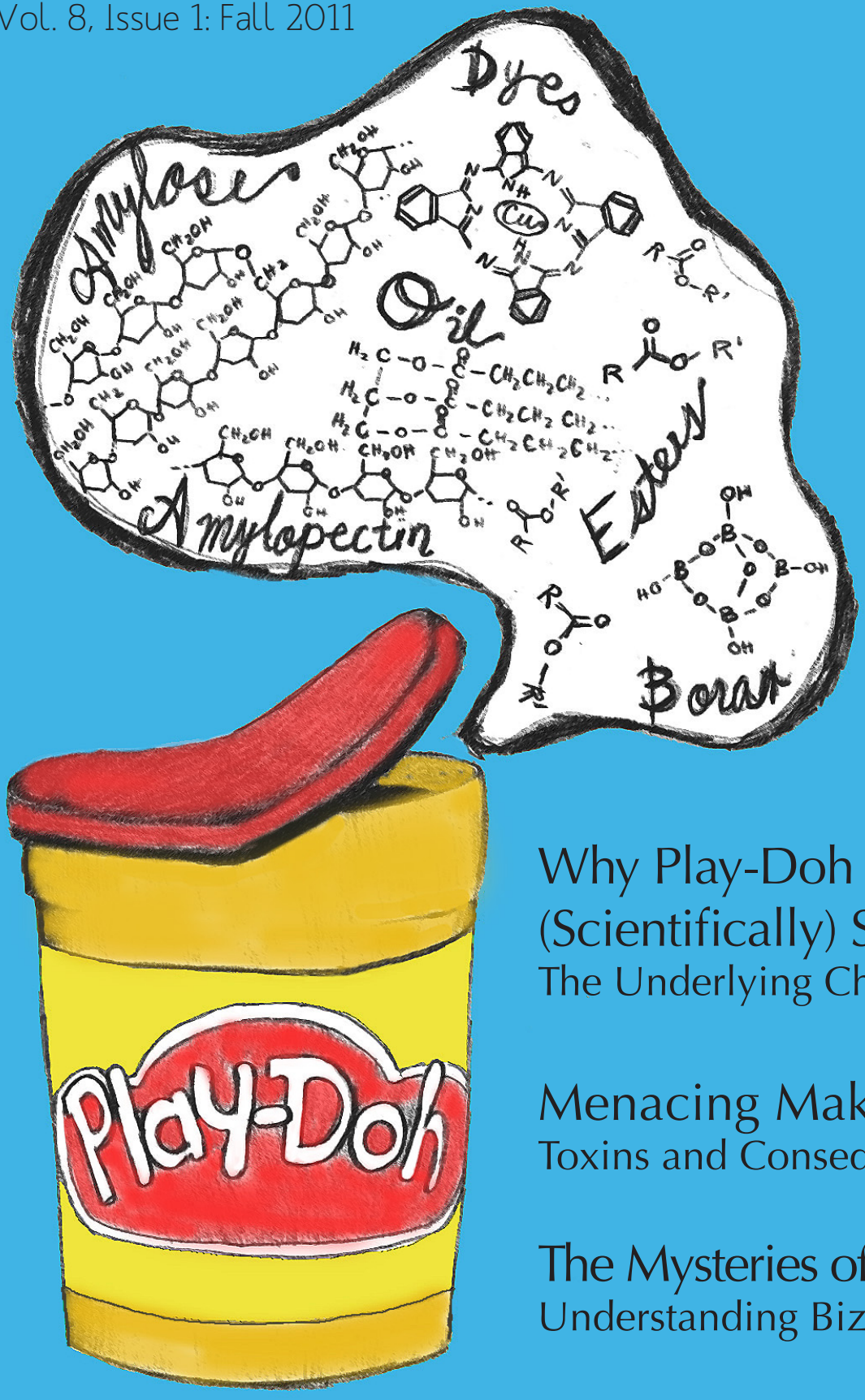
Columbia Science Review

Vol. 8, Issue 1: Fall 2011



Why Play-Doh Is (Scientifically) So Much Fun!
The Underlying Chemistry

Menacing Make Up?
Toxins and Consequences

The Mysteries of Black Holes
Understanding Bizarre Phenomena

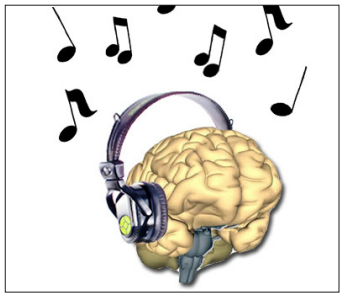
The Columbia Science Review strives to increase knowledge and awareness of science and technology within the Columbia community by presenting engaging and informative articles, in forms such as:

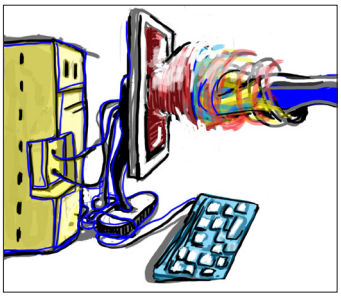
- Reviews of contemporary issues in science
- Faculty profiles and interviews
- Editorials and opinion pieces

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

contact us at
csr.spreadscience@gmail.com

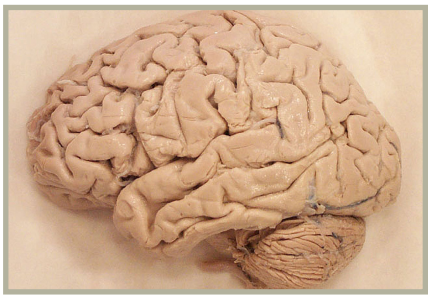
Columbia Science Review





Alyssa Ehrlich
Grace Baek
Starlyte Harris
Veena Kumar

Cocktail Science

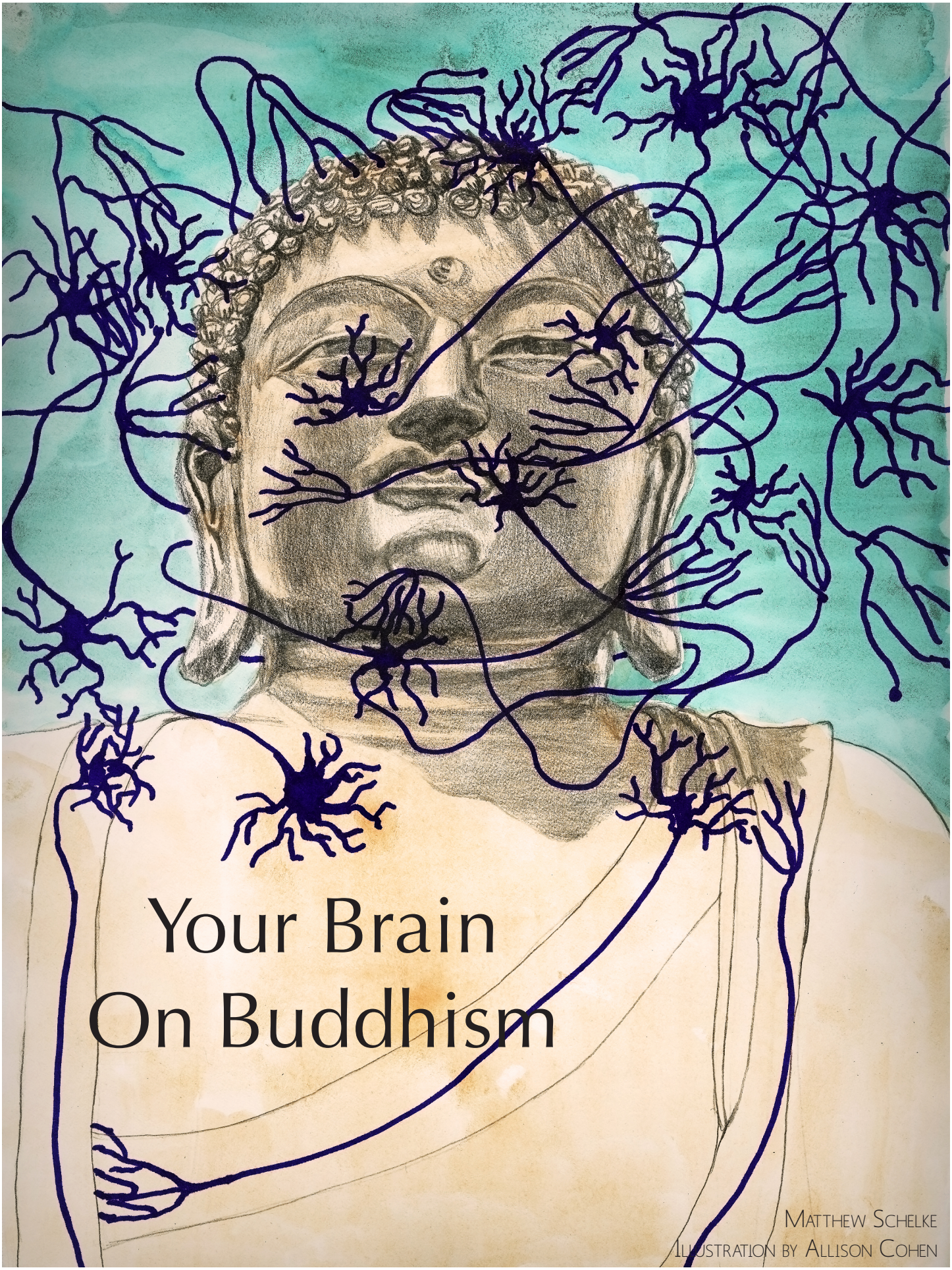


While the notion of growing a working brain in a Petri dish may sound like science fiction, researchers at the University of Pittsburgh have recently managed to do just that. Henry Zeringue and his colleagues created an artificial microbrain by sticking adhesive proteins onto a donut-shaped silicon disk, and then adding neurons cultured from the hippocampus of embryonic rats. The hippocampus is a brain structure that serves an important role in the consolidation of new memories. In time, the brain cells along the ring grew together and interconnected, forming a natural neural network. By stimulating these neurons with an electrical pulse, researchers were able to evoke the sort of persistent, post-stimulus activity characteristic of short-term memory. According to Zeringue, the prolonged burst of network activity seen in the microbrain - which lasted a full 12 seconds compared to the natural duration of .25 seconds - allowed for extensive observation of how neural impulses were transmitted by the cells. Indeed, this tiny artificial brain presents an exciting new opportunity to peek into the complex world of neuron communication, hopefully allowing us to better understand the cellular mechanisms behind memory formation.

Japan's Fukushima Daiichi nuclear plant was one of the largest nuclear power plants in the world when it was struck by a 9.0 magnitude earthquake and a tsunami in mid-March of this year. The plant's reactor cooling systems malfunctioned and radiation leaks evoked safety concerns worldwide. The medical community has become concerned with the health of the brave workers who stayed behind to prevent further radiation leakage. Some medical experts have encouraged workers to bank their blood stem cells for possible future stem cell transplants. This preventative measure counteracts possible consequences of exposure to radiation, which can include devastation of the immune system and cancer. However, experts continue to be divided over the efficacy of this precautionary plan. Receiving a transplant of their own stem cells would reduce chances of immunorejection, but such a transplant would only be helpful if the workers were exposed to five to ten grays of radiation, according to Dr. Nelson Chao of Duke University. With lower than five grays' worth of exposure, workers would have other treatment options; any more than ten grays' worth of radiation would cause death from severe organ damage. For now, no news of the stem cell bank plan has been released. What is certain is that over a hundred thousand tons of radioactive water still remain in the reactor, and radiation has been found in the urine of individuals living within 40 kilometers of Fukushima reactor No. 1.

Apples. Celery. Strawberries. Peaches. Spinach. Nectarines. Imported grapes. Sweet bell peppers. Potatoes. Domestic blueberries. Lettuce. Collard greens. According to research conducted by the Environmental Working Group, a non-profit organization dedicated to informing consumers and protecting the environment, these popular fruits and vegetables are the most heavily contaminated with hazardous pesticides. While the many health benefits of these foods are well known (vitamins, minerals, fiber), food suppliers and health professionals have failed to propagate recent research concerning the dangers of pesticide residue. According to the US Environmental Protection Agency's human health risk assessment, pesticides negatively affect the nervous system and endocrine (hormonal) system, acting as carcinogens. Human consumption of these chemicals causes toxin levels to rise, and switching to organic options may cause measurable pesticide levels to drop. Therefore, choosing organic food options could prove worthwhile for those hoping to lessen exposure to toxins. Improve your health by exploring healthier food options online, growing your own garden, or opting for organic foods at your local farmer's market.

There has long been speculation of a link between creativity and mental illness. Consider composer Ludwig Van Beethoven, who psychologists Jablow Hershman and Julian Lieb postulate suffered from bipolar disorder. Beethoven's letters to his friends reveal that the cycle of his manic and depressive states (known as cyclothymia) greatly influenced his compositions. Hershman and Lieb speculate that Isaac Newton, Edgar Allen Poe, and Vincent Van Gogh were also manic-depressive. A 1987 study of thirty writers conducted by neuropsychiatrist Nancy Andreasen, found that these writers had a significantly higher rate of mood disorders (80% vs. 30%) compared to "non-creative career" control subjects, a finding which was later supported by Arnold Ludwig. These findings suggest that psychiatric disorders are more common in highly creative people. But is the reverse also true? A study by Dr. Ruth Richards in 1988 found that psychiatric patients with mild cyclothymic disorders such as bipolar disorder showed a greater rate of creativity compared to patients with different psychiatric disorders (corroborated by a study by Dr. Jerry Fodor in 1998), but not when compared to the general population. Although a scientific link may exist, we are far from understanding the extent and cause of this link, and how to define "creativity" during experimentation. Perhaps, as mathematician John F. Nash, Jr. suggested, "Rationality of thought imposes a limit on a person's concept of his relation to the cosmos."



Your Brain On Buddhism

Matthew Schelke
Illustration by Allison Cohen

The red and yellow robes of Tibetan Buddhists appear as tiny spots of color in the sweeping vistas of the Himalayas. In these mountains, Buddhist monks meditate for thousands of hours, focusing on compassion, kindness, and the fundamentals of human consciousness. The contemplation of the monks is a counterpoint to the vast expanses of wild terrain that surround them, just as their vividly hued robes contrast with the whites and grays of the landscape.

Recently, the colorful robes contrasted with the whites and grays of EEG machines far away from Tibet. In 2004 at the University of Wisconsin's Laboratory for Affective Neuroscience, Richard Davidson connected the heads of eight practicing monks to networks of electrodes to monitor their brain functions during meditation. EEG, short for electroencephalography, records the synchronous firing of millions of neurons; the rhythmic patterns of activity are known as "brain waves." These waves range in frequency from delta, indicating deep sleep, to gamma, indicating intense focus. Davidson's interest was in gamma waves during "objectless meditative practice," as Tibetan Buddhist meditation places an emphasis on long periods of focus.

What Davidson found was extraordinary. The eight monks he studied were trained in "compassion mediation," in which "benevolence and compassion pervade the mind as a state of being." In monks and laypeople that are not meditating, gamma waves are weak and barely noticeable on an EEG. But as soon as the monks were told to focus on "loving compassion," they produced stronger gamma waves than researchers had ever seen—about thirty times the strength of the control group. These monks were not born with unusual brains—rather, by training for years, they had altered the physiology of their neurons. Previously, scientists believed that neural activity levels were fixed during late adolescence. Davidson's monks, though, had changed the foundations of their thought far into adulthood.

The discovery that the brain is malleable is new for neuroscience, but the idea found poetic expression over a century ago. Walt Whitman, the bard of the American experience, celebrated the mind's ability to reshape itself in Song of Myself. "I am of young and old, of the foolish as much as the wise," Whitman declares, "maternal as well as paternal, a child as well as a man." Human character is, at its core, mutable.

But how does a change in brain oscillations correlate to Whitman's changes in character? Davidson's study found more than just a dramatic increase in gamma waves. The left prefrontal cortex of the monks was highly active, as if the monks were able to reroute their brain activity there. This area is associated with tranquility, joy, and compassion: exactly the emotions upon which the monks meditated. Purely by mental conditioning, they could change the biology of their inner emotional life.

Song of Myself ends with an ode to the elusiveness of one's self: "I too am not a bit tamed, I too am untranslatable." Our selves, our mental worlds, are not static as was once thought. They are rippling patterns of dynamism, with connections forming and breaking perpetually. Unlike Whitman's "self," our brains are tamable by training. Like muscles, we can flex emotions and thoughts, increasing their strength to the astonishing capacities of Davidson's monks. We can now say that the brain, like Whitman's narrator, is not merely the blueprint of a single individual, but encompasses the possibilities of human potential.

Memory Research Supports Frequent Quizzing in 21st-Century Classrooms

Yang (Sunny) Li
Illustration by Diane Wang

Memory is a child walking along a seashore. You never can tell what small pebble it will pick up and store away among its treasured things. ~Pierce Harris, Atlanta Journal

Our memory, no matter how much we believe we can rely on it, is beyond our control and constantly being transformed subconsciously. We rely on our fickle memories to build strong social connections, to learn the skills we need for tomorrow, and to help us as eye-witnesses. Most importantly, we also rely on our memories to help us succeed in school. How can we improve our memories in order to better retain knowledge taught in the classroom? As many parents, educators, and students currently debate what the best methods of teaching are, some major methods being tested in classrooms include: teaching in short segments of time, implementing more hands-on experiences to stimulate children's interest, and teaching concepts in context (rather than through rote memorization). More importantly, recent studies strongly support the practice of regular quizzes, which allow students to form long-lasting memories.

THE BASICS OF MEMORY FORMATION

Human memory is nothing like computer memory. It is not located in any specific part of the brain, unlike hard-drive memory, which stores files in specific folders. Human memory is also reconstructive—the simple process of retrieving a memory may alter it in some way, since we must reconstruct memories from elements scattered throughout various areas of the brain. Human memory is therefore much more malleable and fallible than computer memory.

However, the three main steps involved in the memory process for humans are similar to those of a computer. These stages are acquisition, storage and consolidation, and retrieval. Acquisition, also known as encoding, occurs as we learn new material. Memories are formed as learning alters the connections between neurons, or nerve cells, within our brains. Neurons communicate with each other through synapses, which are junctions between neurons, and when we learn, the efficiency of signals traveling through synapses increases, facilitating the passage of nerve impulses along a particular circuit.

The second step in the human memory process is storage and consolidation, in which we keep the material in our brain until it is needed. Consolidation fortifies nerve pathways, a process that can span many weeks. Important factors that affect the consolidation of our memories include the quality and quantity of sleep that we get, how well the new memory relates to pre-existing memories, and how much emotion the new memory stimulates.

The final step involves the retrieval of memories. This stage is where many of our memory problems occur—we forget because we cannot successfully retrieve the memory that we want to. During memory consolidation and storage, other memories may interfere, and thus we forget. Successful memory retrieval occurs when the brain reactivates a particular pathway, and the wanted information is remembered.

TYPES OF MEMORY

There are also three fundamental types of memory: sensory memory, short-term memory (STM), and long-term memory (LTM). All memories start out as sensory memory, which is sensory information that travels to the brain and becomes processed as memory. These sensory cues last for only a few milliseconds or seconds, but are integral to normal perception.

Short-term memories are created after information is processed through sensory memory. Building STMs involves changing neuron connections within the brain, which allows for temporary storage of various commonplace experiences and facts, such as the address of a new shopping mall. STM is limited not only by time, but also by the amount of information it stores. STM can only store around seven items simultaneously, which means that we cannot easily remember identification numbers more than seven digits in length without using some memory improvement technique (mnemonics). However, if we were to repeat new information over and over and the information is coded properly, it can be kept in STM or transformed into long-term memory.

Long-term memory requires the new piece of information to travel through both sensory memory and short-term memory. LTM is different from STM in that building long-term memories requires the production of new proteins. LTM stores important life events, has seemingly endless capacity, and lasts a long time.

MEMORY, LEARNING, AND EDUCATION

Now equipped with a basic understanding of memory formation and retrieval, we can explore the issues of student learning in American classrooms and methods of improving retention of course material. One heated topic in the United States is whether and how students should be tested to see their proficiency in different subject areas. Testing includes standardized tests such as the SAT and ACT as well as classroom exams. Some criticize current American testing completely, suggesting that real-world applications do not call for any individualized work, but rather require cooperation among different people to solve challenging problems. Others argue that tests create unnecessary pressure and anxiety for students, which can discourage them from learning in the first place.

While critics of testing may be correct in some aspects, research shows that testing actually has the potential to enhance learning by improving recall of semantic memories. In the United States in the 1930s, graduate student Herbert Spitzer researched the effects of varying the amount of testing on thousands of sixth grade students in Iowa. Spitzer made all the students read an article about bamboo. After splitting the students into different groups, Spitzer used multiple-choice questions to quiz students on the details of bamboos, which they should have learned from reading the article. Quizzes were given to students in Group 1 after they finished the article, the next day, and once more three weeks after their initial quiz, while students in Group 2 were given one quiz three weeks after they had read the article about bamboo. The students did not prepare for the quizzes. The results of this experiment showed that Group 1 students performed significantly better than other students. With these results, Mr. Spitzer advised the educational community that "[i]mmediate recall in the form of a test is an effective method of aiding the retention of learning and should, therefore, be employed more frequently." The results concluded that teachers should quiz students briefly during every class session in order to maximize students' long-term learning.

Henry Roediger, professor of psychology at Washington University in St. Louis, and Dr. Jeff Karpicke of Purdue University further investigate this phenomenon. In a smaller-scale experiment, Karpicke and Roediger conducted an experiment comparing final test scores on word pair recollection of students who received multiple quizzes versus students who simply studied the list of words. The results from this experiment showed in the final exam that students who were quizzed multiple times could correctly list approximately 80 percent of the word pairs, whereas the students who only studied the words could list around 35 percent of the word pairs. Thus, Karpicke and Roediger reported in Science that "students who were repeatedly tested on material significantly outperformed those who repeatedly studied it."

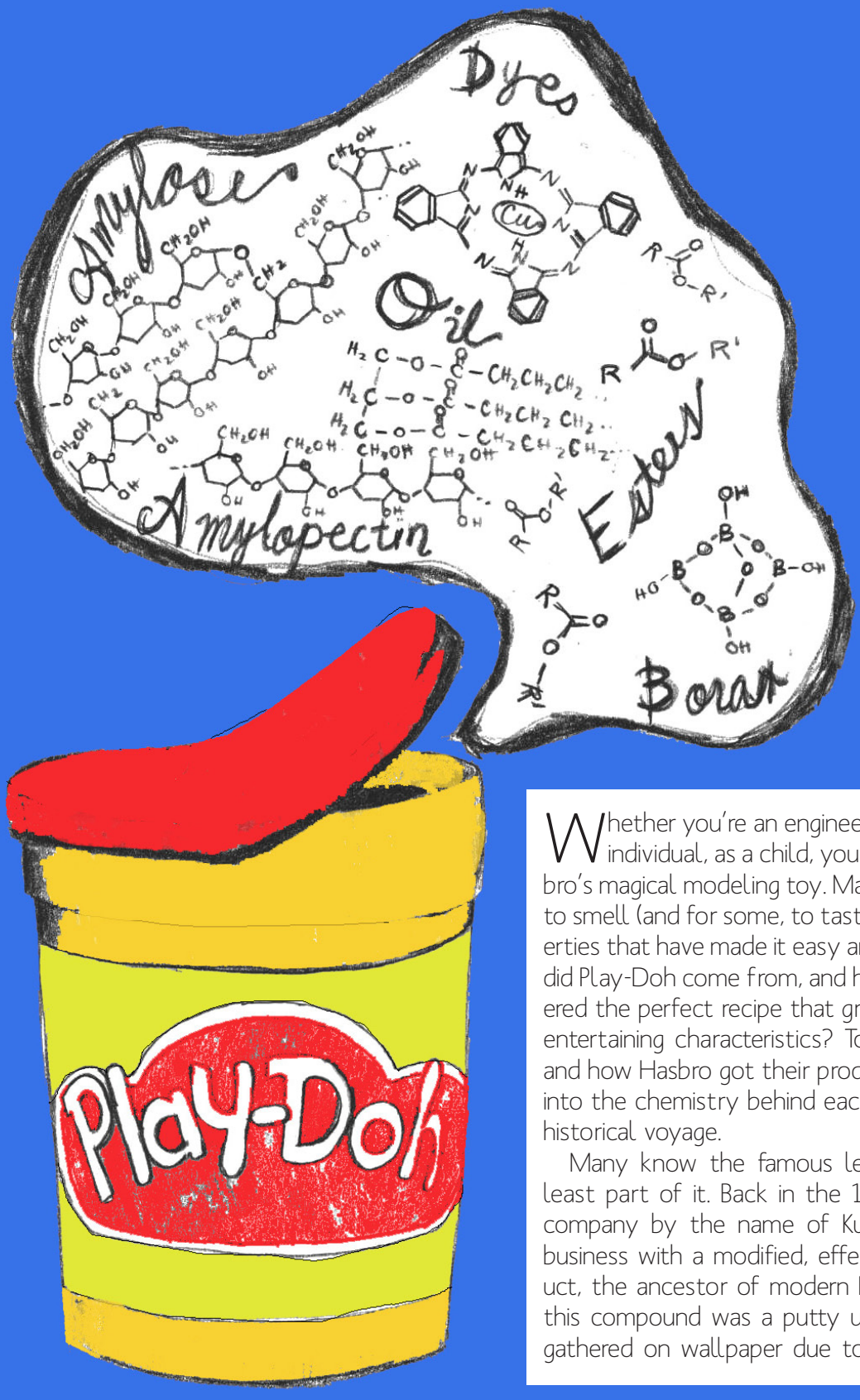
Knowing the positives of regular quizzing is not enough, however. We face a tough obstacle in reforming the educational system and many teachers' viewpoints. Many educators counter that quizzes would take up precious time. Others argue that frequent quizzes only cover specific details that do not help students understand larger themes. However, researchers believe that learning these details is actually a necessary foundation for student understanding. Educator Ms. McDermott elaborates: "In the process of retrieving Fact A…you think, Hmm - what did I learn about this general topic? So in a sense, you're also retrieving Fact B and Fact C, even though that's not what you were directly asked to do." Of course, other teachers want to avoid the additional workload that would result from frequently quizzing students. But a simple solution to this fear is to incorporate handheld "clicker" devices that immediately give students the results of their daily quizzes. Having used this clicker system myself, I found this to be a great way to make sure that I cleared up any misconceptions about old material before learning new material in the following lessons.

Students can even quiz themselves in order to study for exams. A research experiment recently published in Science involved students who were tested on a passage immediately after reading it and those who either repeatedly studied the material or drew detailed diagrams in an effort to learn the material. One week later, the students who were tested were able to recall approximately 50 percent more information than the other students.

Make sure to remember all this for your next exam!

Why Play-Doh Is (Scientifically) So Much Fun!

Andrew Sumner
Illustration by Evelyn Warner



Whether you're an engineer, an artist, or simply a creative individual, as a child, you probably loved Play-Doh, Hasbro's magical modeling toy. Malleable, colorful, and pleasant to smell (and for some, to taste), Play-Doh has physical properties that have made it easy and fun to use and reuse. Where did Play-Doh come from, and how does it work? Who discovered the perfect recipe that grants Play-Doh its versatile and entertaining characteristics? To understand these properties and how Hasbro got their product just right, one has to look into the chemistry behind each component. But first, a brief historical voyage.

Many know the famous legend behind Play-Doh—or at least part of it. Back in the 1920's, a dying Cincinnati soap company by the name of Kutol Products reinvigorated its business with a modified, effective wallpaper-cleaning product, the ancestor of modern Play-Doh. Before it was a toy, this compound was a putty used to remove the soot that gathered on wallpaper due to coal burning furnaces. How-

ever, tragedy struck the company when both oil and gas burning furnaces were introduced after World War II and vinyl wallpaper became easily washable by conventional means. Desperate for a market to sell their product, Kutol found inspiration in a holiday article. Recognizing that their wall cleaner fit the criteria for a new toy, Kutol adjusted their recipe to create an effective modeling clay. Eventually, with a new marketing scheme, they re-released the clay as "Kutol's Rainbow Modeling Compound" (later to be thankfully renamed as Play-Doh) and hit the toy industry by storm.

So how did wallpaper cleaner also function well as modeling clay? To understand, we have to analyze Play-Doh's first two primary ingredients: water and starch. Starch is a polysaccharide—essentially a long string of sugar molecules—that consists of two distinct sugars: amylose and amylopectin. While amylose is a linear string, amylopectin is a branched string. As organic polymers, polysaccharides are generally soft and pliable, and the opposite of rigid, hard metals. These complex molecule strings form what is described as a "starburst" shape around a central point called a hilum. This arrangement of soft yet densely packed starch is what grants Play-Doh its unique texture, mold-ability, and sponge-like absorbency (for cleaning wallpaper).

To gain precisely the right consistency, Play-Doh is made with wheat starch, which contains about 25% amylose and 75% amylopectin. The rationale for this proportion lies in starch's reaction with water. Keep in mind that most organic reactions are dictated by hydrogen bonds. These bonds, most commonly found in water, are relatively strong intermolecular forces that occur between a hydrogen atom and electronegative atoms such as oxygen or nitrogen on other molecules. Thus, when water is added to starch, the two will react. Starch will absorb some of the water and swell without breaking down and dissolving. Amylopectin will swell more than amylose because of its stronger intermolecular attractions. This greater bonding is due to amylopectin's branched shape, which grants more surface area and thus more interfaces for attraction. In order to achieve the best consistency for pliable yet sturdy dough, having a mixture of mostly amylopectin is most desirable. However, a sample of 100% amylopectin will still be susceptible to dissolving in water, so some amylose must be added. When the starch complex is placed in water, amylose, the smaller molecule, will escape and stabilize the surrounding water, allowing the amylopectin to remain intact and maintain the complex's integrity. Therefore, amylose is necessary for sustaining a firm and durable dough. Thus, a 3:1 ratio of these two yields the ideal combination that makes Play-Doh so effective at modeling and shaping.

Another key characteristic of Play-Doh to come out of this starch-water interaction is Play-Doh's reusability. While the hydrogen bonding that occurs at the starch interface suffices to bind the water molecules in place, evaporation will ultimately occur in dry surroundings. This explains why Play-Doh loses its malleability and became grainy when left out overnight. By sealing your Play-Doh inside its can, this moisture remains trapped by the hydrogen bonds, keeping it fresh and ready to use once again when reopened.

In order to preserve its consistency, Play-Doh also contains other vital chemicals. When the starch-water mixture cools, strands of free amylose in the water will tend to bind to each other in a slow yet steady process. Eventually, this process, retrogradation, will cause the dough to permanently harden. To combat this process, extra amylopectin or another "waxy" starch is added. Complicating things further, adding too much of this inhibitor may give your Play-Doh a sticky, paste-like feel, so another ingredient, called a surfactant is added. A surfactant is a compound with one end that is attracted to water (hydrophilic) and another that is attracted to organic compounds and not water (hydrophobic). A surfactant will form a layer on the compound's surface with the hydrophilic end facing in on the starch and the hydrophobic end interacting with the solute, in this case, water. With the surfactant in place, vegetable oil—a lubricant—is added to slicken the dough. Borax is also included to prevent the formation of mold, an issue that arose when Play-Doh was first released. All of these ingredients interact in subtle ways to preserve the lifetime of Play-Doh as a quality, multi-use modeling clay.

Alongside these main components, Play-Doh also has a myriad of other ingredients; many remain part of their secret recipe, protected by patent. For example, special dyes are used for each distinct color, and fragrances are used to give Play-Doh its famous smell. More importantly, these ingredients do not cause Play-Doh to stain (it was formerly a cleaning compound after all), explaining why it was so valuable as a cleaning sponge as well as child-friendly toy. After years of adjustment, retail, and product differentiation, we have ended up with one of the simplest, yet most entertaining toys of all time. So, the next time you get that nostalgic yearning to create in the most innocent and child-like of ways, open up that old can of Play-Doh. I guarantee it will still be fresh and perfect to use because of the deliberate chemistry powering it.

Linking Diabetes and Obesity to Resistin

Monica Chen
Illustration by Allison Cohen

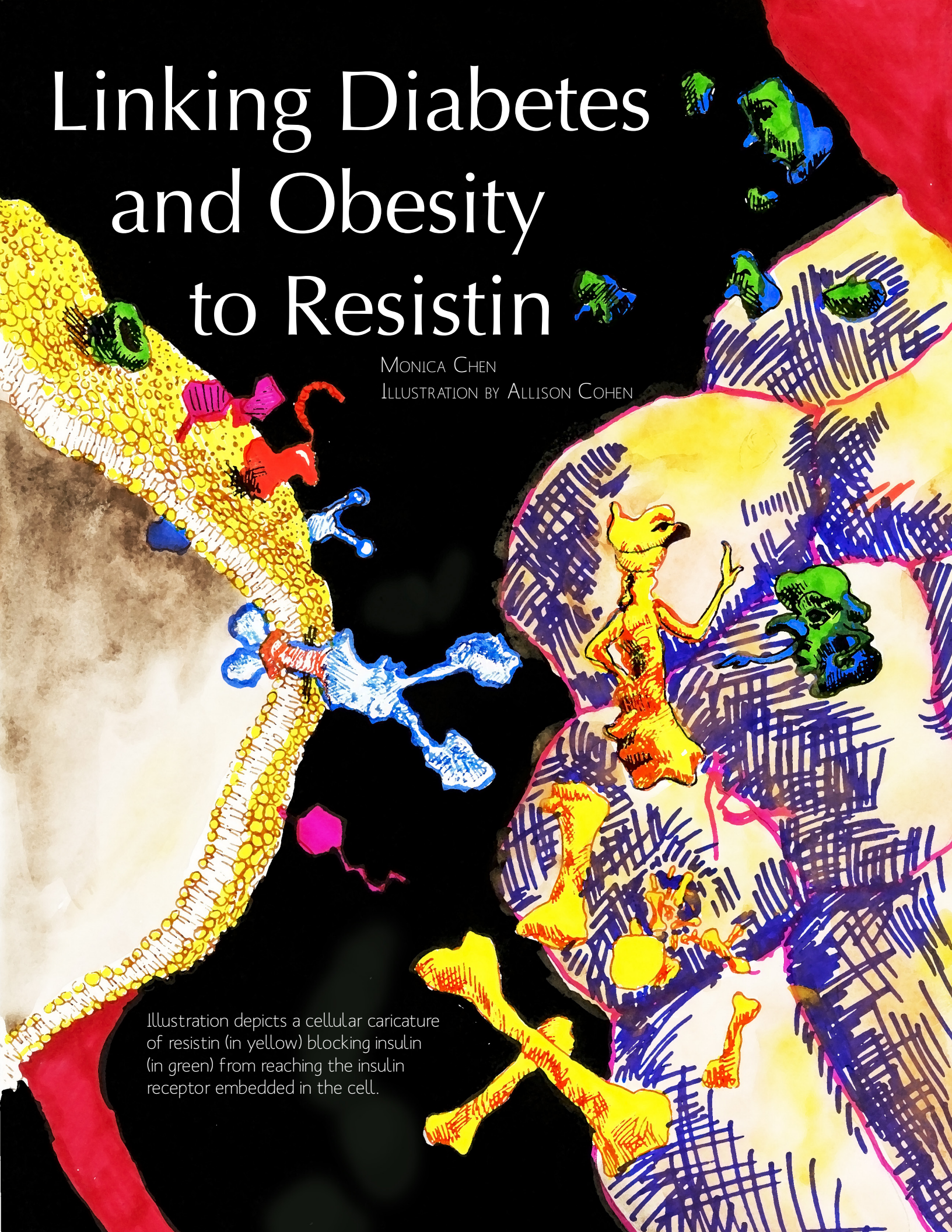


Illustration depicts a cellular caricature of resistin (in yellow) blocking insulin (in green) from reaching the insulin receptor embedded in the cell.

On February 9, 2010, First Lady Michelle Obama announced Let's Move!, a campaign to end childhood obesity in the United States within one generation. According to the official Let's Move! website, childhood obesity rates have tripled in the past thirty years and today, almost one-third of children in the United States are overweight or obese. These numbers are staggering considering the fact that obesity may lead to heart disease, type 2 diabetes, asthma, sleep apnea, and social discrimination.

Obesity is defined as having excess body fat which results in high blood sugar, and is often measured by utilizing the body mass index calculation. Diabetes, a disorder in which a person suffers from high blood sugar, is divided into three types. Type 1 diabetes results from the body's failure to produce insulin, a hormone which helps to regulate blood sugar levels while type 2 diabetes results from cells developing insulin resistance and an inability to utilize insulin properly. Insulin resistance occurs when cells in the body do not react as much to insulin, making it difficult for the hormone to control blood sugar levels. The third type of diabetes is gestational diabetes, which occurs in pregnant women who have never had diabetes before. Although what causes gestational diabetes remains unknown, one possible explanation is that hormones from the mother's placenta block her insulin production, which results in insulin resistance. Diabetes is a serious disease and can lead to complications such as heart disease, stroke, kidney failure, and blindness.

Although there is a strong correlation between obesity and diabetes, a connection between the two was unknown until recently. In 2001, Dr. Mitchell A. Lazar's group at the University of Pennsylvania School of Medicine discovered resistin, a hormone that "potentially links obesity to diabetes" and was named for its ability to give insulin resistance to mice. Before Lazar's work, the mechanism by which obesity causes insulin resistance was unclear. According to Lazar, adipose cells, commonly known as fat cells, "secrete a unique signaling molecule" called resistin. This molecule is released to serve endocrine, or hormone functions likely involved in insulin resistance. To test this mechanism, Lazar injected rosiglitazone, an anti-diabetic drug, into mice and found that resistin levels decreased. In addition, resistin levels increased when mice were induced to become obese. Lastly, when anti-resistin antibodies were injected in mice with diet-induced obesity, both blood sugar and insulin activity improved. These results strengthen Lazar's claim that resistin, a hormone produced by fat cells, plays a key role in insulin resistance, and thus, diabetes.

Although studies have shown resistin's contribution to insulin resistance in mice, studies had previously failed to show a clear association in humans. One issue complicating the use of mice as a model to study resistin in humans is the fact that human resistin is produced by macrophages, or white blood cells, while resistin in mice is produced by fat cells. To address this issue, Lazar's group generated mice that lacked mouse resistin but produced human resistin. By testing these mice that produced human resistin, Lazar and his colleagues determined that "although the site of resistin production differs between species, human resistin...contributes to insulin resistance."

The ability to control resistin levels has many promising implications and is sure to serve as an important tool in understanding the causes of obesity and diabetes. Just as important is finding effective methods to treat and decrease the rates of obesity and diabetes. Michelle Obama's Let's Move! program is a promising step in decreasing obesity rates. A recent study in the Journal of Physical Activity & Health provides compelling evidence that "meeting the national recommendations for PE and recess is effective in mitigating body mass increase among children." Michelle Obama fittingly stated the importance of this issue at the Let's Move! launch, describing how "[t]he physical and emotional health of an entire generation and the economic health and security of our nation is at stake."

Keri Lofftus

The Mysteries of Black Holes

Black holes are one of the most bizarre phenomena in our universe. Their perplexing nature leads to their frequent use in science fiction books or movies. Our imaginations are filled with the notion of black holes as a violent and destructive force, ripping apart planets and tearing up stars. But does this pop culture image correspond to reality? To answer this question, we must first understand black holes themselves. What are they? How do they form? Where are they located? Most practically, how do we detect them?

A black hole is a region where matter is condensed to such an immense density that the resulting gravitational field is extremely powerful. The gravity is actually so strong that not even light, which possesses the fastest velocity in the universe, can escape its embrace. This is why black holes are black. Since light cannot exit the black hole, if you were to observe it directly, you would not perceive anything. There are two critical elements that constitute a black hole. First is the event horizon, which is the radius beyond the center of a black hole at which, if crossed, light could not reemerge. Second is the singularity, which is the nucleus, or "core" of a black hole, where its mass is compressed into a dimensionless point.

The idea that a chunk of matter could be crushed to such a density that not even light could breakout from the gravity was originally theorized by English scientist John Michell. However, it was not until Einstein formulated his theory of general relativity that such an object could be mathematically demonstrated. In 1916, German astronomer Karl Schwarzschild solved

the field equations in Einstein's general relativity for a point mass of near-infinite density. Unfortunately, Schwarzschild's results were dismissed by many as only a mathematical curiosity, not something which could manifest in reality.

In 1939, the skeptics were astounded when J. Robert Oppenheimer (of Manhattan Project fame) determined the mechanism by which black holes could actually originate in the universe: the collapse of a giant star. A giant star begins to die once it has converted all its hydrogen and helium, into iron. In an instant, the star begins to collapse. The inner core of the star collapses into a solid ball of neutrons. As the outer layers of the star collapse, they collide with these immovable neutrons and bounce off, exploding into a supernova. At this point, if the star originally had a mass of 10-20 times the mass of our own Sun, the ball of neutrons would stabilize, and a neutron star is formed. However, if the giant star possessed a mass greater than 20 times the mass of our Sun, the ball of neutrons would persist in the collapse. Eventually, it would become so extraordinarily dense that it would drastically warp the fabric of space-time, generating a black hole.

The locations of black holes are determined by their mass. There are three fundamental classifications of black holes: stellar, intermediate, and supermassive. Stellar black holes are under 20 solar masses and have formed by the collapse of a giant star as detailed above. They can be located almost anywhere you find giant stars, especially in the disks of spiral galaxies. About 20 potential stellar black holes have been identified within our galaxy, the Milky Way. They do not, however, roam the galaxy, randomly destroying entire solar systems. Usually, once a stellar black hole has been constructed, it stays in the same relative position. Black holes only consume matter which crosses their event horizon. They do not "suck" like a vacuum. So, even if our own Sun was magically turned into a stellar black hole tomorrow, the Earth would continue to orbit around it like it has for billions of years.

An intermediate black hole generally has a mass of tens, hundreds, or thousands of times the mass of our Sun. They are believed to be formed by the accumulation of a multitude of smaller, stellar black holes. Intermediate black holes are consistently detected at the center of globular clusters. A globular cluster is a spherical congregation of thousands or even millions of extremely old stars located away from the majority of stars within the galaxy.

Supermassive black holes are the heavyweights of black holes. They contain a mass which is 100,000 or even 1,000,000,000 times the mass of our Sun. These huge black holes are commonly found at the centers of galaxies, including our own Milky Way galaxy. Astronomers continue to debate how supermassive black holes are created. One theory of their formation is that they are an aggregation of intermediate black holes. Another is the gathering of an enormous amount of matter by a single intermediate black hole. A third is that supermassive black holes originated from the extreme temperatures and pressures existing in the moments after the Big Bang.

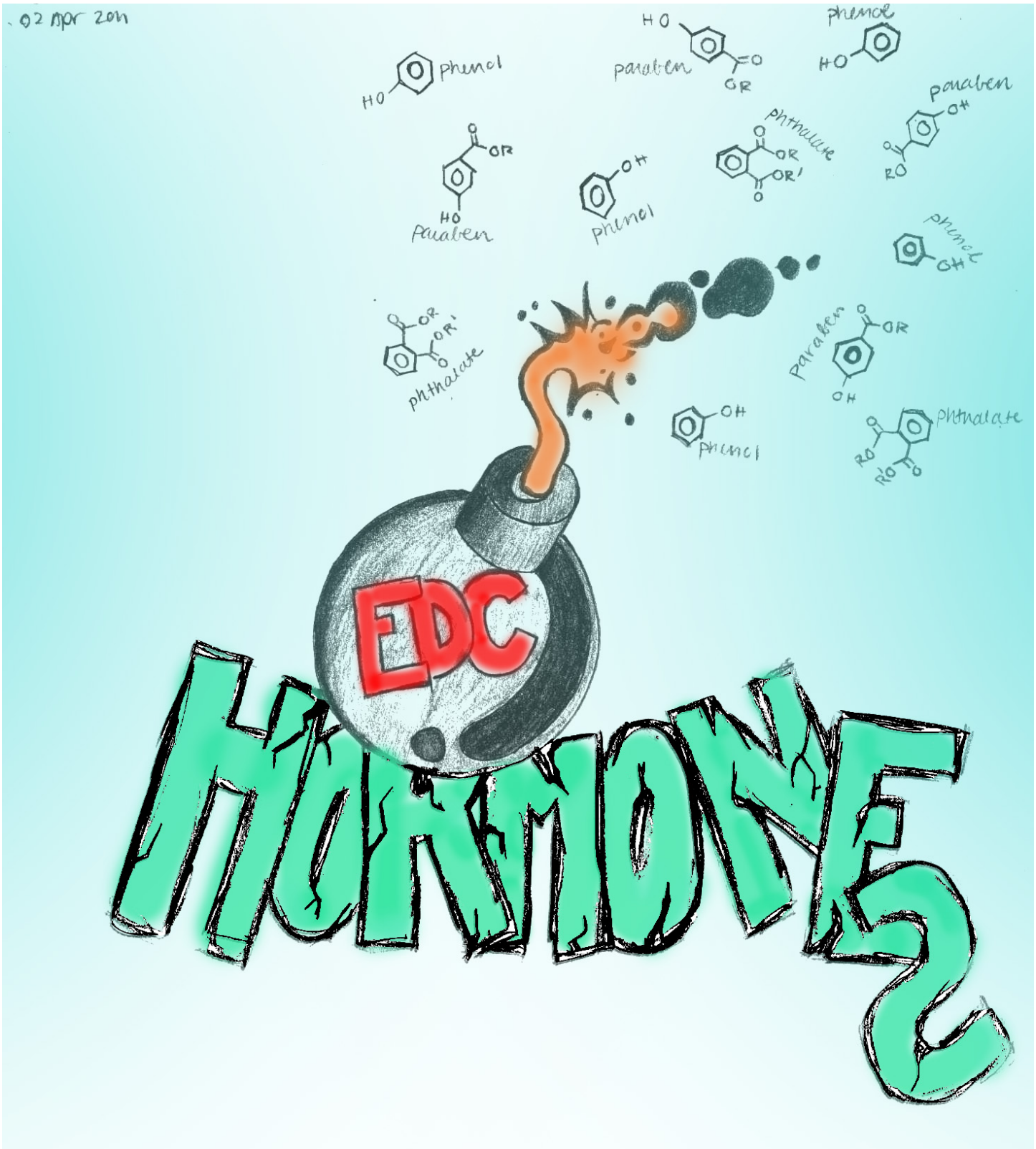
Detecting black holes of any size is a challenge for astronomers. Stellar blacks holes tend to be located as part of a compact X-ray binary. This means that either a black hole or a neutron star rotates around another star at such a close distance that matter is drawn off the star and accumulates onto the black hole or neutron star. During this transfer, the matter itself reaches such a tremendous temperature that it emits x-rays. Certain telescopes are able to observe and recognize these x-rays. However, sometimes it is difficult to tell the difference between black holes and neutron stars in these binary systems. Intermediate black holes are generally found in a similar fashion as stellar black holes.

Supermassive black holes must be located with another method, since they abide in the centers of galaxies, where x-ray sources are too dense to pinpoint. Instead, the Doppler-effect is utilized. The Doppler-effect is the shifting of light either to the red-end or the blue-end of the electromagnetic spectrum which occurs when a light source is either moving away from or toward an observer, respectively. Using the Doppler-effect, astronomers can measure the velocities of the star at the precise center of a galaxy. What they have discovered is that these stars are moving immensely fast in a relatively tiny area. The only known phenomenon which has enough gravitational force in that small of an area is a supermassive black hole.

Black holes are still mysterious. Countless questions still remain. What happens to matter pulled inside a black hole? Is it lost forever, or does the black hole spit out everything it has consumed in another universe? Since we find black holes at the center of galaxies, were they necessary for those galaxies to form? Do we owe our very existence to black holes? Doubtlessly, as astronomers continue to investigate the enigmatic black hole, even more questions will arise. Black holes are some of the strangest entities in our universe, and we may never decipher all their secrets.

Menacing Make Up?

Tehreem Rehman
Illustration by Evelyn Warner



Mounting evidence indicates that girls in the United States are undergoing puberty at earlier ages now than ever before. One study conducted earlier this year by Dr. Frank M. Biro, Cincinnati Children's Hospital Medical Center's Director of Adolescent Medicine, found that the proportion of Caucasian girls from the ages of 7 to 8 who experienced precocious puberty was greater today than as recently as the last decade. Assessment methods mainly relied on looking at breast and pubic hair development within study participants. While the African American and Hispanic girls who were examined were shown on average to still develop faster than other groups, as was shown in a previous study conducted in 1997, Caucasian girls faced the greatest rise in rates of early puberty.

While some researchers have strived to explain these growing trends of precocious puberty by pointing to changing socioeconomic conditions or dietary habits, it has become increasingly clear that such factors cannot sufficiently account for the alarming rise of American girls experiencing puberty at markedly earlier ages. More recent studies indicate that analysis of variations in exposure to environmental toxins better predicts differences in the rates of early puberty. This emerging area of research has mostly focused on a particular class of chemicals known as endocrine disrupting compounds (EDCs). EDCs are chemicals that mimic hormones, in particular estrogen and progesterone, which are the most pertinent in the case of precocious puberty. The major consequence of early puberty is a prolonged period of exposure to environmental toxins that can upset hormonal levels, and as a result, induce the onset of reproductive diseases such as breast cancer.

It seems that girls who have faced an earlier than average onset of puberty are also likely to have high blood levels of EDCs which are typically found in nail polishes and other cosmetic products. Leading brand name cosmetic products have been shown to have alarmingly high levels of toxic chemicals. According to the Environmental Working Group database's scale of 1-10, with 7-10 indicating a "high hazard," makeup from popular brands such as Revlon, Sally Hansen, Sephora and Elizabeth Arden have all received the maximum score of 10. The lowest score designated to a brand was a 3, which was given to Elegant Minerals. However, even that indicates a "moderate hazard" and none of the makeup products in the database received a score from the range of 0-2 which indicates a "low hazard." Nonetheless, the presence of cosmetic products with a relatively low score suggests that cosmetic companies do indeed have the capacity to generate goods that are safer for their female customers.

Unfortunately, manufacturers are not currently required to list the incorporation of EDCs such as parabens, phenols and phthalates in their products. Subsequently, consumers are often exposed to these toxins on a daily basis without even being aware of their presence. Some companies claim that the concentrations of EDCs in their products are below established guidelines on minimum "safe" levels. However, what these companies fail to take into consideration is that their particular product is often not going to be the sole source of EDC exposure for the consumer. Rather, the interaction between multiple EDCs can greatly amplify their individual effects, thus trumping the conventional linear-threshold model used in risk assessments.

What is even more disconcerting is the fact that many young girls already have substantial levels of EDCs in their blood before they are even born. Numerous studies are now demonstrating how the environmental toxins women are exposed to during their lifetime can be transferred maternally to their children. In other words, the parabens or phenols that these women are individually exposed to through the application of various cosmetic products can also adversely affect their future offspring. These findings suggest that female consumers need to be more wary about the products they purchase not only for their own welfare but for the well-being of future generations as well. This is a huge burden to place on a consumer body that is either deliberately misinformed about the potential adverse effects of the goods they are purchasing or either simply unaware of due to the lack of sufficient federal guidelines that necessitate transparency from companies. Federal agencies such as the Environmental Protection Agency (EPA) have historically been too slow in enacting crucial legislation that would ensure the protection of American consumers. Consequently, there are a growing number of organizations in addition to the Environmental Working Group that are dedicating their time and resources to raising awareness about the prevalence of deleterious chemicals in consumer goods. Some examples are the National Library of Medicine's Tox Town, the Citizens' Environmental Coalition and the Center for Health, Environment and Justice. Ideally, this cluster of social movement organizations would eventually morph into a full-fledged national grassroots movement in order to make sure that women's bodies aren't needlessly being subjected to toxins, which cosmetic companies can replace with safer ingredients.

Veena Kumar
Illustration by Diane Wang

Book Review: *Musicophilia: Tales of Music and the Brain*, by Oliver Sacks

Music is what feelings sound like." -Author Unknown

Music: the art of creating and perceiving sound as more than arbitrary notes, but as an evocative metaphor for life itself. Evolutionarily, music is probably a purely human development. There is much speculation as to whether music and language evolved together. The famous composer and philosopher Rousseau believed that language at first exhibited a "singsong" nature similar to music, in which words had distinct pitches, but that this similarity eventually diverged. Steven Pinker argues, "As far as biological cause and effect are concerned, music is useless...it could vanish from our species and the rest of our lifestyle would be virtually unchanged." Yet at the same time, we each have a musical instinct, and music is intrinsic to us as a species.

From a neurological perspective, what is music other than electrical impulses wired by the complex circuitries of the brain? The "complex sonic patterns woven in time, its logic, its momentum...the mysterious way it embodies emotion and 'will'" collectively assemble in our minds as music, harmonious and unified. One way to scientifically study what music is involves studying anomalies-people who musically differ from the norm. Columbia's own Oliver Sacks, Professor of Clinical Neurology and Psychiatry, writes a compelling compilation of these stories in *Musicophilia: Tales of Music and the Brain*. Sacks recounts anecdotes of patients with various neurological conditions he has encountered, who are vastly different, and yet similar in one sense: they all help explain the complex and intricate neurological connections which cause us to perceive, appreciate, and perform music.

What if our brain was not able to put together the various auditory cues that make music? In the chapter Things Fall Apart: Amusia and Dysharmonia, Sacks describes "total amusia" as the condition in which "tones are not recognized as tones, and music, therefore, is not experienced as music." Instead of hearing notes, one will hear clanging or screeching noises. Yet even with amusia the ability to perceive and respond to speech remains unaltered. This is because in the auditory cortex, areas involved in the perception of voices are separate from those involved with the perception of musical timbre. Sacks relates that there are two main forms of musical perception. The first is recognition of melody, which primarily involves the right-hemisphere of the brain. The second is the perception of rhythm, which involves much more of the brain, including the left hemisphere, basal ganglia, and cerebellum. It has been shown that patients with congenital amusia have diminished development in the right inferior frontal gyrus. This area is involved in perception and memory of melody, which is why these patients have lost the ability to distinguish between tones.

But what makes us hear music as harmonies and integrative motifs rather than notes layered on top of one another? What makes us hear a symphony rather than a violin over an oboe over a trumpet? Rachael Y., one of Sack's patients, was once an accomplished musician. After suffering severe head and spine injuries, she developed a type of amusia in which she could still perceive tone and rhythm, but could not filter what she had heard. In her own words, "I absorb everything equally, to a degree that becomes at times a real torture." Putting each instrumental line together can be done but she has to do this intellectually by "quickly switching attention between the different musical elements" to "integrate them into a musical piece."

Sacks also raises that question of what causes people to be exceptionally talented with music. In the chapter "Two Thousand Operas: Musical Savants," Sacks describes that when we are born, our right hemispheres kick in immediately, so that perceptual functions develop before the higher cognitive capabilities of the left hemisphere. Researchers Geschwind and Galaburda have hypothesized that in savants-- people with extraordinary musical capabilities -- the left hemisphere is damaged or underdeveloped during infancy, causing a "compensatory overdevelopment of the right hemisphere." This explains the abilities of Sacks' patient Martin, who was born normally but contracted meningitis at three years of age (a critical period in the development of the left hemisphere). Although socially inadequate, Martin developed extraordinary musical capabilities, including an extensive phonographic memory and piano skills. Sacks observed the same astonishing musical capabilities in Stephen Wilshire, an autistic musical prodigy. These case studies suggest that we all might have the potential to become musical savants as infants while our right hemisphere remains dominant. In a 1999 study, scientists Allan Snyder and D.J. Mitchell inhibited the left temporal lobe, which is involved in conceptual thought processes, in human subjects. What they discovered was that after a few minutes, skills such as drawing, calculating, and proofreading improved. This finding implies that some of us may have "latent or suppressed savant potentials which may be released." This scientific development may also explain why certain neurological conditions stemming from strokes or head injuries can lead to the onset of musical abilities.

In *Musicophilia*, Oliver Sacks recounts many other interesting case studies of people with increased or diminished musical abilities and perception. Through his interesting anecdotes written from the perspective of both a neurologist and music aficionado, the book is the perfect intersection of neurology and music. Although the book is in some ways very technical, Sacks aims to describe all of his stories in personal terms, and the balance he achieves makes the book immensely enjoyable. It forces us to reassess a process we normally take for granted. Yet we also realize that there is still so much to learn, not only about how the brain perceives music, but also the way in which the brain functions in general. For every music-lover and scientist, this book is a must-read.

Madeleine Jensen
Illustration by Allison Cohen

Why Stress Responses Could Be Mapped in Your DNA

We are all subject to varying degrees of stressors - a coffee spill, exams, or troubles with friends and family. But, our tolerance for stress and susceptibility to depression and anxiety vary widely. While some people develop major depression in response to taxing events and lose interest and motivation, others seem unfazed by similar stressors.

Recently, the molecular mechanism responsible for this behavioral difference has begun to be unraveled by Dr. Shusaku Uchida and his colleagues at Yamaguchi University and Nagoya City University. Studies were performed using two mouse strains, one of which was known to be stress-resilient (B6) and the other stress-vulnerable (BALB) based on previous work. Comparing both the behaviors and the DNA of these mice unveiled a link between tendencies toward depression-like characteristics in response to stress and epigenetic regulation of the expression of a particular protein, glial cell-derived neurotrophic factor (GDNF).

Expression of many genes is controlled by epigenetic modifications, which do not change the DNA sequence, but rather alter the structure of the DNA to either promote or inhibit genes. Often, cells accomplish this by adding or removing specific functional groups on specific nucleotides, pieces of the DNA, or regions of proteins bound to that DNA. Cells frequently perform these alterations on histones, proteins that bind to DNA and control its compaction, which regulate the rate of gene transcription. This regulation changes the rate of production of a specific protein in cells.

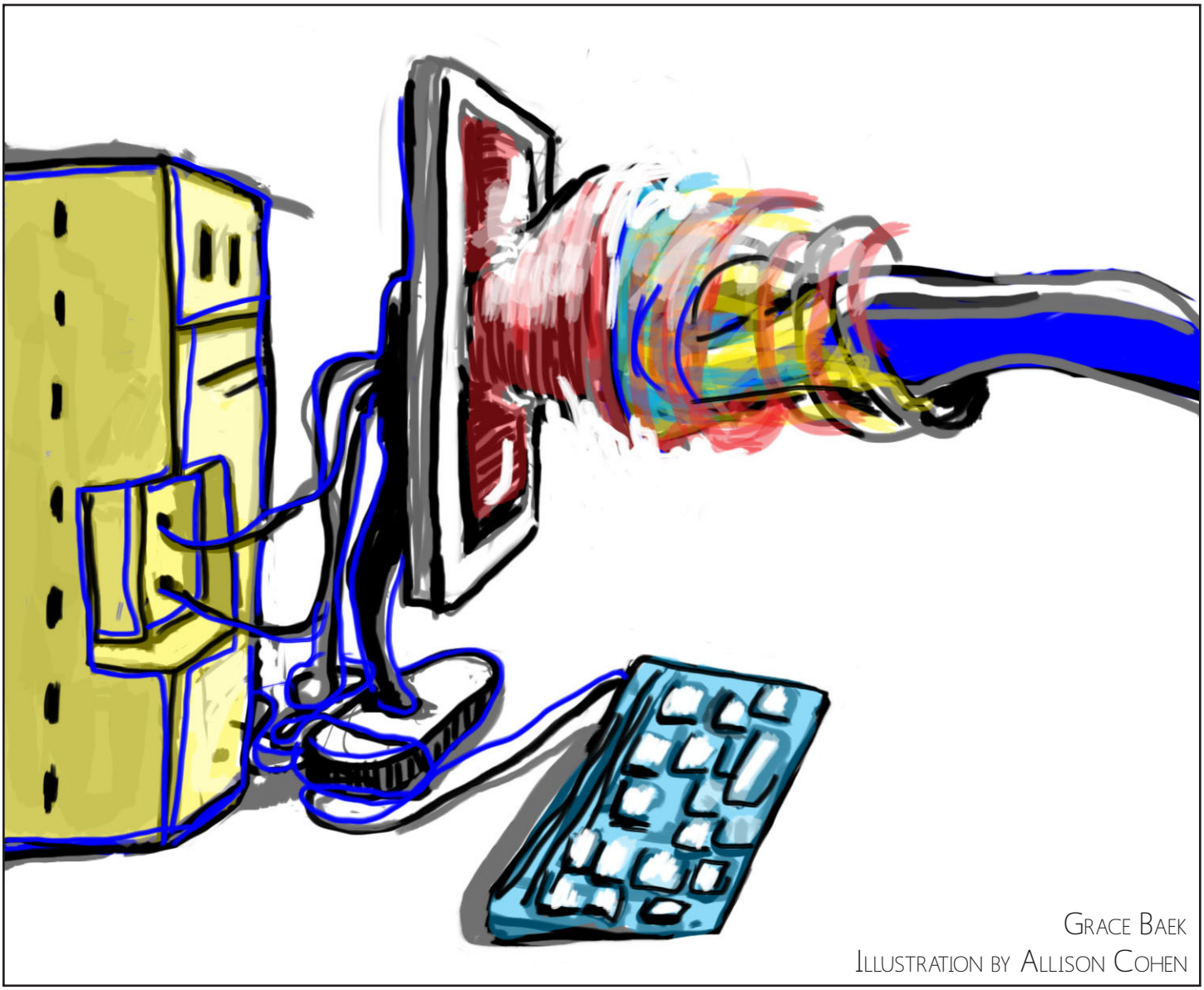
Researchers first showed that increasing GDNF protein levels could reduce depression-like behaviors in mice, highlighting the potential impact of a single molecule. The critical distinction between stress-vulnerable and stress-resilient mice emerged when researchers found that lower levels of the GDNF protein were correlated with behaviors characteristic of depression and anxiety. Additionally, BALB mice with overexpressed GDNF (artificially increased levels of GDNF) placed in stressful conditions showed an increase in social interaction time and a preference for sucrose over their counterparts without GDNF overexpression. This indicated that GDNF was sufficient to reduce depression-like behaviors, but the underlying mechanism regulating GDNF levels remained a mystery.

In order to better understand how GDNF might be important in anxiety or depression behaviors, scientists wanted to determine exactly how GDNF is regulated. Since both the B6 and the BALB mice had the same promoter DNA sequence to control gene expression, researchers hypothesized that epigenetic modifications might alter the amount of GDNF produced. They looked for changes in the DNA-bound histones of the GDNF gene promoter and found that stressed BALB mice had a lower quantity of a specific histone marker when compared to B6 mice. Furthermore, treatment of BALB mice with an antidepressant increased the levels of that marker, and stressed B6 mice showed a higher frequency of the marker in comparison to unstressed B6 mice. All of these results demonstrate that having this histone modification might make an individual more stress-resilient.

Researchers then identified HDAC2 (Histone Deacetylase 2) as the enzyme responsible for removing the key histone marker and increasing stress-vulnerability. Stressed BALB mice had significantly more HDAC2 than non-stressed BALB mice, HDAC2 expression could be reduced by treatment with an antidepressant, and high levels of HDAC2 were found bound to the GDNF promoter in stressed BALB mice. In contrast, stressed B6 mice did not have increased HDAC2 expression. Interestingly, this indicates that the HDAC2 enzyme plays an important role in reducing GDNF expression only in stress-vulnerable mice. It seems that HDAC2 alters the histone modifications, which changes how tightly the DNA at the GDNF promoter is wound and reduces how much GDNF protein can be produced.

Though GDNF expression immediately affects behavioral responses to stress, the epigenetic modifications of histones and DNA ultimately govern the fate of the GDNF gene. Epigenetic studies have identified the GDNF promoter as a critical determinant of behavioral responses to stress, and will likely lead to a better understanding of how individuals adapt to or respond to stress on a molecular level.

Internet Protocol



Grace Baek
Illustration by Allison Cohen

The Internet has come a long way since 1969. The Advanced Research Projects Agency Network (ARPANET) was first connected that year, marking the beginnings of the Internet as we know it today. In early February of this year, more than forty years later, the Internet Assigned Numbers Authority (IANA) has assigned the last 300 million of its nearly 4.3 billion addresses of Internet Protocol version 4 (IPv4). The IP, or internet protocol, is the set of digital formats or protocols in which data is sent across a network within the Internet Protocol Suite. Five Regional Internet Registries (RIRs) have the responsibility of matching these IP addresses to devices with new Internet connections.

The end to the age of IPv4 is a testament to the unrelenting popularity and growth of the Internet in the daily lives of the world population. IPv5, the next logical version of Internet Protocol, began development in the latter half of the 1970s under the name "Internet Stream Protocol" to experiment with transmission of vocal and video data. In the 1990s, IPv5 was updated to ST2 and utilized in projects by companies such as IBM, but was never developed into something for public consumption.

IPv6, the successor to IPv4, has a great deal of potential to be more popular with the public; however, this potential has not been fully realized yet. IPv6, first developed in 1998, has yet to be embraced by the public on a widespread scale comparable to IPv4. This is not to say that IPv6 is a technical flub, however. While IPv4 provides 32-bit addresses in the form of #.#.#.# with each # a number from 0 to 255, IPv6 provides larger, 128-bit addresses in the form of #;#;#;#;#;# with each # representing a separate set of hexadecimal digits. Hexadecimal digits, as the name implies, use as its base 16 and often use numbers 0 to 9 in conjunction with letters A to F (equivalent to numerical values 10 to 15). Thus, IPv6 has one billion-trillion, or 1021, times the number of addresses available for IPv4.

Other significant benefits of IPv6 over IPv4 include scoped addresses, which make file and printer sharing more private, stateless autoconfiguration, which Microsoft describes as "lowering the complexity and management burden"; and mandatory IP security, which increases privacy and means of authenticating connections. IPv6 certainly seems to be more capable of handling a larger demand for Internet addresses in the future.

Part of the concern regarding the transition from IPv4 to IPv6 is that Internet service providers (ISPs) have been reluctant to implement IPv6 for the past fifteen years. Google's Chief Internet Evangelist, Vint Cerf (also the former chairman of both the Defense Advanced Research Projects Agency (DARPA) and the Internet Corporation for Assigned Names and Numbers (ICANN)) has stated that although "operating system vendors [like Microsoft] and router vendors did implement the protocol," the Internet Service Providers (ISPs) failed to follow through with the transition to IPv6, preferring to use network address translation boxes. The ISPs essentially attempted to resist transition into IPv6 by condensing many private Internet addresses that used IPv4 into a single public Internet protocol (IP) address, address, decelerating IPv6's integration of IPv6 into common public use.

This reluctance to change the protocol could mean an unstable and inoperable system if half IPv4 and half IPv6 are implemented, as the protocols are inherently different. For instance, users on a social network or business continuing to implement IPv4 at least partially could not contact other users via email and Web servers if these other users were on IPv6-based devices. Granted, since 2008, Google has taken early steps in implementing IPv6 through its main search engine and Youtube. However, many businesses still remain mired in IPv4-based communications. In the end, perhaps all corporations or public users who wish to continue communicating with others via the Internet will need to transition to IPv6 for the long term, and fast.