Vol. 7, Issue 2: Spring 2011

Columbia Science Review

Jellyfish Takeover
A Fundamental Change in the Food chain?

The Science of Caffeine
Coffee on the Brain

Graphene
A Scientific Magic Trick

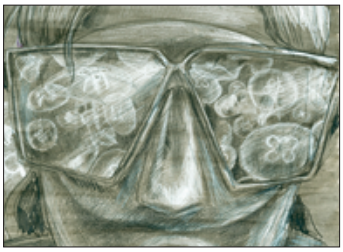
The Columbia Science Review strives to increase knowledge and awareness of science and technology within the Columbia community by presenting engaging and informative articles, in forms such as:

- Reviews of contemporary issues in science
- Faculty profiles and interviews
- Editorials and opinion pieces

Sources and credits for this issue can be found online at www.columbia.edu/cu/csr.

contact us at
csr.spreadscience@gmail.com

Columbia Science Review



Kelvin Chan
Emma Meyers
Grace Baek
Grace Wang

Cocktail Science

While many know Charles Darwin for his revolutionary theory of natural selection and evolution, scientists are now looking to a lesser known project of his, which may offer critical insight towards the future colonization of Mars. During Darwin's five year trip on the HMS Beagle, he found himself exploring an isolated volcanic island off the west coast of Africa. Ascension Island, as it is known today, was initially a near-barren land mass of poor vegetation and limited fauna. Seeing this, Darwin had taken it upon himself to create an entirely artificial ecosystem on the island. Currently, the island is populated by a multitude of non-indigenous plants. Full grown trees, which had not existed over a century ago, now trap the limited rainfall on the island. Clouds now hover over the island to trap the island's condensation. Scientists are now looking at Darwin's long forgotten project for hints at future terra-forming experiments.

Good news for Harry Potter: scientists have at last discovered the secrets of the invisibility cloak … sort of. Two independent research groups have recently discovered a way to use naturally occurring crystals to make 3D objects appear to disappear. Called a "carpet cloak," the seemingly magical crystal apparatus is made of the ubiquitous mineral calcite. Because of the special optical properties of calcite and the small bent mirror fixed in a notch at the base of the cloaking device, some hocus-pocus light bending makes the bent mirror look like a flat plane and anything tucked inside the notch disappears. This simple structure is a major improvement over earlier carpet cloaks, which were made of nano-sized fragments called metamaterials assembled with the help of lasers. But wizards-in-training beware, as of yet, the new and improved carpet cloaks can only vanish objects 1 to 2 mm in length, and only works when a light source is aimed from specific angels. Still, this technology presents a great deal of potential: not only can it make things disappear, it can be used in the development of new microscopes to reveal what still remains invisible.

The human body is a relatively self-sufficient entity, but there are certain compounds that it cannot produce on its own. One such group of compounds is omega polyunsaturated fatty acids, which can be found in foods such as walnuts and fish. Omega-3 polyunsaturated fatty acids aid in maintaining a healthy heart and brain. Recent research by Mathieu Lafourcade of The French National Institute for Health and Medical Research (Inserm) Magendie Neurocenter published in Nature Neuroscience has found evidence that an omega-3 (healthy) to omega-6 (harmful) imbalance may cause mood disorders. Omega-3 has already been used to treat adults and children for certain cases of depression, and the mice involved in the study with omega-3 deficiencies demonstrated depressive, anxious, and antisocial behavior. The mice were found to have malfunctioning presynaptic cannabinoid receptors, which help control appetite and pain. In addition, the levels of polyunsaturated fatty acids—like docosahexaenoic acid, the omega-3 that is most plentiful in the brain—in the mice were found to be abnormally low.

We've all heard at one point or another that the mighty cockroach survives everything. Recently, biologists have been looking into the science behind the idea. With antibiotic resistant bacteria on the rise, scientists have been investigating natural antibiotics; seeing as your neighborhood cockroach can live in just about anything, cockroaches have become the center of a new study. Researchers Simon Lee, Ian Duce, Helen Atkins, and Naveed Ahmed Khan from the University of Nottingham have published preliminary findings showing that a mixture of brains from American cockroaches (Periplaneta Americana) and desert locusts (Schistocerca gregaria) can kill more than 90 percent of certain bacteria. While the researchers also tested mixtures of muscle, fat, and haemolymph (the "blood" of these insects), these did nothing to prevent bacterial growth—and this was no ordinary bacteria. The team tested antibiotic resistant Staphylococcus aureus, a worrisome bacterium that is increasingly found in hospitals, and E. coli K1, which causes neonatal meningitis. Cockroach brains appear to contain antibacterial compounds, which, for better or worse, do not seem to react negatively with human cells. While it probably won't do you any good to snack on cockroaches when you're sick, there's no telling if the future holds cockroach-related antibiotics..

Privacy in the Digital Age

Kelvin Chan
Illustration by Allison Cohen

While many online social-networking sites and search engines are taken for granted, the price paid for them by users may be high. Users constantly and unknowingly reimburse these websites with personal information, a policy masked in the fine print and terms and conditions of the websites. These days, the most popular websites are indirectly funded by breach of user privacy.

Since the early days of web hosting services such as Geocities, websites have collected personal data by analyzing caches. Containing pockets of information, caches are stored in order to provide quicker repeated access to websites online. While these caches don't necessarily collect data, in principle, this invasive technique usually stores data without the user's permission. Today, caches and cookies are implemented by a multitude of websites in order to streamline a user's browsing experience. While these caches don't necessarily collect data, the practice of storing information without notice by the user is still considered unethical by some.

Cookies, however, are different. These pockets of information do store personal data. Every time a user returns to a previously logged-on site, cookies will automatically re-authenticate the user so he or she does not need to log-in again. In this case, efficiency is valued over security. The potential information cookies can store, however, is nearly limitless. For example, until recently, Google, set the expiration of cookies to 2038. Though the privacy policy has since been altered to 2 years, this is a small and relatively insignificant change as the expiration date resets with each new visit to Google.

Currently, notifications from the browser occasionally come up, warning users about the website collecting cookies. However, many users these days automatically accept them due to apathy or unawareness. Other times, the websites are set to use cookies by default. Thus, the potential of exploiting a user's lack of awareness in order to store information for profit becomes extraordinary.

Profit, however, must come from somewhere and the high cost of running a website is perhaps a motivating factor in the usage of cookies and caches. Although personally owned websites may cost only $10 a year, these sites rarely get the millions of visitor traffic that websites like Facebook or Google receive. Amazon alone, in 2008, paid over $86 million in server fees, not even including advertising or operating fees. And yet, these websites remain free for public usage.

Profit is earned in a number of different ways, depending on the nature of the website. Online shopping websites like Amazon earn money from the actual products they sell. In addition they increase cash-flow through the small commissions made when third-party sellers decide to sell items through Amazon in a similar system used by eBay. However, to increase shopper awareness, Amazon does make use of many cookies. Registered or not, Amazon will try to keep a tab on what products the users have been looking at. Using these stored cookies of information, Amazon will then try to pick recommendations for the shopper. Although this practice may seem harmless, when it relates to companies such as Google and Facebook, the implications are far worse.

Both Google and Facebook's main source of revenue originates from advertisements. Whereas Amazon uses cookies to target other products in its inventory to the shopper, Google and Facebook use cookies to target advertisements towards the user. In Google's case, whether or not the person has a registered Google account, Google will keep a tab of every search made on its website. In case you're unaware, when going into your Google account settings, you'll be able to find a catalog of nearly every search you've made since last registering. Even for unregistered users, the catalog is still there. These cookies, which are supposedly set to expire every 2 years as mentioned before, are reset each time the user visits the site again.

Utilizing these search results, Google would continuously update its Google Adsense (Google's advertisement technology) algorithm to better target advertisements to users according to the types of searches they make. Excluding the storage of cookies, Google is also known to keep tabs of every email sent from its Google Mail or Gmail site to, as mentioned previously, improve target advertisements to the user. This is stated quite transparently in Gmail's privacy policy page. In addition, deleted emails are also indefinitely retained by Google's servers. "Even if a message has been deleted or an account is no longer active, messages may remain on our backup systems for some limited period of time." Despite this, Google claims these emails are never read by humans, but merely by set algorithms in the system that target ads automatically. Keeping things in perspective, sites like Yahoo Mail and Windows Live Mail may do the same thing, though their privacy policy is actually far more ambiguous and unclear than that of Google. Eric Schmidt, CEO of Google, once responded in a 2009 interview with CNBC to privacy allegations by saying, "If you have something that you don't want anyone to know, maybe you shouldn't be doing it in the first place. If you really need that kind of privacy, the reality is that search engines - including Google - do retain this information for some time ..."

Like the practices of search engines such as Google, social networking websites such as Facebook rely on a similar practice. However, while Google only has access to the person's search queries, Facebook has access to the person's profile. Both Facebook and Google have appeared numerous times in the news, seemingly in breach of privacy policy. Facebook's controversies with News-Feeds and Mini-Feeds, pages of regularly updated statuses from various friends and mutual friends, as well as Facebook applications, have proved major points of contention. Third-party Facebook apps, which Facebook does not actively control, demonstrate many risks for the users. Examples include the game-maker Zynga, which is behind the popular Farmville, who was sued for providing the personal information of over 218 million of its users to various advertising sites, without user knowledge. Often, a poll or group will try to entice a user through a shocking or interesting group or poll name, only to trick the user into allowing the application access to the user's profile, and automatically spamming the user's friend's inboxes with ads. Undoubtedly, Facebook has been making efforts towards removing these types of scams.

Though Facebook is doing all it can to quash abuse of users profiles through third-party apps, Facebook's own actions as a business are not too different. The bottom line is: Information drives profit and knowing a user's identity and profile will help target ads towards the user. Thus, whether it's Google, Facebook, or some third-party Facebook app, many businesses will attempt to keep digging into a user's privacy in order to better target ads towards the user. The breach of user privacy is verging dangerously close with a business's profit, providing an inherent conflict of interest between user and company.

Though the intended benefit of privacy breaches are not always realized, it is only through these breaches, that Google attempts to make subtle improvements to its search database.. Google Buzz, Google's attempt at social networking in response to Facebook's dominance, faced immense controversy at its release. Initially, Google had decided to automatically "follow" every member in a Google user's contacts list, and at the same time, publicly reveal these contact lists to other registered users of Google. Although Google soon rectified the situation, it still demonstrated just how much Google knew about its users and how important privacy issues could be.

Google continues to face even more extreme privacy issues with its Street View feature to Google Maps. Recent litigations have raised the issue of taking pictures of private citizens and property, citing that the obscuring of faces is not enough. In fact, Austria has already banned the service with additional European countries considering its censure. Google recently admitted to accidentally recording fragments of user emails and passwords with its Street View cars, which are also designed to collect information about wireless networks.

Google Latitude, another service developed by Google, which shares user locations on Android phones, was also at the forefront of controversy. Search results are also targeted with ads from local businesses around the user's location. Since then, Google has made the possibility of sharing one's location optional and clear. Still, in 2007, non-profit organization Privacy International ranked Google among a selection of popular websites as having the worst privacy policy. Currently, Google has done much to address privacy concerns such as nominating a new privacy director of the corporation. Still, the numerous controversies over Google's privacy policy still exist. In fact, in February 2010, three Google executives were convicted of privacy violation in Italy while a suit against StreetView Cars led to a requirement that these Google cars be labeled and identifiable.

The fact that users drive the free services offered by large multi-billion corporations clearly demonstrates the extent of user apathy toward privacy. Despite this, over time, privacy controversies and lawsuits against these corporations have been more prevalent. Technically, there is an option for Google not to collect information just like there is an option not to publish information in one's Facebook profile. Yet, there is a reason why information collection is, by default, turned on in Google, and published by default in Facebook. Perhaps purposefully, such practices necessitate the user to navigate through the multitude of and confusing Google or Facebook privacy settings to turn the default settings off, whichwere only recently streamlined.

Information has become the new currency for these ad-based businesses. There has been an inevitable clash of user privacy and corporate efficiency. However, just as cookies that allow users to stay logged-on on a browser contribute to overall user efficiency, it can also be said that at the cost of privacy, Google is able to provide various convenient services ranging from the free Google Apps to Google Maps. However, at what point, does the cost of our privacy outweigh the cost of efficiency? With all these recent breaches of privacy allegations and cases, it seems companies are nearing their limit.

Helena (Hao) Wu
Illustration by Allison Cohen

The New Era of Bubbles

We have all hear of bubble economy, bubblegum, bubble bath, but do you know about antibubbles? Antibubbles are pockets of liquid enclosed by a thin film of air. These globules are the exact opposite of conventional soap bubbles, which are films of liquid enclosing air. The air film that covers the liquid is approximately ten nanometers, making the antibubble extremely fragile; the delicate air shell can easily collapse, causing the antibubble to pop. Consequently, the average lifespan of an antibubble is about two minutes. Possibly because of its short lifespan and rare occurrence, the antibubble was an unrecognized phenomenon until 1974. Since the discovery, scientists have found numerous practical uses for these bubbles.

Scientists have developed a long-lasting lubricant consisting of froth made from antibubble foam. This type of antifoam can also be used as a filter for air and other gases because antibubbles provide twice the surface area for gas exchanges and reactions than regular bubbles do. The antifoam can be useful for lubricating industrial machinery.

Other uses such as antibubble drug capsules and pollutant removers are being researched. An antibubble capsule would consist of a drug-containing solution surrounded by an ultraviolet light-activated liquid polymer. When the capsule is activated, the polymer shell would harden and thus create a medicinal pill. An antibubble capsule allows liquid-air interface chemical and biological reactions. This unique advantage makes antibubble capsules more versatile than traditional capsules. Another use of antibubbles is as a pollutant remover. Antibubbles are present in smokestack emissions control devices, colloquially known as chimneys. The toxic emissions are forced through the liquid solution with antibubbles and are dispersed into the environment in a much less concentrated form.

Because antibubbles have important applications, it is necessary to understand the chemistry behind them. Antibubbles form in a liquid containing a surfactant, a substance that lowers the tension of the solution. Most surfactants are structured to have double affinity meaning that they have a hydrophobic end and a hydrophilic end. The hydrophilic, or water-loving end of the molecule is oriented towards the liquid both inside and outside of the antibubble. The hydrophobic, or water-fearing end faces away from the liquid and traps an air film between the interior and the exterior of the liquid, thus creating an antibubble. The two sides must be closely balanced for the antibubble to exist.

Until recently, antibubbles were believed to be formed only from soap solutions consisting of common dishwasher fluid. However, recent studies have shown that antibubbles can be formed in Belgian beer. The beer contains a protein that makes the beverage a surfactant similar to soap. Various other types of surfactants, such as Ammonium Lauryl Sulfate, Cocamidopropyl Betaine, and perhaps even Belgian beer, may pave a new future for antibubble research. Prolonging the lifespan and improving the stability of these small wonders will benefit the many scientific uses of antibubbles. In the meantime, we can conduct some experiments of our own. The bubbles can be made in a bowl of dish soap solution. By steadily injecting a stream of soap solution with an eyedropper, you can create these bubbles at home.

Emma Meyers
Illustration by Evelyn Warner

The Science of Caffeine

It's 3 AM, and after a long day of class, practice, and work, any college student would be exhausted. But when the only thing separating you and your bed is your ten-page final paper, it's not uncommon to find yourself reaching for that can of Red Bull or double shot of espresso for the caffeine fix to get you through the night. 1, 3, 7-trimethylxanthine, more commonly known as caffeine, is the most commonly used psychoactive drug in the world. In fact, it is estimated that between 80 and 90 percent of North Americans are habitual users. But what exactly is caffeine? How does it work? And why are so many of us getting hooked?

The average cup of coffee contains about 100 mg of caffeine, and one or two cups of coffee a day is considered a moderate amount of the chemical. Tea and soft drinks have about 40 mg each. Energy drinks, like Red Bull and Monster, contain about 80 mg of caffeine per serving. When you consume a caffeinated beverage, the caffeine is absorbed into the blood stream from the stomach. It takes about 45 minutes for all the caffeine to be absorbed, but you can feel the effect when blood concentrations of the drug peak in as little as 15 minutes after consumption. With a half-life of 3 to 7 hours, caffeine keeps us going all day.

Caffeine is a psychoactive stimulant: a drug that works directly in the brain to rev up the nervous system and increase alertness. To keep you awake, caffeine interferes with the activity of a chemical messenger in the brain called adenosine. Normally, adenosine binds to its specific receptors in order to slow down nerve activity in the brain and make you drowsy. Because caffeine has a molecular structure similar to that of adenosine, when it is present in the brain, caffeine molecules bind to adenosine receptors, blocking the binding of adenosine. This process, known as competitive antagonism, not only prevents adenosine from slowing brain activity down, but also speeds up the rate of communication between neurons. The brain interprets this elevated rate of activity as a sign that there is a dangerous situation, and initiates the release of adrenaline, a hormone that controls the "fight or flight" response, getting the body ready to deal with threatening situations. Adrenaline increases the heart rate, tenses the muscles, and releases sugar into the blood stream for extra energy. This is why caffeine does not just prevent you from feeling sleepy, but also increases your level of alertness and gives you an all-around boost.

Not everyone responds to caffeine the same way, though. Sensitivity to the drug can vary, partly based on how much caffeine you're used to consuming and partly due to a number of health factors, including age, weight, use of tobacco and other drugs, and stress levels. Gender may even play a role in your response to caffeine: according to the Mayo Clinic, men are more sensitive to caffeine than women are.

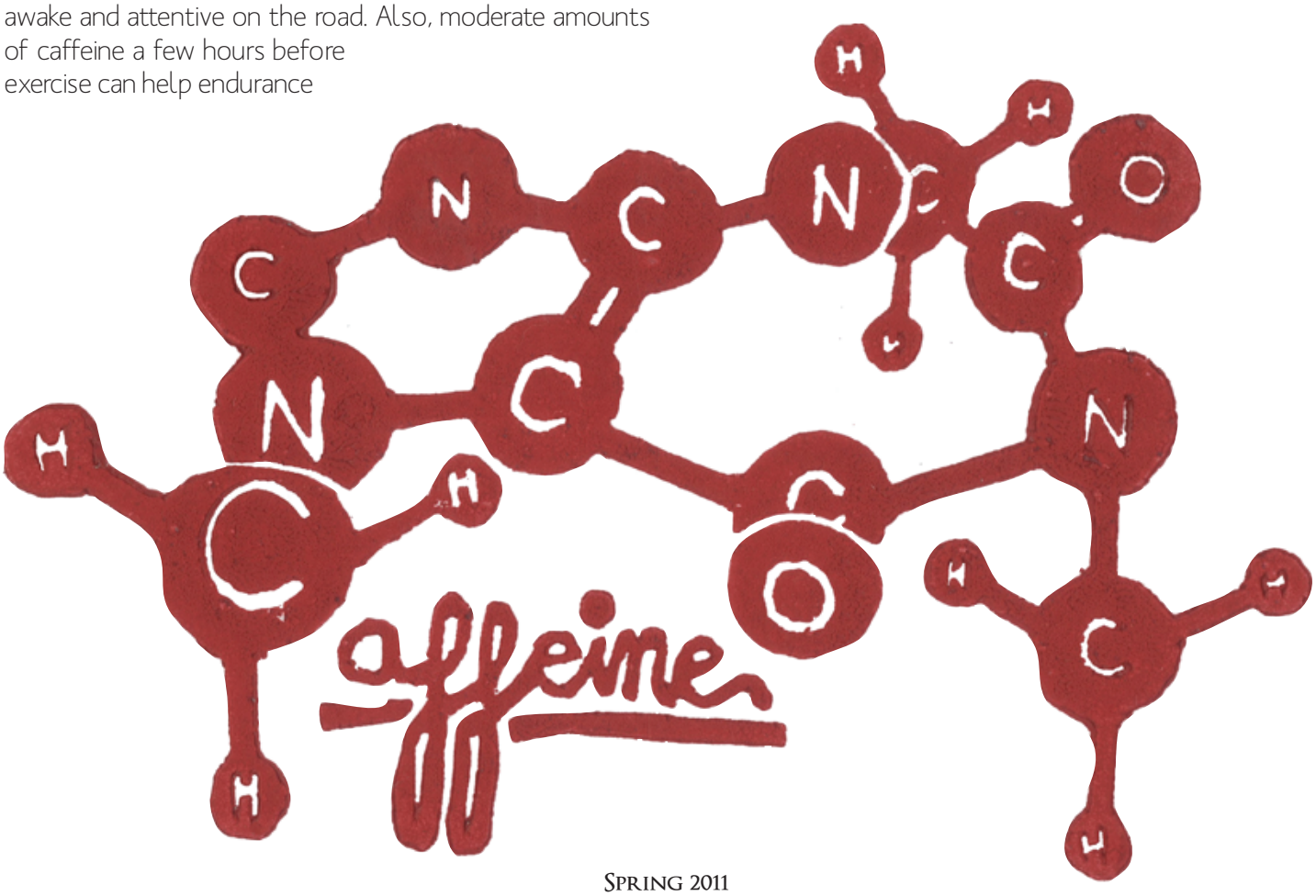
Caffeine has long been infamous for the myriad of heath risks it poses to innumerable frequent coffee drinkers. Because caffeine keeps the body in an alert state, it can disrupt sleep patterns and keep drinkers up late into the night or lead to a less restful night of sleep. The magnitude of the sleep disturbance can vary greatly between individuals and can range from severe in those who are not regular consumers to minimal in those who are accustomed to large amounts of caffeine and who have developed a tolerance to caffeine's sleep-altering effects. Large doses of caffeine can also produce negative mood changes. More than two cups of coffee can increase levels of anxiety and leave you feeling jittery. In fact, studies have shown that as little as two cups of coffee (200 mg of caffeine) can cause panic attacks and that people with panic disorders are highly sensitive to caffeine.

Caffeine is a drug, and, like any drug, one of the greatest risks to regular users is addiction. In a mechanism similar to that of amphetamines, caffeine induces the release of the neurotransmitter dopamine into areas of the brain associated with pleasure and reward. When highly addictive drugs like cocaine and methamphetamine interact with the brain, they increase the amount of dopamine in these pleasure

centers to create a high. The high - the intense stimulations of reward centers - becomes addicting, and a physical dependence on the drug is developed. Since caffeine works in the same way, it is similarly addictive, though its effect is much less than those of amphetamines. Caffeine dependency plays into a vicious daily cycle: excessive consumption during the day keeps you up later and reduces your quality of sleep, so you find yourself exhausted and turning to even more caffeine the next day. This pattern continues, and as a result it is possible to spiral into a sleepless state of total addiction. Caffeine withdrawal has many unpleasant physical manifestations, not unlike withdrawal from other addictive drugs. For regular coffee drinkers, mornings without a cup of Joe often lead to headaches, sleepiness, difficulty focusing or working, irritability, anxiety and depression, decreased attentiveness and cognitive abilities, and, in more serious cases, nausea, vomiting, and chills.

While excessive caffeine consumption does pose considerable risks, new studies are shedding light on some benefits of moderate amounts of caffeine. For one, caffeine increases alertness, and small amounts - half a cup of coffee or less is recommended by Harvard scientists - consumed periodically throughout the day can keep you feeling fresh and awake. In fact, French researchers recently found that a cup of coffee is more effective than a 30-minute nap when it comes to keeping sleepy drivers awake and attentive on the road. Also, moderate amounts of caffeine a few hours before exercise can help endurance athletes, like long-distance runners or cyclists, perform better and last longer. Caffeine slows and steadies the release of glycogen, the body's primary source of energy during extended physical activity, so that glycogen reserves last longer and more fuel is available farther into a long workout. Lastly, caffeine's adenosine antagonism naturally fights headaches. A moderate amount of caffeine causes vasoconstriction, a tightening of the blood vessels, as it blocks adenosine's ability to widen, or dilate, them. This makes caffeine a useful cure for painful migraines caused by vasodilation found in popular remedies like Excedrin. Studies have also shown that regular coffee drinkers also may enjoy decreased risk of developing type 2 diabetes, Parkinson's disease, colon cancer, and even Alzheimer's.

And so, while the jury is still out on the long debate over the risks and benefits of caffeine, coffee drinkers can rest easy that they're not doing too much harm to their bodies with their daily morning cup. But if you're a regular of the late-night Butler scene, next time you find yourself polishing off your 16 ounces of Red Bull or 6 shot Americano, remember that you're one of millions of users of the world's most popular drug. Chances are, tomorrow afternoon you will be jonesing for a latte, but in a world where the vast majority of Americans are in line at Starbucks to get their morning fix, at least you're not alone.



Snap Decisions and First Impressions

Thin-Slicing and its Criticisms

Grace Baek
Illustration by Allison Cohen

"Thin-slicing is generally considered flawed in the scientific community, as existing biases along with information gleaned from the first few moments of contact inherently affect snap judgments."

We try not to judge, but it's impossible not to form an opinion.

In Blink, Malcolm Gladwell addresses the idea of "thin-slicing," a concept first introduced by Nalini Ambady and Robert Rosenthal in 1992 to describe the human ability to make snap judgments about what is relevant in a specific situation. This capability is pertinent to everyday life, as we are constantly making instantaneous judgments based on first impressions. In job interviews, business attire and personal hygiene are important in helping a candidate appear immediately ready to take on a new job, even before the actual interview begins. On the first day of class, you take in a classmate's posture, attire, interaction with others, handshake firmness, and other factors in less than a minute and immediately form a judgment that has a high probability of sticking. More flashy demonstrations of thin-slicing in Blink include a discussion of John Gottman, a psychologist who can predict with 94 percent accuracy whether a married couple will remain in marital bliss after 15 years based on a single conversation between the two. What is really interesting about the results from the Gottman Relationship Institute is that after a longer period of analysis (approximately 15 minutes), accuracy drops to 90 percent.

To some degree, the accuracy of thin-slicing can be attributed to evolution. For instance, females are generally choosier than males, as females generally invest more in parenting from an evolutionary standpoint. When making quick judgments on which males are better potential mates, then, females look for indicators of physical and genetic fitness in males. One such indicator is the symmetry of male faces, which implicitly demonstrates adaptability to environmental changes. Another marker of genetic fitness is the body shape of adult males, especially the width of a male's shoulders and his posture. These physical factors are a measure of a male's hormones, particularly testosterone. In other words, animals are shallow creatures in that physical attractiveness will increase the likelihood of mating. Evolutionary success is often measured in how many progeny survive to adulthood and are able to reproduce; parenting investment is thus an important factor for females judging potential mates.

Another important application of thin-slicing is judging how well a "target" one conforms to societal norms. Reinforcement learning models demonstrate that changes in the rostral cingulated zone (RCZ) and the nucleus accumbens (NAc) - or neural "error" indicators signaling too radical of a deviation from social norms - occur. This neural "error" is a large biological red flag. Social conformity may have a bad name in modern society were individualism is encouraged, but evolutionarily speaking, a refusal to conform to societal norms was nearly equated with death. For example, hunting and gathering were group efforts, and those who were ostracized from the rest of the group faced death from starvation.

Thin-slicing is an acknowledged phenomenon, but most of the criticism of Blink is aimed at whether thin-slicing should be considered a wholly good and useful tool, and whether thin-slicing is so reliable that it can replace long-term observation in order to make an accurate judgment. Thin-slicing is generally considered flawed in the scientific community, as existing biases along with information gleaned from the first few moments of contact inherently affect snap judgments. While Gladwell argues that such an ability to increase the accuracy of thin-slicing to a consistent, reliable level can be achieved by everyone with continued practice, most researchers argue that such thin-slicing abilities are applicable to only certain situations and to certain groups of people, such as the case when individual judgments are in agreement with those of the majority. The Realistic Accuracy Model, for one, justifies the idea of thin-slicing to an extent. Based on limited interaction with a human "target" and brief observations of how the target interacts with others, the person making a judgement can arrive at an accurate conclusion regarding certain traits of the target. Even Dr. David C. Funder, a psychology professor at the University of California, Riverside, who established the Realistic Accuracy Model, qualifies his theory by noting the near impossibility of judging every facet of another's personality accurately based on such a small time sample. To make such a judgment on a rapid basis, then, is thus even more problematic for an individual who is untrained or lacking in natural instinct in this area.

In addition, the Federal Appeals Court judge Richard Posner has criticized Gladwell for arguing that everyone's first impressions, particularly in business transactions, are tainted by racist or sexist prejudices. Blink includes a discussion regarding the 1995 study by law professor Ian Ayres, in which car salesmen offered much lower initial prices of new automobiles to white males than to black and/or female customers. Gladwell argues that this study illustrates an instance in which our first impressions could have been off the mark. Richard Posner finds this conclusion inaccurate, as car salesmen must rely on quick thinking and first impressions to make a living. In the same vein, other critics agree with Posner in being wary of categorizing thin-slicing as necessarily based on positive assumptions alone.

Thin-slicing as Malcolm Gladwell presents it is a wondrous power of sorts. Armed with it, an individual can succeed in the workplace, on the dating scene, or in a game of chess. However, the reality as presented by many other psychologists is that thin-slicing is not quite as powerful or broadly applicable as Gladwell writes. The best way, then, to utilize thin-slicing is to take the concept with a grain of salt: trust your basic instincts but give the "target" the benefit of the doubt over the long run.

Exoplanets

Discovering Distant Worlds

Keri Lofftus
Illustrations by Diane Wang

We owe our existence to the planet Earth. For a substantial amount of human history, we believed the Earth was the center of the universe and the stars were small and distant spheres that orbited us beyond the outer planets. Scientific advances during the Renaissance began to change the way we perceive our universe. Eventually we realized that our own sun was actually a star, just one among billions in our universe. Naturally, as our star supported an entire solar system, we wondered if those other stars had planets orbiting around them. Searches for exoplanets, planets orbiting other stars, started in the mid to late 1980s, with the first discoveries being confirmed during the early 1990s. Currently, almost 500 of these exoplanets have been found.

Finding exoplanets is extremely challenging. While stars are extraordinarily large and emit massive quantities of light, planets are relatively small and can only reflect light from the stars they orbit, making them dim compared to those stars. The planet's closeness to its star means what little light it does reflect is washed out in the brightness of the star. This makes direct imaging of exoplanets difficult, although not impossible. Instead, other techniques are frequently used to locate these distant worlds, including, but not limited to, the Doppler shift method and the transit method.

The Doppler shift method (or the radial velocity method) is the most successful detection method. This technique measures the movements of a star to uncover exoplanets. We often say that the Earth revolves around the sun, but that is an oversimplification. In reality, the Earth and sun orbit each other around a common center of mass. Since the sun is over 300,000 times as massive as the Earth, the center of mass is within the sun, but not exactly at its center, so Earth does a majority of the revolving. Despite this, the Earth does pull on the sun, inducing it to wobble slightly.

Astronomers can see this same effect with another star by measuring the light which the star emits. When an object moves towards you, the wavelength of light it emits becomes compressed, increasing the frequency of the light. This is called a blue shift. When the

object moves away, the wavelength of light becomes stretched out, decreasing the frequency of the light. This is called a red shift. This change in the frequency of the light is called the Doppler effect. If a star does have a planet, that planet will pull on the star as it orbits, causing the star to wobble back and forth and the star's light to alternatively red shift and blue shift. By focusing a powerful telescope on the star, we can see the star's shifting light and deduce that there must be a planet tugging on that star. The Doppler shift method is best at locating extremely large planets (several times the mass of Jupiter, the largest planet in our solar system) since the more massive the planet, the larger the star's wobble. Knowing the extent of the star's wobble allows astronomers to estimate the mass of the planet.

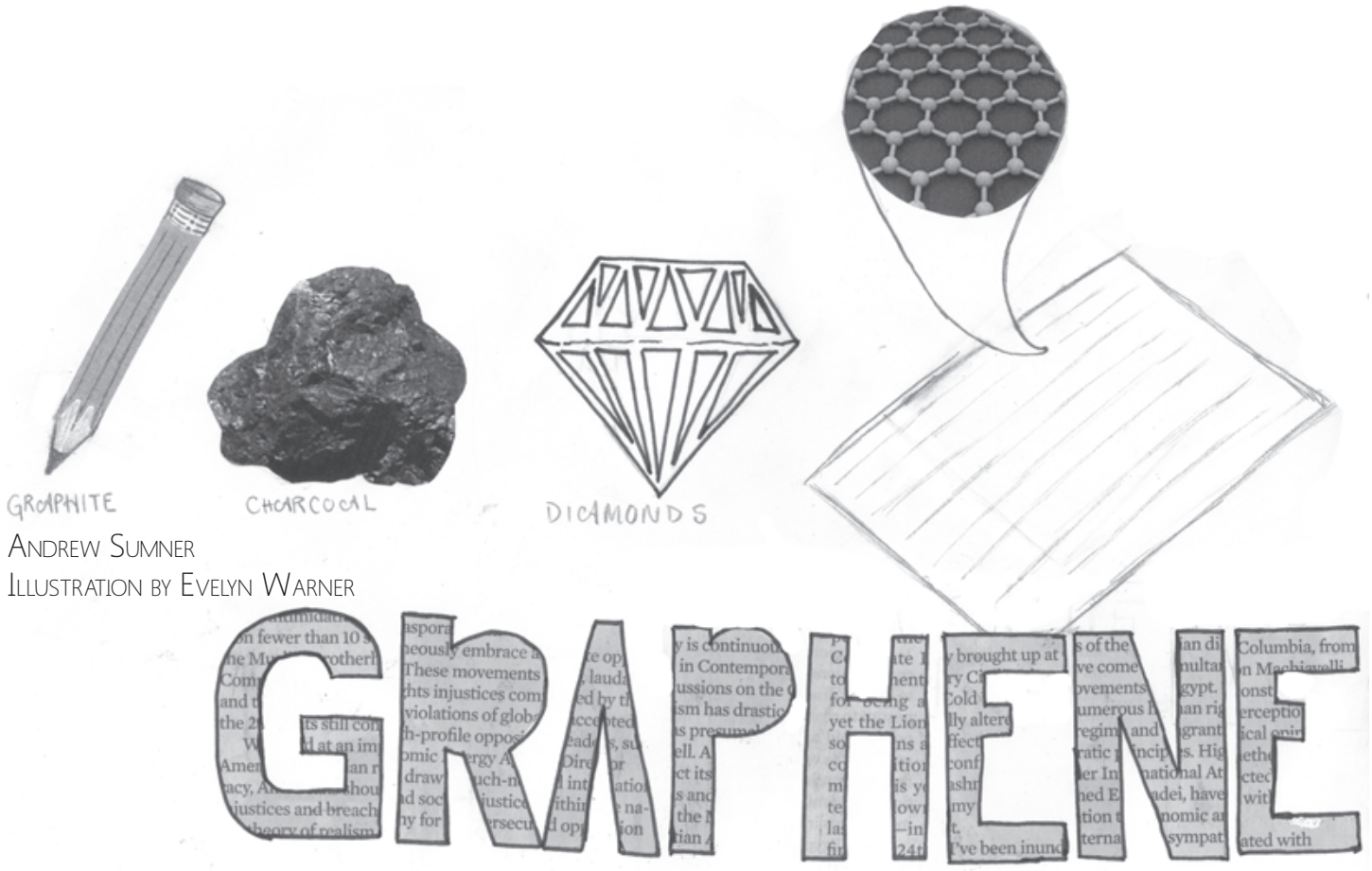
Another method for detecting exoplanets is called the transit method. Conditions are rarely perfect for our moon to traverse of the disk of our Sun, obstructing the sun's light and creating a solar eclipse. Similarly, a planet orbiting a distant star might cross in front of the star, blocking out a portion of the star's light for a short period of time. By gazing at the star with a telescope, this dip in the star's light can be measured and we can surmise that there is a planet. Although useful, this method has a major drawback: the exoplanet must cross the disk of its star from the perspective of the Earth. Unfortunately, only a small-percentage of exoplanets do this. This means a preponderance of the exoplanets detected in this manner orbit in close proximity to their star, since the nearer the planet is to the star, the more probable it is to eclipse the star. Like the Doppler shift method, the transit method tends to find immensely massive planets, as those planets will generate a more extensive decline in the light from the star.

The transit method has additional benefits. By measuring the proportion of missing light during the eclipse, it is possible to ascertain the radius of the planet, and therefore, its volume. Combine this with the mass found employing the Doppler shift method, and a planet's density can be calculated. Knowing a planet's density tells us whether the planet is a gas giant (like Jupiter or Saturn) or a solid, rocky planet (like the Earth or Mars).

A third method of exoplanet detection is direct imaging, or actually taking a picture of the planet. As previously mentioned, the enormous brightness of a star tends to wash out the dim light of a planet, but direct imaging is still possible under limited circumstances. Specifically, the planet must be gigantic (at least several times larger than Jupiter) and orbit substantially far away from the star, so that a greater amount of the planet's light is able to reach our telescopes. The immense difficulty of taking these images means only a miniscule handful of exoplanets have been directly imaged. One problematic obstacle in this method is confusing actual planets with brown dwarfs: small, star-like objects which often orbit around larger stars.

The past twenty years have shown an astronomic increase in the rate of exoplanet discovery. New technologies have allowed astronomers to find smaller and more distant exoplanets. In March 2009, the Kepler Mission was launched by NASA. It contained the Kepler telescope, built specifically to locate Earth-like planets using the transit method. As a space-based telescope, Kepler is not limited by the distorting effects of the Earth's atmosphere and therefore is able to detect smaller decreases in a star's light. In its first six weeks of operation, Kepler discovered five new planets. In June 2010, it was revealed that Kepler had discovered over 700 viable exoplanet candidates, more than the number of exoplanets currently known.

With the assistance of technologies such as the Kepler telescope, astronomers will eventually locate close, Earth-sized planets. New technologies are also allowing astronomers to learn more about these exoplanets with the data gained from both the transit and Doppler method. For example, using the transit method, astronomers are beginning to isolate and analyze light shining through the exoplanet's atmosphere, exposing the planet's atmospheric composition. Concurrently, engineers are creating technologies to travel through space at faster and faster velocities. The eventual goal of these combined fields is to discover viable candidates that are close and habitable for eventual human exploration and then build spacecraft to make the journey and begin colonization of these far-off and alien worlds.



The Quintessential Material, Relativistic Toy-Model, and Scientific Magic Trick

Andrew Sumner
Illustration by Evelyn Warner

The versatile and elegant nature of carbon has been unraveled further as Andre Geim and Konstantin Novoselov receive the Nobel Prize in Physics for their work with the carbon allotrope "graphene." Further investigation of graphene's properties has lent a glimpse of the molecule's unique uses and potentially valuable role in future technology.

Carbon, one of the universe's most important elements, exists purely in several forms called allotropes. Most commonly, these include diamond and graphite. However, other forms have been discovered recently, such as spherical fullerenes and one-dimensional nanotubes. New to the scientific community is graphene, described as the "building block of graphite."

Graphite, found every day as "lead" in pencil points, is a compound made up of stacked sheets of sp2 benzene-carbon rings. For decades, graphene existed as the theoretical concept of an isolated, single sheet of graphite through which flows a sea of delocalized electrons. However, its extraction from graphite was deemed impossible because of proposed thermodynamic instability in such thin sheets that would ultimately cause the material to decompose. In reality, freestanding graphene is now readily prepared in high-quality samples at standard conditions.

Geim and Nososelov were able to isolate few- to single-sheet samples of graphene while working at the University of Manchester through a method they called "mechanical exfoliation." Essentially, a thin sample of graphite is constantly peeled away by adhesive tape. With the appropriate substrate,

one can observe a single sheet of graphite through a microscope and conduct research.

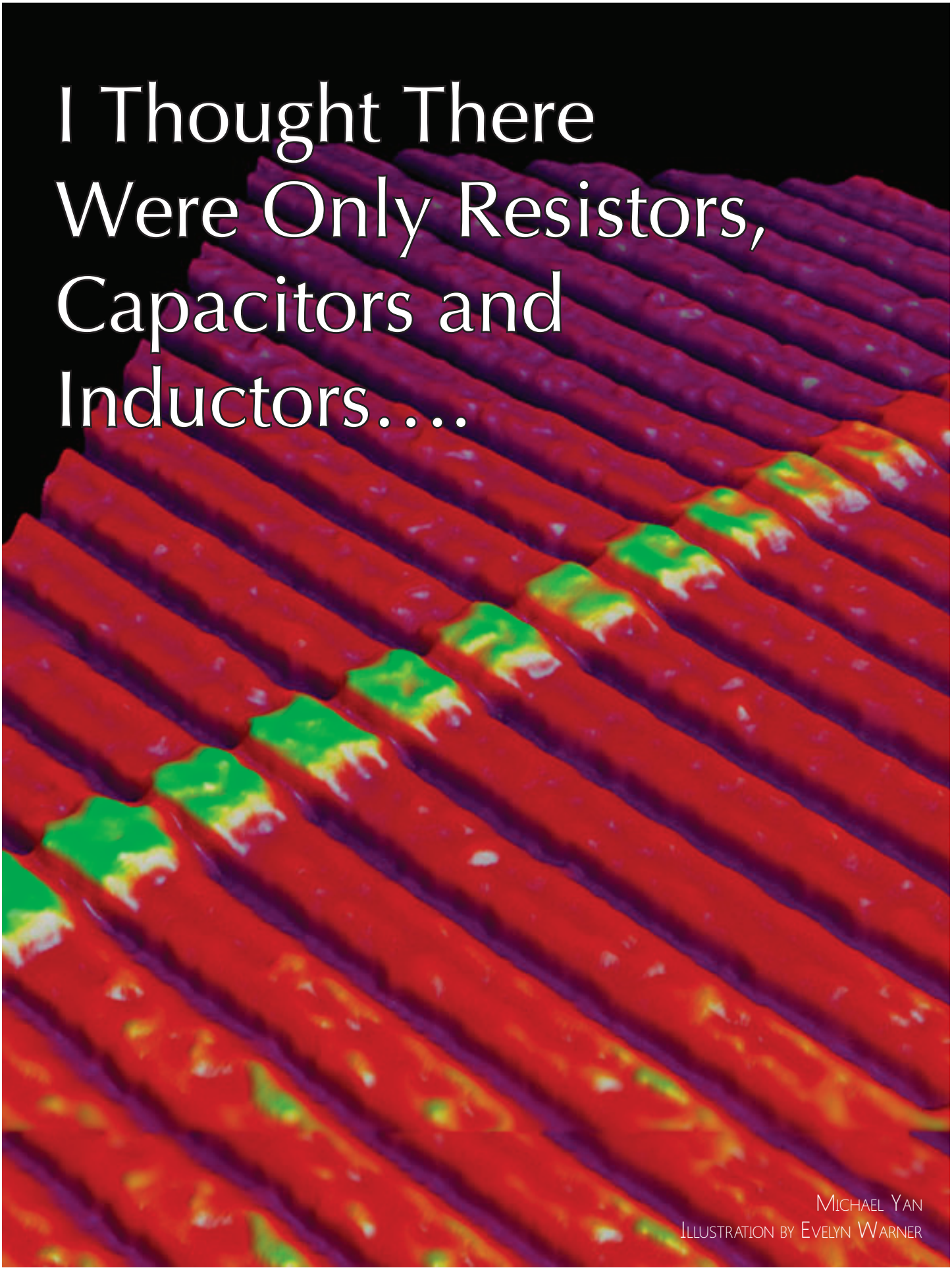
Aside from their groundbreaking method (first performed in 2004), Geim and Nososelov received the Nobel Prize for their comprehensive studies into the actual properties of graphene over the past few years. Although graphene is only one atom thick, these properties are astounding. Graphene is approximately 100 times stronger than steel, more conductive than copper, and, because it is a single-layer molecule, 97 percent of light can escape through graphene's lattice, rendering it transparent. A conventional example describes one square meter of graphene. This surface would weigh less than a milligram yet be strong enough to support a cat. Meanwhile, the cat would appear to be floating over this "invisible" surface, even if an electric current happened to pass through at the same time. Furthermore, according to tests conducted by Jeffrey Kysar and James Hone of Columbia University, if scaled up to the thickness of plastic wrap, a sheet of graphene stretched over a coffee cup could support the weight of a truck bearing down on a pencil point.

More than a material "magic trick," the anomalous graphite has opened the door to new studies into the more esoteric reaches of physics. Due to it's unique and irregular electronic spectrum, graphene is capable of serving as a "paradigm of 'relativistic' condensed-matter physics," according to Geim and Novoselov. Graphene exhibits what is described as a pronounced ambipolar electric field effect in which charge carriers exist at high concentration and are allowed high mobility. This efficiency stems basically from the simplicity of graphene's single layer composition, allowing electricity to flow fluidly and unimpeded without scattering. Interestingly, these charge carriers have been experimentally determined to be different than those proposed by classic physics. Rather than obey Schrödinger's equation, graphene's charge carriers mimic relativistic particles and are more accurately described by Dirac's equations. Interactions within graphene's carbon lattice give rise to "quasi"-particles called massless Dirac fermions. These particles are best described as electrons that have lost their rest mass or neutrinos that have acquired the electron charge "e-" and behave more like waves than particles. With graphene, relativistic experiments are no longer restricted to particle accelerators but can be conducted on a table top.

In the practical realm, physicists believe that graphene could serve as the gateway for carbon to replace silicon. In computer chips and semiconductors, scientists struggle to overcome the size constraints when modifying previous models. Graphene's single sheet size would again allow for new advancements to be made, leading, for example, to terahertz processors. Graphene as a strong, conductive, and transparent material has also been classified as a perfect candidate for touch screen/display technology. Furthermore, graphene's high sensitivity would make it an effective biosensor. Considered studies include the interaction between antibodies with specific antigens and the detection of individual binding events. Graphene's alterable capacitance could also make it capable of storing large amounts of renewable energy.

Conclusively, thanks to Andre Geim and Konstantin Novoselov, a new field of research has exploded. Scientists everywhere are working now to first improve on the "exfoliation" technique and develop a method for mass production of graphene and then look towards developing graphene into usable materials. The potential is unprecedented and graphene can be expected to remain a prevalent topic in the scientific community for years to come.

I Thought There Were Only Resistors, Capacitors and Inductors….



Michael Yan
Illustration by Evelyn Warner

Imagine a single device that can replace RAM, flash, and disk memory. This device can potentially hold 128 Terabytes or 1282 DVDs in a square centimeter of space. Unlike today's computers where processing is done in the CPU (Central Processing Unit) and memory storage is done in chips called RAM (Random Access Memory), this device can simultaneously process and store data. This contraption also performs many of the functions of transistors, the building blocks of modern electronics. However it is more power efficient and denser, which means that this component takes up less space than a transistor but is able to perform the same functions. This new technology is called "the memristor" and while it is still relatively new, it has the potential to revolutionize electronics much like the transistor did in the 1950s.

Interestingly, memristors were made well before scientists realized their capabilities. In 1971, Leon Chua published a paper describing a memristor as the fourth fundamental circuit element because it had properties that could not be reproduced with the other three fundamental circuit elements: the resistor, transistor and capacitor. He noted that there are six possible relationships between the four fundamental circuit variables: current, voltage, charge and magnetic flux. Two of these relationships existed by definition (charge is the time integral of current and flux is the time integral of voltage) and three were given by the other fundamental circuit elements: the resistor, capacitor, and inductor. The relationship between flux and magnetic charge was missing, so Chua postulated the existence of a fourth fundamental circuit element, the memristor. However, the nature of memristors was very mysterious due to the fact that their properties are only really noticeable on the atomic scale. However, in 2008 Stan Williams at HP successfully constructed a working memristor from platinum and titanium dioxide and thus proved its existence.

The key to a memristor's properties is the ability to "remember" the electric current that has flowed through it, or basically retain its shape after current stops flowing through it. The standard analogy describing a memristor is water flowing through a pipe, where water represents current and the pipe represents the memristor. This pipe has the interesting property that when water flows through it in one direction, the pipe expands and allows water to flow even faster and when water flows in the other direction, the pipe shrinks and slows the rate of water. When the water is turned off, the pipe will retain its most recent diameter so essentially it remembers how much water has flowed through it. In the current memristor developed by HP, an electric current displaces the positions of atoms in the titanium dioxide film which causes a change in resistance. This change of state is remembered even after electric currents cease to be applied.

There are huge implications for this property of memristors because memristors can act as non-volatile memory, or memory that still retains storage when unpowered. Nowadays if you pull the plug on your computer, you can expect to lose most of your work and data because the data that your computer is working on is being stored in RAM for quick access rather than your hard drive, which is much slower to access. A computer built with memristors could retain all the information and data being worked on in the computer before the plug was pulled. Additionally, computers would not need to go through the slow boot-up sequence where the computer has to load all the information needed for start-up because memristors remember the state of the computer before it was turned off.

An intriguing potential of memristors is their similarities to the synapses of the nervous system. For those who need a refresher on the nervous system, synapses are the junctions between neurons. When a neuron fires an electrical impulse to convey a message to the brain, the signal must pass through a sequence of neurons in order to reach its destination. Max Di Ventra from the University of California, San Diego built a memristive circuit in where the memristors acted like synapses. The ability of memristors to remember their state allows them to mimic the synaptic action of the nervous system. Unlike a normal electrical switch (like a light switch) which can only exist in two states, on and off, memristors act like a dial that can represent all the states in between. The memristors in the circuit were able to alter their behavior based on the strength and frequency of currents fired in the circuit much likes synapses in the nervous system.

These are only a few of the many future applications for the memristor. They can potentially change the future of electronics forever by replacing the transistor as the main component of electronics. They may become the choice of storage for data, eliminating the CD/DVDs, flash memory and even random access memory. Get ready for the memristor revolution.

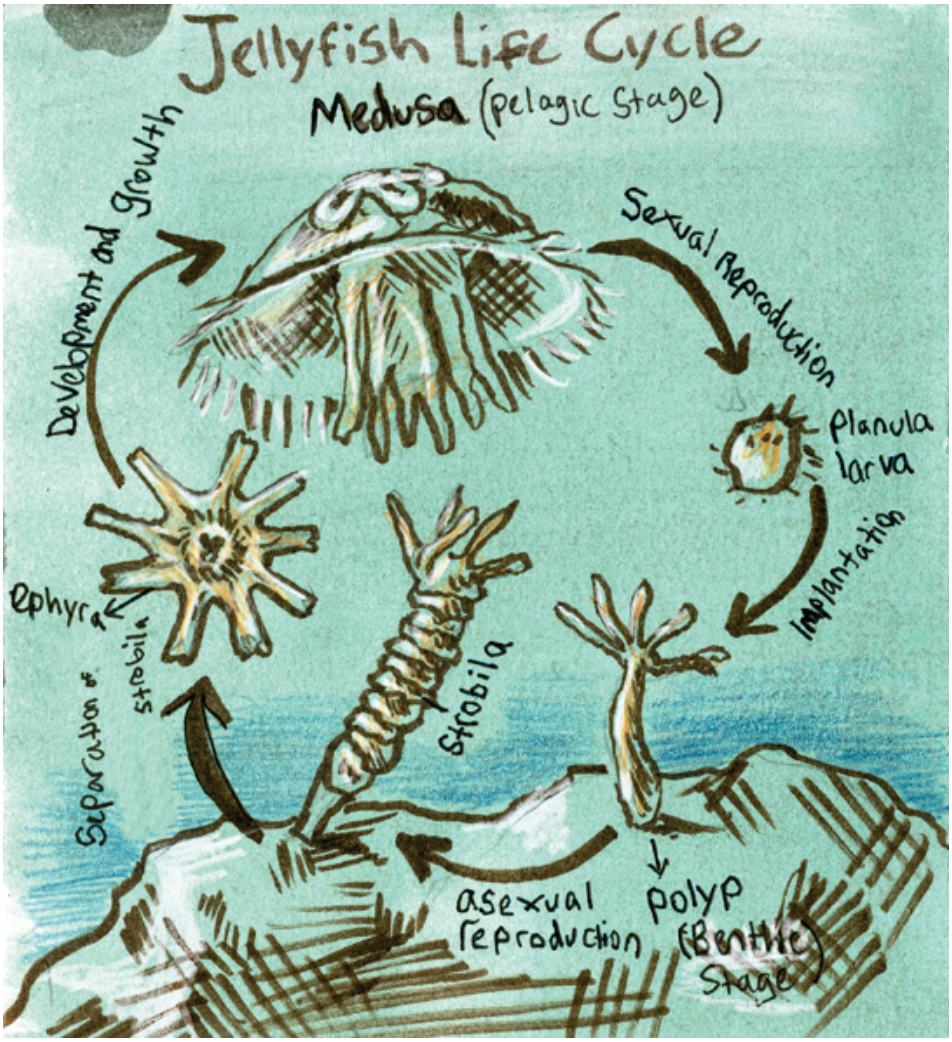
Article and Illustrations by Allison Cohen

Jellyfish Takeover?

We all know them as the gelatinous, otherworldly creatures that fascinate us with their beauty, yet irritate us with their stings. Over the past decade, fisherman, bathers, and scientists have observed a seemingly unprecedented increase in the abundance of jellyfish. Large numbers of these simple predatory invertebrates cause many problems for fishermen and swimmers. Jellyfish directly compete with predatory fish for food and other resources, so their abundance may indicate a fundamental change in the marine food-web. The few organisms that can prey on jellyfish, such as leatherback sea turtles, sharks, and tuna, are becoming scarce. Scientists are trying to determine whether these perceived population increases are consistent with quantitative studies, and whether the population increases can be attributed to periodic jellyfish blooms due to oscillating environmental changes and the nature of the jellyfish reproductive cycle, the introduction of invasive species, or anthropogenic (man-made) causes, such as pollution, climate change, over-fishing, and eutrophication.

In order to better understand seasonal jellyfish blooms, we must first take into consideration their complex life-cycle. Jellyfish undergo two major phases during their life-cycle. As medusae, they are generally bell-shaped and motile (able to move). They are the easiest to recognize and what we primarily think of when hearing the world jellyfish. The medusa phase is also referred to as the planktonic or pelagic phase, which

refers to the upper zone of the ocean where they float around. As polyps, they are sessile (stationary), and attach to substrates on the benthic zone, or sea floor. The medusae reproduce sexually. Individuals are either male or female, and they exchange gametes to form an embryo that develops inside the female jellyfish. The zygotes develop into small free-swimming larvae, called planulea, that enter the water column, and anchor themselves on a solid structure in the benthic zone. They grow and develop into polyps, which then reproduce asexually through budding, creating many identical buds or cysts. When conditions are favorable, the buds separate from the polyp and form small medusa jellyfish, called ephyra, which grow until they become the large medusae jellyfish that we are familiar with.



Since the buds all tend to form medusae at certain times when conditions are most favorable, such as during the warm summer months, certain regions tend to experience large seasonal increases in jellyfish populations. For example, bathers in the Mediterranean are familiar with the obvious seasonal population fluctuations of the jellyfish Pelagia noctiluca, or Mauve Stingers. The high temperature, low rainfall, and high atmospheric pressure that characterize the summer months correlate with large blooms of these jellyfish. Pelagia is one of the only species recorded whose population blooms are well studied. Moreover, environmental oscillations that exist over greater periods of time, such as the presence of the El Niño current that increases water temperatures, cause greater seasonal blooms in some years than others.

Also, many jellyfish travel to new locations in the ballast of ships and by other means. These non-native species tend to have high reproductive success because they can fill a new ecological niche, or out-compete native species of pelagic predators. For example, three species of medusae, probably indigenous to the Black Sea, were introduced to the San Francisco Bay and Chesapeake Bay. These species thrived in low-salinity estuaries in the San Francisco Bay that were not previously inhabited by jellyfish. In the Chesapeake Bay, these jellyfish joined native, low-salinity populations, but did not proliferate as extensively. The abundance of the jellyfish in the San Francisco Bay can be attributed to their introduction into an environment favorable for their reproductive success.

Unfortunately, not a lot of data has been collected about jellyfish populations earlier than the 1970's, so scientists do not have a lot of information with which to make conclusions about the natural model of jellyfish blooms, and whether or not today's recent observations of jellyfish abundance are consistent with the normal cycles. However, qualitative observations, and some quantitative studies have indicated that some species of jellyfish have been observed in unprecedented abundance in important fishing sites and in bodies of water affected by industrial and agricultural pollu-

tion. For example, scientists at Alaskan fisheries in the 1990 have observed an unprecedented biomass of the large jellyfish Chrysaora melanaster in the Bering Sea. The biomass of these jellyfish increased ten-fold from the 1980s to the 1990s. Since the Bering Sea is under ecological pressure due to the overfishing of Pollock and other popular species, scientists infer that a decrease in the number of predatory fish leaves more food available for jellyfish, so they are able to proliferate. Other heavily exploited regions have experienced similar trends. The northern Benguela off the coast of Nambia, a nutrient-rich environment that has supported large stocks of anchovies and sardines, has seen increased abundance of large jellyfish, such as Chrysaora hysoscella and Aequorea forskalea. Before the decrease in fish stock observed recently, the common presence of large jellyfish in this region had not been documented. Although jellyfish are simpler and evolved earlier than predatory fish, they occupy the same trophic level, or niche in the food web. Fish and jellyfish both feed on similar prey, including smaller organisms and larva. In-fact, some large jellyfish can predate on larger predatory commercial fish and their eggs.

In areas where industrial and agricultural pollution is great, changes in water conditions seem to favor jellyfish. Agricultural runoff causes eutrophication, an increase in the nutrients available in a body of water, such as phosphates and nitrates. These nutrients cause large blooms in algae populations. The algae eventually die, and their decomposition causes hypoxia, or low oxygen levels, and increases turbidity, which constitutes increased sediment levels that cause low visibility. These conditions, especially turbidity, are unfavorable for fish survival because fish rely on their sight to capture prey. Jellyfish, however, thrive in turbid water because they can capture prey regardless of visibility. Jellyfish use their tentacles that usually contain stinging nematocysts to trap and paralyze their prey. A group of non-stinging ctenophores, commonly referred to as a comb jellies, capture prey using sticky cells on their cilia or tentacles to trap prey. Since jellyfish are less active than fish, they require less oxygen and can survive more easily in hypoxic conditions. Power plants also increase the temperature of the water, which generally favors the proliferation of jellyfish more than that of fish, with a few exceptions mentioned below. In the Gulf of Mexico, the area near the delta of the Mississippi River, which empties pollution and runoff into the ocean, has seen local increases in the abundance of Chrysaora quinquecirrha, and general increases in the number of Aurelia aurita (moon jellies) probably due to the factors mentioned above.

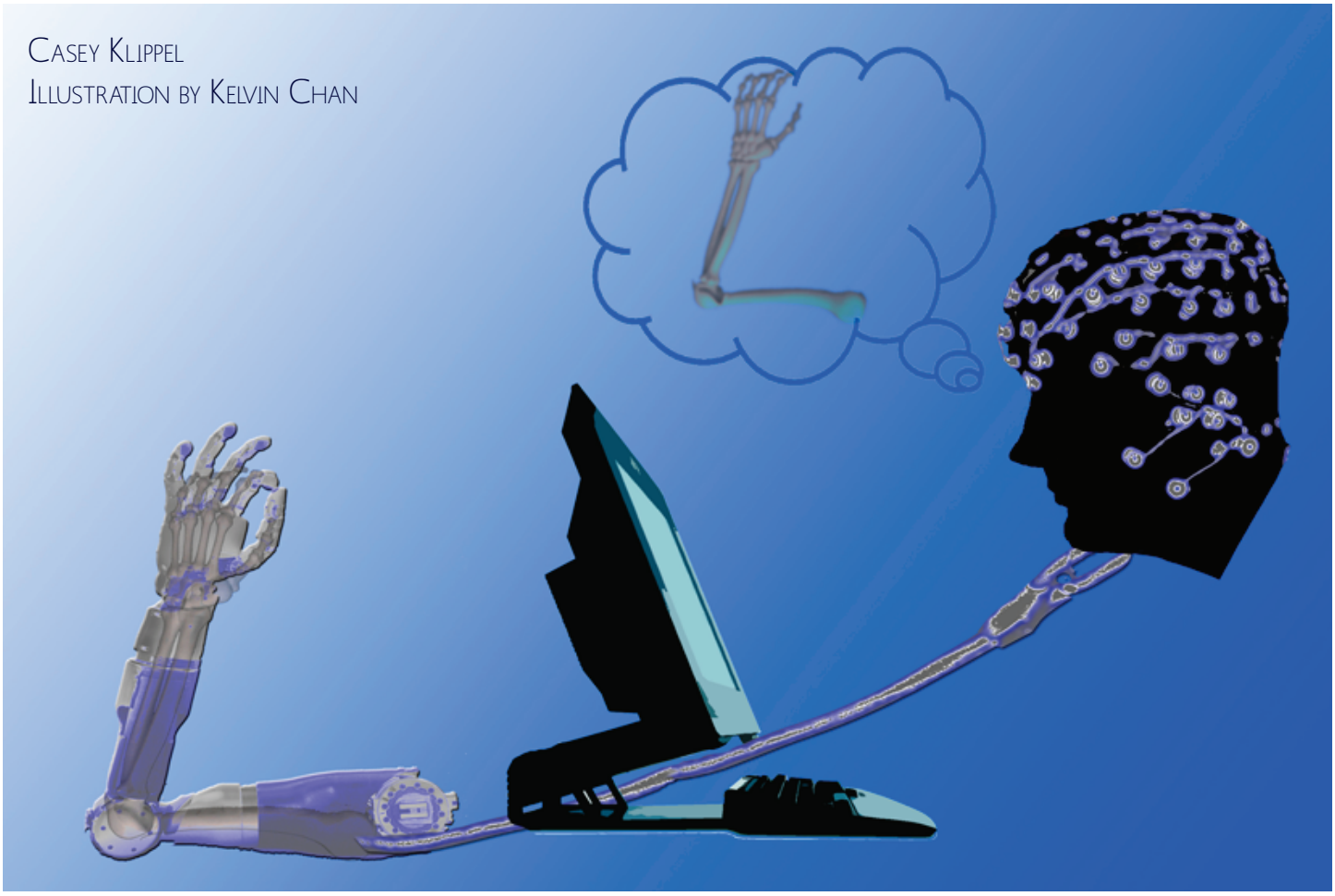
On the other hand, the populations of some jellyfish species have decreased in response to degrading water quality. A type of jellyfish in the Adriatic decreased in numbers when hypoxia was present in the benthic zone and hyperoxia (oxygen abundance) was observed on the water surface. It is speculated that the polyps of this species were unable to survive in the zone with extremely low oxygen availability, so the reproductive cycle of this species was impeded. Not much data supports this hypothesis, since not much is known about the polyp stage in the jellyfish's lifecycle. Also, some tropical species cannot tolerate a large increase in water temperature, so their population size declines. For example, a species of Mastigias, known as golden jellyfish, lives in tropical marine lakes in Palau. In 1997, when the El Niño current caused a dramatic increase in the temperature of these lakes, Mastigias sp seemed to have disappeared.

The recent observations could just be part of the periodic life-cycle of these invertebrates. Also, there is almost no available about the conditions under which the polyps of different jellyfish species develop, since polyps are not as conspicuous as their medusa counterparts. We know almost nothing about mesopelgaic (mid-water column) and deep-sea jellyfish because they are not as easy to spot as surface jellyfish. However, if jellyfish are increasing, this means they are probably replacing fish as predators in marine ecosystems, although the factors contributing to the increase are very complex and still unclear. Once jellyfish are established, it will be very hard to facilitate an increase in fish stocks, even if overfishing is stopped, because jellyfish will continue to prey on fish and their eggs, and compete with them for food. Large jellyfish populations can also cause economic setbacks, since they are known to break trawl nets, clog power station cooling mechanisms, and impede tourism. Maybe we should get ready, and start coming up with some creative jellyfish recipes: jellyfish burgers, jellyfish soup, deep-fried jellyfish. Sounds tasty.

Brains, Games, and Mainframes

An Overview of Selected Brain-Computer Interfaces

Casey Klippel
Illustration by Kelvin Chan



Have you ever opened a Skymall catalog to find a "brain obstacle course" game among the wacky gadgets? After donning a thick headband, you attempt to move a ball through the air using only your Jedi-esque powers of concentration. Perhaps you have come across Emotiv's Epoc, a headset that allows you to think your way through video game adventures. Or maybe you'd like to play a game of ping-pong using equipment controlled solely by your brain? While these brain-computer interactions may seem like just frivolous flights of fancy, several virtual games have had serious roles in the development of faster and more accurate brain-computer interfaces. For example, a 2004 paddle-less ping-pong game represented a breakthrough in real time computer processing of brain signals; the software advancement allowed two human opponents to play simultaneously from fMRI machines.

This article seeks to give an overview of human brain-computer interfaces, highlighting some of their differences in design and intention, as well as pointing out some possible directions for future advancements. Human brain-computer interfaces (BCIs) have the amazing potential to improve, repair, or replace sensory or motor functions in patients with severe injuries. There are also several types of prosthetics that help patients regain lost functions by interfacing with the peripheral nervous system instead of directly with the brain. Brain-computer interfaces also have great promise for more seamlessly connecting the data-handling capabilities of human brain with the processing power of computers, a combination with a huge variety of possible applications.

BCIs are a relatively new technology because they depend greatly on both high-performing computer systems and, in the case of implanted BCIs, complicated medical operations. Advancements and innovations have occurred rapidly in both the mechanical devices physically collecting the brain's signals and the computer systems interpreting the gathered information. Two additional related concerns are implementation and portability, depending on the intended use of the BCI. The skull diffuses brain waves, so a clearer electrical signal is obtained by implanting sensors within the skull. However, few casual research-study participants or intrigued gamers would have a device implanted in their brains simply to control a computer program with their thoughts. On the other hand, because a precise signal is of utmost importance in medical situations, many BCIs in patients come into direct contact with the brain. Work is being done both to increase the accuracy of external sensors and to reduce the invasiveness of subdural BCIs. Finally, the desire for portability drives design changes in BCIs; clearly an fMRI or mainframe is less mobile than the unscientific Skymall headset. The researchers that developed paddle-less virtual ping-pong hope that people who practice tasks in an fMRI could eventually use an EEG, a small machine that records brain activity via sensors placed on the scalp, to detect their brain signals. Additionally, computer systems in general are constantly being made smaller and more efficient, and these improvements benefit BCI development.

Most implanted brain-computer interfaces are being developed for patients with widespread paralysis, such as quadriplegia. Interfaces between the brain and machines started to be developed in the 1970s and 80s, and at the outset most human BCIs registered the electric activity of the brain with receptors outside the skull. After training and practice, patients could learn to control computer cursors. In the early 2000s, scientists began experimenting with implanting receptors directly into the brain to pick up clearer signals. In 1998, Philip Kennedy and a team of neurosurgeons were the first to implant BCI electrodes directly in the brain. To stabilize the implanted electrodes and establish a secure connection between sensors and neurons, glass cones filled with chemicals encouraged neurons to grow through the cone and attach themselves to the wires. In 2004, John Donoghue and Leigh Hochberg developed BrainGate, a tiny array of 96 microelectrodes implanted into the brain of their quadriplegic patient, Matthew Nagle. After implantation, he accomplished such tasks as operating robotic limbs and changing the channel and volume of his television. He also controlled an email program and played a Pong-type computer game.

Additionally, there are currently several types of prosthetics that connect computer systems to the peripheral nervous system. For example, cochlear implants connect external microphones to the auditory nerve system and are in widespread use. Prosthetic arms that connect to healthy nerves in the torso appear to be much more dexterous than traditional prosthetic arms and capable of performing multiple movements at once. Mechanical replacements for damaged eyes are currently being developed and improved; some systems seek to connect electrodes to the retina, while others are true BCIs and connect to the visual cortex.

As it is easy for the brain to become damaged from an implant, improvements are constantly sought to ease the boundary between the neural matter tissue and the abiotic, or non-living, receptor. Some BCIs balance obtaining a clear signal and minimizing intrusion by residing within the skull but outside the gray matter, the area of the brain responsible for processing information. In 2006, Eric Leuthardt and other researchers at Washington University developed a BCI for a teenage boy who already had an electrode grid implanted on top of his brain to detect seizures. The resulting software on a special computer - the new BCI - allowed a him to play Space Invaders using only his thoughts. More recently, researchers are developing a circuit printed on silk that could can be laid over the folds of the brain.

The circuit then bends to fit the curves and crevices of the brain surface, and the underlying silk can be washed away. The result is a close and non-invasive fit between the sensors and the neurons. When further developed for use in humans, these thin films could even be rolled up to minimize the invasiveness of the implantation surgery.

While many current medical applications involve in-skull implants, equally remarkable non-medical systems gather information externally. At Columbia University, Professor Paul Sadja, director of the Laboratory for Intelligent Imaging and Neural Computing, has developed an external EEG electrode array that harnesses the human brain's incredible object-recognition prowess. The BCI picks up neural signals that indicate the user recognizes an image, even when the pictures are being presented at much faster than normal speeds. In a different type of image recognition, in 2008 Japanese scientists used fMRIs to reconstruct pictures viewed by study participants. Non-medical applications of BCIs may currently be less obvious and less explored than medical uses, leaving much room for innovation in coming years.

As with many new technologies, philosophical and ethical questions surround brain-computer interfaces as they become more and more sophisticated. Because therapeutic uses and information gathering are currently two main goals of human BCIs, most human brain-computer systems receive signals from the brain and then influence a computer or computer-controlled system. An ongoing hypothetical fear - and the subject of countless sci-fi stories and shows - is the reversal of that situation: computers giving instructions to the human brain. Ethical considerations of BCIs in medical applications, as well as larger philosophical questions of personhood versus machinery, should and will be continued to be discussed as the technology develops. Right now, however, brain-computer interfaces represent the incredible possibility for injured patients to regain sensory and motor functions, and an innovative way to combine the best of human thinking and computer processing in analyzing data. Perhaps their most perilous side-effect will be that familiar nemesis of university students: a new, exciting way to procrastinate with a beloved video game.

Timothy D. Weber

Is More Scanning Better Medicine?

Since the introduction of computed tomographic (CT) scanners, doctors and physicians have drastically altered their diagnostic techniques. What once required a tricky surgery or the insertion of a camera into the patient could now be easily visualized in three dimensions on a screen. Better yet, the scan was supposedly noninvasive and pain-free. The current paradigm in medicine is that more information, more imaging, and more scanning will invariably lead to better medicine. But can we really be sure the benefits of increased scanning outweigh potential risks?

According to the National Council on Radiation Protection and Measurements (NCRP) the average American's exposure to radiation from all sources has more than doubled over the last 30 years. While radiation exposure from background sources has mostly remained constant, exposure due to medical imaging has increased by a staggering 6-fold. The largest contributor is the CT scan (also known as CAT scans), which alone accounts for 24% of per capita radiation exposure.

During a CT scan, a revolving projector fires multiple x-rays through a subject. The individual x-rays are computerized and constructed into a three-dimensional model. Because this technique requires the use of many x-rays, the effective radiation dosage can become alarmingly high. The US Food and Drug Administration (FDA) estimates one common abdominal CT scan can deliver the equivalent radiation dose of 400 chest X-rays or approximately 1000 dental x-rays.

The individual risk associated with a single CT scan is relatively low, but over many scans the risk increases. Based on information from

various large health databases, Berrington de Gonzalez et al. project that among the 72 million CT scans performed in 2007, 29 000 patients will develop cancer after their scan. They further estimate at a 50% mortality rate, in approximately 20 years, CT scans performed now will be responsible for 15 000 deaths annually. In a second study Smith-Bindman et al. calculate based on current radiation exposure data from scans that 1 in every 270 women will develop cancer as the result of a CT coronaray angiogram.

Despite its dangerous nature, in the United States CT scanning is almost entirely unregulated. This is contrary to the policy for radiation in the workplace, where it is strictly regulated, but contributes far less radiation to the population. Doctors and technicians have the option of adjusting the doses in order to produce finer resolution images. In a study by Smith-Bindman et al. it was found that for the same procedure radiation dosage could vary by as much as 13-fold. Additionally, technicians are not required to update their knowledge of CT instruments, although the technology is rapidly improving.

Medical imaging is unregulated by US agencies with one exception: the 1992 Mammography Quality Standards Act (MQSA). The act, which originally addressed certain quality concerns, successfully established national regulations on all institutions performing mammography in the US. Today radiation from mammography makes up less than 1% of the total population exposure.

Earlier in 2010 the FDA launched an "Initiative to Reduce Unnecessary Radiation Exposure from Medical Imaging", but the stated measures were mostly voluntary and did not mandate any real change. In his commentary, Dr. David Brenner of the Columbia University Medical Center points out that in the early 1990s, the MQSA replaced mostly voluntary measures, which had not been effective. Brenner suggests that similarly, federal mandate must be seriously considered for all medical imaging in order to improve safety and quality.

Passing legislation may prove more difficult than expected because the community of established physicians is often reluctant to adjust their procedures. Furthermore, several scientists at the FDA have reported intimidation and improper overruling after expressing their concerns about the safety of new CT scanning devices. One of the scientists, Dr. Julian Nicholas said he had his contract "terminated" after repeatedly denying approval of a specialized CT scanner for colon cancer screening, citing safety concerns. Although the FDA may appear to be suppressing safety concerns, an independent agency hired to investigate the claims found no evidence if retaliation.

The authors of the previously mentioned studies all agree that patients must be better informed of the risks associated with CT scans. Whether or not this will be federally mandated is currently unknown.

A Glia-ful Frontier

Sonal Noticewala

Photo courtesy of Eric Kandel, New York State Psychiatric Institute

Recently researchers have injected the brains of mice with human glial progenitor cells. The results indicate that these human cells integrate well within the mouse brain. Even more intriguing was that the brains of these mice injected with these human cells were becoming more human. Conditioning studies performed by Maiken Nedergaard at the University of Rochester School of Medicine and Dentistry of the Department of Neurosurgery on these mice suggest that these mice are conditioned more rapidly and that their synaptic connections differ at the molecular level from those mice that do not receive human glial cell injections. Thus, do the different cognitive abilities from species to species rest on the fundamental difference of glial cells between species?

The central nervous system consists of two types of cells: neurons and glial cells. Classically, brain function has been attributed to the activity of neurons. There have been several reasons for this deduction. Primarily, neurons have numerous ligand- and voltage-gated channels that can generate electrical currents to transmit information. Secondly, neurons have processes that terminate on glands, muscles, and sensory organs. On the other hand, glial cells are not electrically excitable since they possess relatively few membrane channels, and they lack long processes. Glial cells are more generally described as passive cells that provide trophic, structural, and metabolic support for surrounding neurons, without actively participating in information processing. As a result, the study of glial cells, which are ten times more plentiful than neurons, had been pushed to the fringes of neuroscience research.

However, with recent technological innovations, methods for measuring the minimal electrical activity generated by glial cells were developed. These methods have revealed that neurons and glial cells engage in significant back and forth signaling which is not only critical to basic information processing by the brain but also central to the course of neuropathologic processes. In fact Maiken Nedergaard of the University of Rochester has developed a way to measure astrocyte (a type of glia cell) activity through a laser system that measures the amount of calcium

within the cells. The data indicates that "astrocytes use calcium to send signals to the neurons and the neurons respond; neurons and astrocytes talk back and forth indicating that astrocytes are full partners in the basic working of the brain."

In addition to being able to generate cellular signals, glial cells have also been shown to play a significant role in synaptic transmission. The interaction of glial cells with neurons at synapses has been labeled as a tripartite synapse. Through activation of neurotransmitter receptors on glial cells, a calcium-based signal is generated. The elevations in cytoplasmic calcium then lead to release of substances (gliotransmitters) into the synaptic space which can influence neuronal excitability. These transmitters are though to inhibit or enhance synaptic plasticity. Synaptic plasticity is the mechanism through which learning and memory occur. Astrocytes have been in implicated in affecting long tem potentiation (LTP), the molecular mechanism of learning and memory. Research indicates that the release of ATP by astrocytes promotes the insertion of AMPA receptors of post synaptic neurons, a key feature of LTP.

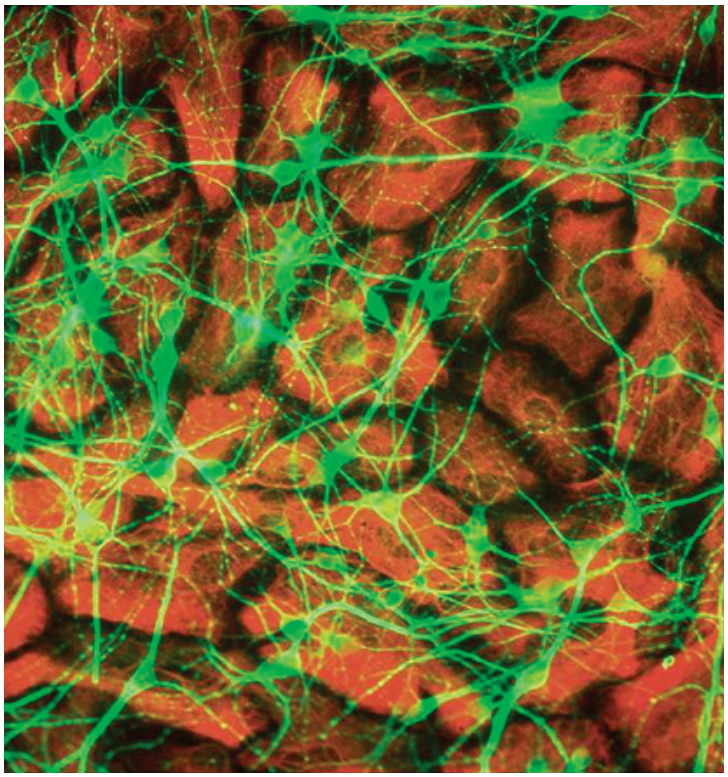


Photo courtesy of Rajiv Ratan, Burke Medical Research Institute

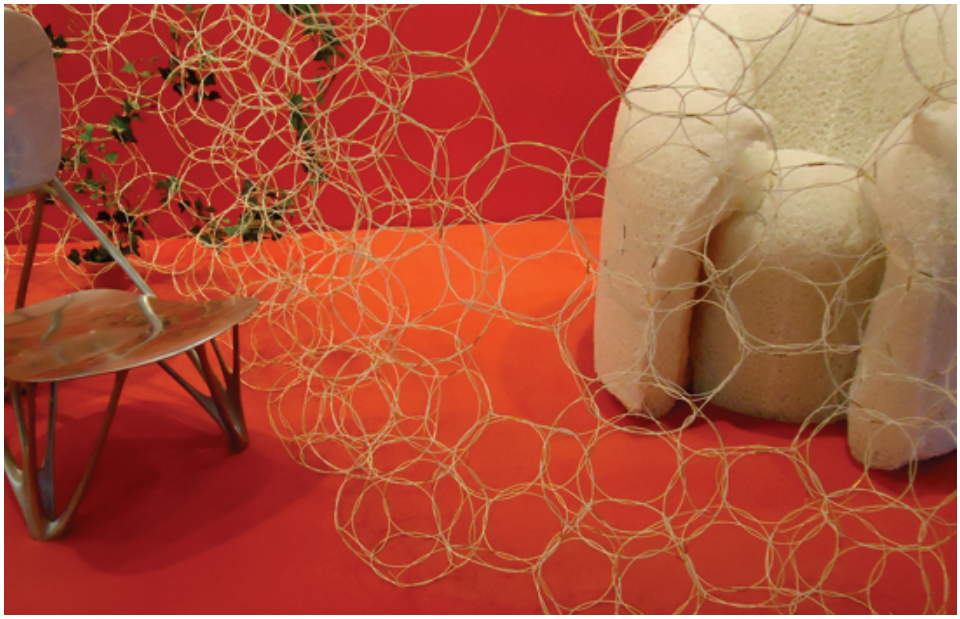
Furthermore, glial cells do not respond passively at synapses. Instead, they show processing of information similar to neurons. A single neuron in the mammalian central nervous system is in contact with thousands of synaptic terminals. Each neuron is able to selectively respond to its input signals and generate a single output signal. Glial cells are able to communicate with neurons in a similar fashion and demonstrate a similar non-linear input-output relationship.

The current working model has one glial cell with thousands of processes as an integral member of many neuron-glial tripartite synapses. In response to neurotransmitter stimulation, a calcium-based activation signal is generated and a gliotransmitter is released. This gliotransmitter (for example, serine, adenosine, or glutamate) can diffuse locally and influence the actions of adjacent neurons or it can be released at a more distance synapse. Furthermore, different gliotransmitters may be released by a single astrocyte at multiple synapses or a single gliotransmitter in a single synapse can have divergent affects different neurons. In all, a heterogeneity of responses can occur throughout the central nervous system based on the output of a single glial cell.

Currently, major research holes remain in identifying more types and sub-types of glial cells as well as the phenotypic, physiological, and functional properties of these cells. A second area of focus needs to be investigation of the neural-glia network. Much has already been discovered about the sub-cellular and cellular features of glial cells but the significance of these features as they relate to the functioning of the entire nervous system has not been elucidated. The two strategies being invoked to study both these areas are: 1) selective stimulation of glial cells, and 2) specific loss of function in glial cells without sacrificing the supportive function of the cells. Thus, the endless possibilities of the role of glia in neuronal functioning as indicated by the current and future of glia research is in fact a glia-ful endeavor.

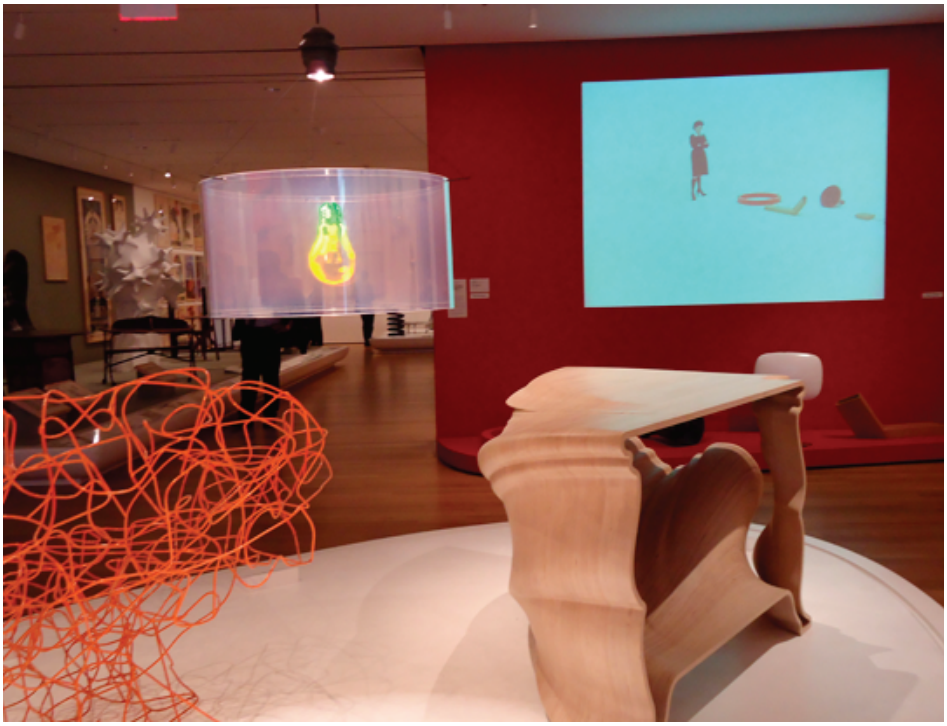
Science at MoMA

Article and Photographs by Allison Cohen



"The blurring of the distinction between art and science opens up wonderful opportunities for collaboration."

A show at the MOMA called Action! Design over Time showcases a fascinating collection of objects that demonstrate how the design process has changed over the years. Some of the most recent pieces display how the use of computer technology and scientific knowledge inform the design process. The show includes many prototypes of furniture made by creating a computer algorithm that allows the design to grow within a computer in a way that mimics natural growth processes observed in nature. The growth was then stopped and translated into a physical object. One piece, a hybrid-energy delivery device, is made of flexible photovoltaic panels shaped like ivy that convert solar and kinetic energy created by the wind into electrical energy. Another piece creates a visualization of air traffic over the United States. Other exhibits include one about sexual selection using smell, featuring devices meant to enhance this sense of smell, a vase made by bees out of beeswax, and a holographic light bulb.



The show emphasized how the process of creating and designing objects has changed and diversified, with the use of very slow methods, such as leaving a vase-shaped scaffold in a bee hive for a while, and faster methods involving the use of computer software that can quickly design and allow for the manufacture of an object. In this show, the distinction between art and science education is obscured. Even though the focus is on how art, science, aesthetics, and sustainability are interrelated in the twenty-first century, it is still surprising to find a scientifically intensive exhibit in a museum dedicated to art.

Traditionally, art and science occupy separate realms. Science deals with clear, objective facts while art deals with subjective concepts such as emotion and beauty. Now, it seems as though art, in its process, has come to resemble science in some ways, and sometimes represents scientific concepts, such as in this most recent show. In recent years, art has become very process oriented; it is focused not on the final product, but the journey, much like scientific inquiry, where the question and the experimental procedure take precedence over the results of the experiment. While scientists can think of possible outcomes in advance, and the experimental results are often as one expected, more often than not experiments are dead ends. A lot of conceptual process art emphasizes this idea. Artists choose a process for mark-making, such as dropping cards in random places about a canvas, and record this process. The main question becomes "what happens if I do this?" instead of "How can I manipulate my process to create the desired image?" In performance art, the purpose is often to see how museum-goers will react to a certain manipulated social situation. The outcome, which the artist cannot control, becomes even more important than the actual performance, which can be controlled. The blurring of the distinctions between art and science open up wonderful opportunities for collaboration. We can display the beauty of science in art museums, and have artists use their creativity to think of new and exciting ways to study our universe. Artists can illustrate scientific ideas so they are accessible to more people. Designers can use scientific discoveries to design our future. The possibilities are endless.

Columbia Science Review

www.columbia.edu/cu/csr