52. Isoleucine abbr., or a French island
53. Standard in data transfer cables

DOWN

1. Birthplace of Bill Clinton
2. Protein that binds rapamyacin
3. The smallest piece of information stored in a computer
4. Euler's logarithm, abbr.
5. American agency that certifies meat
6. Tin, or a class of RNAs, abbr.
7. Something composed of two subunits
8. The first cell in the gametophyte generation
9. The cause of Creutzfeldt-Jakob disease
10. Tears to pieces
11. Dean of Students at Oberlin
15. Symbol for the second halogen
18. Hits across the face
19. Titanium or a calculator co.
22. "For" or "While" to a programmer
25. Physicist Richard _____
27. _____-science, such as astrology
28. The metric system, abbr.
30. The explosive trinitrotoluene, abbr.
32. Sodium, abbr., or a dismissive reply
33. Zones, or objects an astronomer studies
34. _____-drugs, early antibiotics
35. Code used to represent text in a computer
37. With 41-acroess, half of the day
38. Specific parts of a sleep cycle
40. 3.14159…
44. Early internet service provider
45. Rotating disk electrode, abbr.
46. Unit of measure equivalent to a Da
50. Disease caused by mycobacterium infection, abbr.

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/syn·apse/ *noun* **the point at which a nervous impulse passes from one neuron to another**

The Synapse is a relay point of science-related information with a twofold objective. First, we aim to stimulate campus interest in science by exposing students to its global relevance and contributions. Second, we strive to facilitate collaboration between members of the Oberlin College community, especially within the math and science departments.