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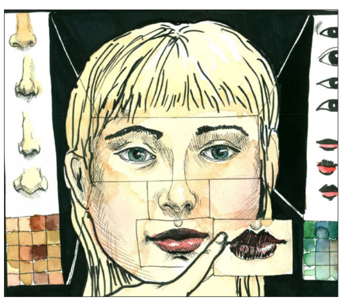

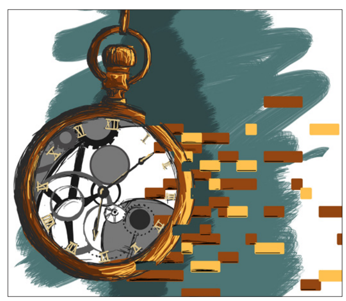

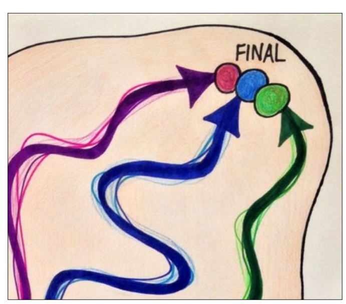

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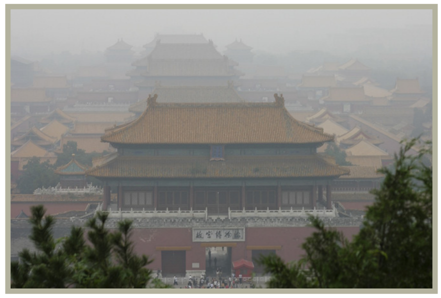
Cocktail Science

How many times have you seen someone let go of a helium-filled balloon and watched as it drifted into space? As the balloon rises up in the atmosphere, the helium in the balloon expands as the air pressure outside the balloon decreases, and eventually, the balloon pops. Due to helium's light weight, the helium gas from the balloon escapes into outer space. Helium, the second-most abundant element after hydrogen, is mined from natural gas fields, and Amarillo, Texas, is the most helium-rich gas fields. About 75% of helium is produced by the United States alone, but helium is getting harder to come by. In addition to cryogenics, high-energy accelerators, arc welding and silicon wafer manufacturing, helium is also crucial in cooling MRI magnets. Demand for helium is exceeding the supply, located in deep underground reserves regulated by the government.

For the past 70 years scientists have been trying to find out why the universe is overweight — really overweight. The strength of the gravitational field coming from massive objects is too large to originate solely from the matter in the universe that we can see. Hence, the theory of dark matter was formulated to remedy the problem of the overweight universe. The theory goes as such: unlike normal particles that are affected by all the forces of nature, dark matter interacts with the cosmos only through the gravitational force. This means that light does not reflect off of its surface, making it invisible and detectable only by observing its gravitational effect on the objects around it. So far the search for dark matter has been a fruitless endeavor, with little progress taking place. However, particle detectors and accelerators all over the world are on the hunt for dark matter, and it is only a matter of time before the elusive particle is finally brought to the light.

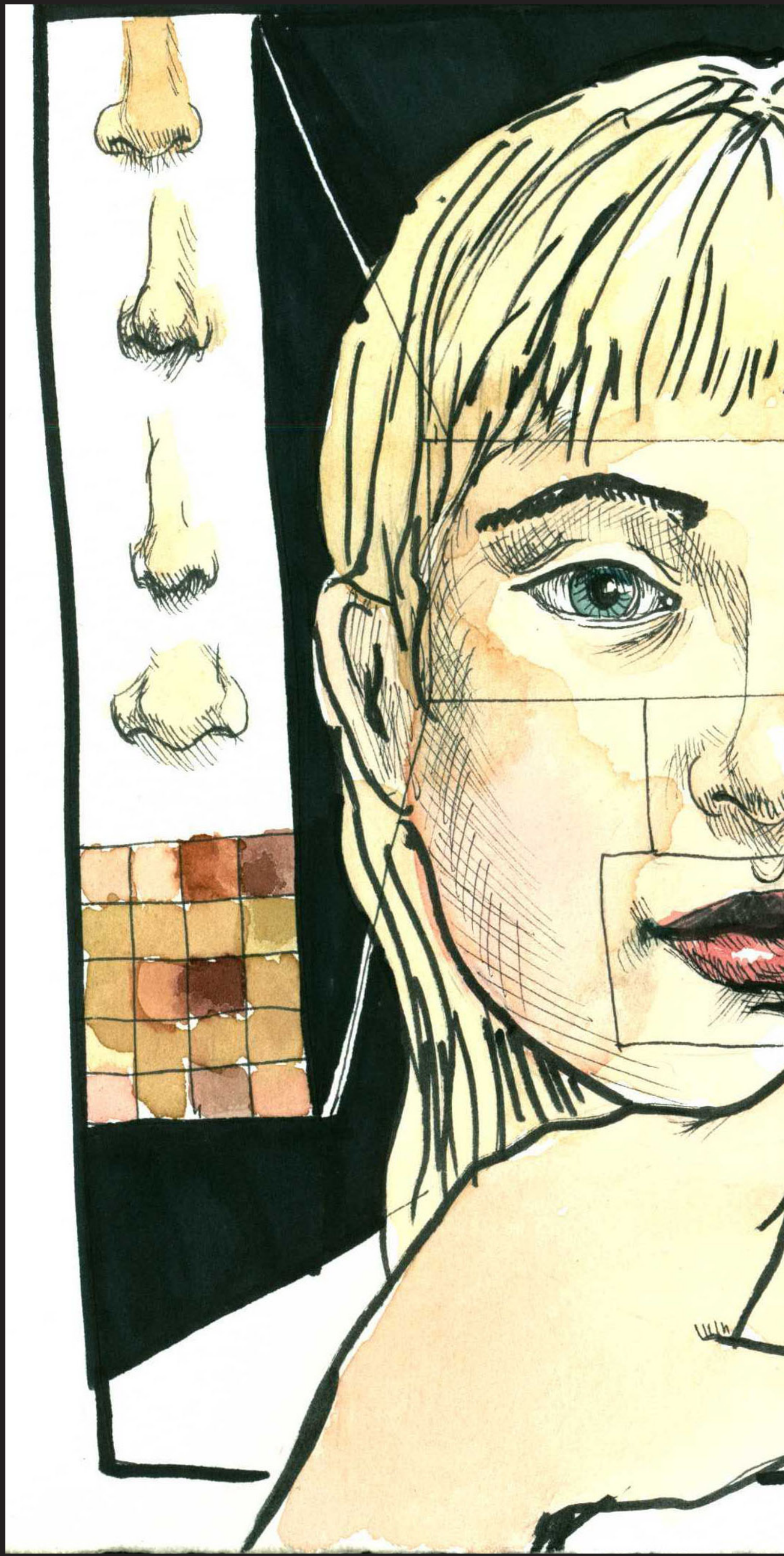


The United States Embassy in Beijing had just announced the jaw-dropping number 755. 755, the value of Beijing's air quality, shocked the world, not just because it was over the "Hazardous" zone, but also because it well exceeded 500, the absolute limit of the United States's Environmental Protection Agency Index. China's air pollution is indicative of an urgent and rapid global movement towards alternative energy sources and remedies for the current state of affairs. In 2010, Germany conducted a study and tested the effectiveness of paving slabs, which could clean the air. After covering an entire street with the unique stones, the Fraunhofer Institute for Molecular Biology Ecology verified the paving slabs' effectiveness. Coated with a layer of titanium dioxide, the slabs converted harmful substances in the air like nitrogen oxides into benign nitrates, and they also functioned as a photocatalyst since exposure to sunlight accelerated and sustained the spontaneous chemical reactions. Similar experiments with the slabs in Italy also proved to be promising, and this solution may very well pave our streets in coming years. These paving slabs may not solve global air pollution problems once and for all, but they are a step towards the right direction.

Every year, millions of children die as a result of health complications from vitamin A deficiency. A balanced diet that includes a variety of beta-carotene-rich fruits and vegetables is the best prevention for such deaths but unfortunately not many can afford such a diet. In an effort to improve dietary health across populations, researchers have designed food items that are rich in certain nutrients that they would otherwise lack. Take golden rice as an example. Golden rice, named for its bright yellow color, is a strain of rice that has been genetically modified to produce provitamin A carotenoid, specifically beta-carotene, in the grain. Rice already contains the genes necessary for beta-carotene production in its genome; however, these genes are turned off during development so no beta-carotene is produced in the edible part of the plant. Researchers have found a way to restore beta-carotene production in the rice, which causes its characteristic yellow-orange color. Researchers targeted rice because its prominent role as a dietary staple in many societies will increase golden rice consumption and hopefully decrease the number of children afflicted by blindness as well as other diseases as a result of vitamin A deficiency.

The Future of Designer Babies

By Alisha Maity
Illustration by Allison Cohen



One of the best movies to feature the uncertain ethics of reproductive technologies is the 1997 film Gattaca, which tells the story of a man deemed genetically inferior due to his natural birth leaving him with a genetic heart condition. In the world of Gattaca, genetic discrimination is commonplace: those who are deemed genetically superior are sought after for high-level employment while the rest are relegated to menial jobs. While this story takes place in the "not-too-distant future," our current technological advancements have allowed parents to select for and even manipulate genes in their children. However, as this form of genetic engineering becomes more accessible, the ethics of these uneasy reproductive technologies have been put into question by those fearing a dystopian future in which natural weaknesses are discriminated against and rejected by society.

The first of these technologies to develop has been around for decades: prenatal testing. This testing is generally recommended by obstetricians and is used to test embryos or fetuses for medical conditions and birth defects in the form of a follow-up, after regular blood tests indicate that such defects may be present. Normally, these tests are invasive procedures such as amniocentesis and chorionic villus sampling. However, prenatal testing has developed so quickly in the last few years that researchers at the University of Washington have discovered they can take a blood sample from the mother and saliva sample from the father to map a fetus's genome, with 98% accuracy. While this particular form of noninvasive DNA mapping is not ready for public use yet due to its high cost, the fast pace at which this technology is being developed indicates that it will be ready for use within the decade. Currently, available tests can detect the presence of sex or chromosomal mutations of a fetus, but tests allowing for the mapping of the full fetal genome would let researchers test for Mendelian disorders that stem from point mutations, single base changes in the genome, like Marfan syndrome and Tay-Sachs disease.

These more complex types of prenatal testing have received mixed responses by the general public because of the varying ethical complications accompanying the testing. With the knowledge of a fetus's medical condition, hospitals can better prepare for delivery and parents can prepare themselves for the way

their life will change with a medically diagnosed fetus, both of which appear to be beneficial aspects of testing. However, parents may choose to abort the fetus based purely on his or her medical disorder, something that continues to be debated as a proper course of action. New York Times columnist Lisa Belkin writes in her article "Deciding Not to Screen for Down Syndrome" that due to "the way information is provided to women and the way our culture talks about and conceives of individuals with chromosomal abnormalities... prenatal testing more often serves to devalue all human life and to offer parents and doctors an illusion of control." Critics of prenatal testing believe that adding more tests to the typical fetal screening will only amplify the myriad of ethical dilemmas accompanying standard prenatal testing.

The newest technology in the fetal genetics sphere is one that parallels Gattaca's own eugenic society to a significant degree. The use of genetic modifications to "improve upon" the natural genetic make-up of fetuses is an idea that is slowly starting to become a reality. A Los Angeles fertility clinic once offered customers undergoing in vitro fertilization the ability to select the gender and other physical attributes of their baby through a procedure called pre-implantation genetic diagnosis (PGD). Initially, this practice was used to ensure that parents with certain medical disorders would not be forced to pass these genes that code for lethal diseases onto their children. Now, however, the practice involves taking cells from fertilized embryos to test for biomarkers indicating traits such as sex, eye color, and hair color. Only these chosen embryos are then implanted into the mother's womb. While PGD used to control against genetic disorders maintains a certain level of appeal, doctors such as Dr. William Kearns, who practices PGD for medical issues, firmly oppose trait selection in fetuses. Dr. Kearns states, "My goal is to screen embryos to help couples have healthy babies free of genetic diseases. Traits are not diseases." Individuals such as Lisa Belkin already have qualms about testing for and aborting fetuses that are found to carry medical disorders. Where does one draw the line between preventing children being born with the diseases that plagued their parents and enhancing or selecting for traits primarily based on personal tastes?

In the new age of genetics, with perfectibility as a feasible possibility, traits such as creativity and athleticism that were in the past associated more strongly with environment rather than genetic make-up are being studied more closely in the genome. If it were discovered that these complex traits were associated with genes, they would certainly and perhaps dangerously become targets of genetic reproductive technologies. A world in which all parents, or at least those who are able to afford the treatment, use PGD to select for intelligence and physical attractiveness may unfold in our future. We can only hope that we are able to examine and discuss the consequences of these new fetal genetic technologies before we allow our world to transform into the frightening eugenic societies that once only existed in science fiction movies.

Directionality of Time in Quantum Computing

Joanna Diane Caytas
Illustration by Allison Scott

Now and then, science reaches critical points of striking detachment from social reality by transcending barriers previously deemed axiomatic to contemporary thinking. While average computers still display the "blue screen of death" at every turn and supercomputers speak Mandarin to accommodate hackers from China, the torch has slowly been passed since about 30 years toward the crossing of another barrier always thought unbreakable: the directionality of time. As everybody "knows," time cannot flow backwards, and the number of visitors we receive from the future has been infinitesimally small. Yet it may come as no surprise that the possibility of bidirectionality of time was seriously (if not entirely first) raised by Einstein in his Special Theory of Relativity proposed in 1905: a time when horse-drawn carriages were still the predominant mode of transportation and the last German emperor Wilhelm II was heard saying, "I believe in the horse. The automobile is but a transitory phenomenon." But enough said about the environment of Special Relativity's manifestation, the theory enabled practical visions that have yet to catch up with technology well over a hundred years later.

Asher Peres, an Israeli physicist of Polish descent at Technion-Israel Institute of Technology in Haifa, took an information theoretical approach to quantum theory. He was one of the first to propose quantum teleportation, also known as entanglement-assisted teleportation, a fundamental step in quantum information theory. In 1935, Einstein had referred to quantum entanglement, a form of quantum superposition, as "spooky action at a distance." If particles such as photons, electrons or even larger items of molecular size interact physically before being separated, each particle features the same quantum mechanical state with regard to indefinite criteria including momentum, polarization, position, and spin-at least until measured. This effect remains in force across indefinite distances. These entangled particles share common characteristics but lose their individual characteristics. If it were possible to entangle a pair of dice, the number of dots shown would remain uncertain until measurement. But upon measurement, both dice would invariably show the same random number. Erwin Schrödinger described this phenomenon as the fundamental feature of quantum mechanics. Entanglement is central to quantum information science, arguably the most promising field opening new ways of communication and computation beyond binary information science.

A group of researchers at Austria's Institute for Quantum Optics and Quantum Information and at Vienna Center for Quantum Science and Technology designed a photon pair experiment based on a thought experiment by Peres. They published their findings in the April 2012 issue of Nature, proving that quantum entanglement between two pairs of photons capable of being created "a posteriori" (retroactively, i.e. after the entangled particles have been measured) may no longer exist. "Quantum steering into the past" may thus enable linking input and output of quantum computers, allowing a future quantum computer to calculate a problem in the past that is defined by an input that will only exist in the future. In this experiment, effect appears to happen before cause. Breaking the directionality of causality and time opens immense perspectives for new computational mathematics and further development of probability.

To better understand the potential significance of this breakthrough, it is necessary to take a closer look at why and how quantum computing differs from binary computing. First of all, quantum computers do not yet exist. It is estimated that even the simplest version may be approximately ten years ahead and useful ones, as much as fifty years. Theoretical ground work and practical experiments have accrued since Richard Feynman pioneered the field in 1982, but yielded few certainties except adherence to the Church-Turing principle: "There exists or can be built a universal computer that can be programmed to perform any computational task that can be performed by any physical object." Under Church-Turing, anything from a single atom to the entire cosmos could be instrumentalized as a "computer" for computational purposes. Cutting a transistor down to the size of an atom could remedy Moore's law, which describes a process unsustainable by known technology beyond 2020 whereby the number of transistors allowed on an integrated circuit doubles every 18 months to two years. As David Deutsch famously conjectured, "quantum computers will solve problems that would take today's computers longer than the age of the universe."

Quantum computation is based on quantum bits (qubits) rather than binary digits (conventional bits). Just like a bit, a qubit can have two possible values, 0

Article continued on page 25


gemma gené

Grounding Art Perception in Action

Matthew Schelkes
Illustration by Gemma Gené

Consider a common scenario in the Columbia University core class, Art Humanities (Art Hum — you are looking at an unfamiliar painting that you just do not "get." Perhaps it's a medieval "Madonna with Child," or a frenzy of curves and squiggles from the twentieth century. Either way, the work leaves you cold. However, somebody points out that two lines seem to dance around each other and certain colors seem to pop out of the canvas, and suddenly the painting becomes alive. You can see how colors, shapes, and figures fit together. You have a sense of what the artist was attempting to convey and, finally, begin to appreciate the painting.

How does this process of appreciation happen in the brain? Attempts to understand the neuroscientific mechanism of art appreciation focus on hypothetical neural correlates of beauty or pleasure, rather than changes in perception involved in appreciation. However, recent research on attention, particularly the premotor theory of attention, can offer some fundamental insights into the biology of art appreciation.

The premotor theory of attention posits that circuits normally involved in movement and motor skills also control voluntary shifts in attention. For example, the neurons of the frontal eye field control the muscles involved in eye movements, but they are also active in shifting attention covertly—that is, without any actual eye movements. Similarly, motor neurons involved in grasping are also used for focusing attention on tools and graspable objects, indicating that regions of the brain seemingly used for action are also critical for shaping perception.

This attention-modulating role of the premotor cortex is particularly important for the perception of biological motion and visual patterns. Single points of light moving in a human-like fashion can activate premotor regions. Deactivation of the same regions prevents recognition of similar biomechanical movements. In addition, focusing attention on dynamic visual patterns, such as circles that change color in a certain sequence, also requires the premotor cortex. Our motor skills shape how we perceive purely visual stimuli: seeing something as a tool and not an abstract object, for example, depends on our motor skills of grasping the tool. Similarly, perception of human motion in a pattern of moving dots relies on our ability to move our own limbs.

But what do these details of attention modulation tell us about art appreciation? The roots of appreciation are precisely these mappings between motor skills and visual elements. Attention to different formal elements of a work, including object shape, visual rhythms, and color brightness, requires the use of different motor areas. Focusing on object shape, for example, requires activation of grasp-related neurons; perception of visual rhythms depends more on neurons for full-body motion. From the brain's perspective, action causes different perceptions.

Thus, when you are looking at that painting in Art Hum, and somebody points out that certain shapes seem to be dancing and that certain lines seem to slither around the canvas, you see the painting differently because those shapes and lines have taken on active, motor-based meanings. Through motor modulation of perception, the shapes are no longer just swatches of pigment and the lines no longer mere borders. Rather, they are living elements that interact with each other in the work. Your perception of the painting has changed because objects that were purely visual are now linked to action. The visceral feeling of movement and motor skills induced by words like "dancing" and "slither" has given you a new understanding of the painting.

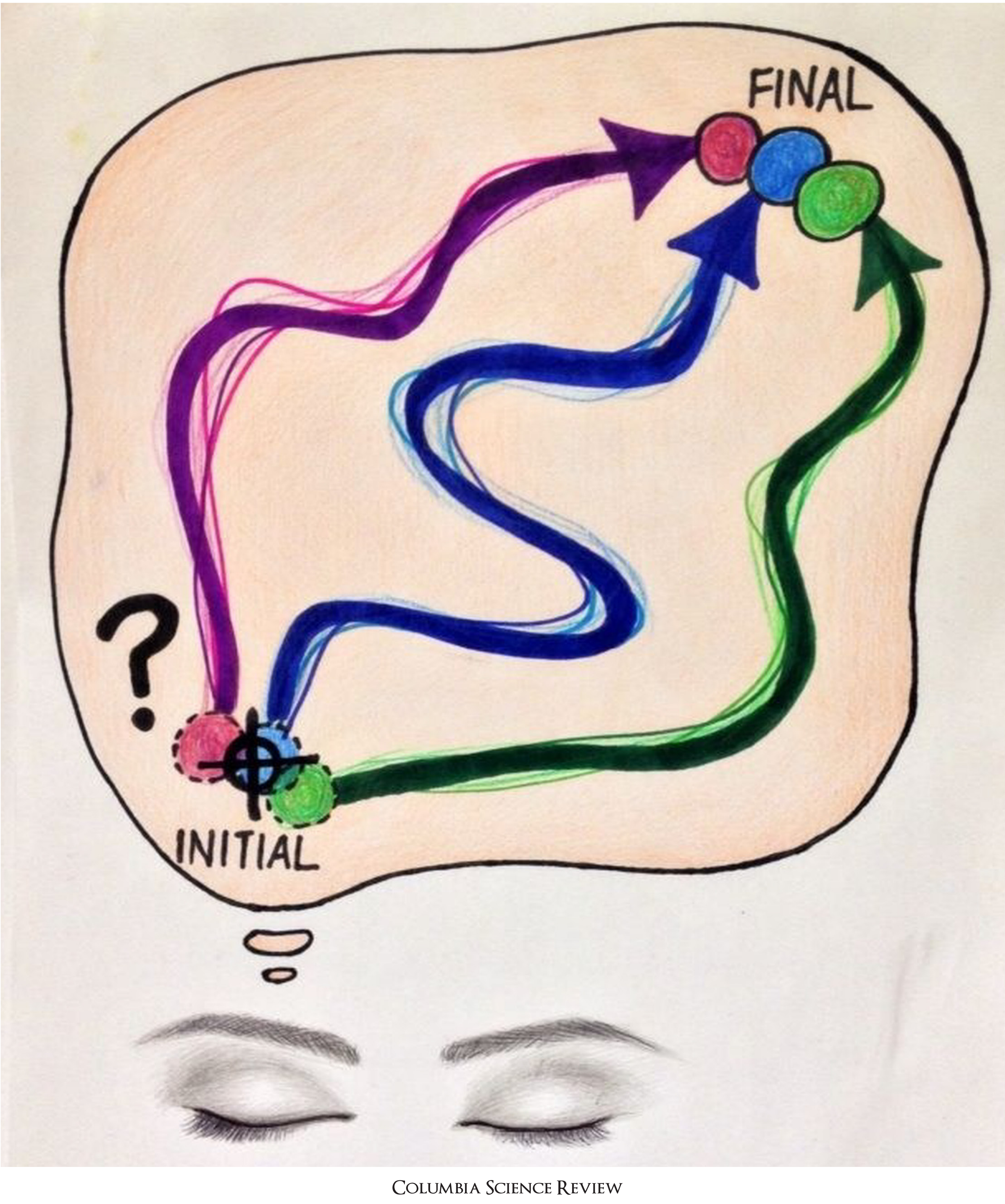
The dependence of perception on action in the studies discussed above may seem counterintuitive but numerous examples exist in everyday life. A tennis player, for instance, may focus only on the speed or target of the ball and not notice the color of the court lines or the grid-like pattern of the net. His perception is driven by the actions involved in the point and he only sees what is necessary for hitting a certain shot. Interestingly, a study of golfers reveals a similar effect: as opposed to an average golfer, highly-skilled golfers perceive the hole as a larger one.

In both tennis and golf, perceptions are guided by the actions involved in playing the sport. However, art demonstrates a different mechanism. In tennis, perceptions guide the single action of hitting a shot. Appreciating a painting, by contrast, involves flexible perception-action links: a single line may dance, droop, or soar depending on how you see it in relation to other elements of the painting. In art, you can use multiple motor skills to perceive a single set of visual elements. Normally, you just pick up and tilt a cup; in a still life, though, it can be highly textured and charged with energy.

Aestheticians from Pythagoras to Kant have claimed that artistic experience is a kind of detachment from the everyday world and entrance into a rarefied realm of expression. But the neuroscience of perception and action denies this claim—art plays on the same action-perception links that are critical in everyday tasks. Rather, the flexibility of these links is characteristic of artistic appreciation, and artistic detachment is really detachment from habitual actions. In daily life, a tree branch may be just something to be pushed aside, while in a landscape painting, it might be aggressive, threatening, weary, or exuberant—depending on your premotor state.

Catching the Quantum Wave

John Dodaro
Illustration by Jenny Park



There is one thing about quantum mechanics we can all agree upon: it's confusing. Thoughts such as wave/particle duality, the inherent uncertainty in the universe, or cats in dark boxes being poisoned with cyanide come to mind. American physicist Richard Feynman succinctly said, "I think I can safely say that nobody understands quantum mechanics." Professor Emlyn Hughes said, "In order to learn quantum mechanics, you have strip to your raw, erase all the garbage from your brain and start over again." So what is it about quantum mechanics that gives even the brightest physicists such pause?

Newton's laws can put a man on the moon, but break down when it comes to microscopic phenomena. While the laws of quantum mechanics dominate this realm as far as making experimental predictions, they are only coherent on a statistical level. The laws tell us nothing about the outcome of an individual experiment, rather, they provide an algorithm for computing the probability of the outcome for an ensemble of particles. This motivates the question: in the microscopic regime where the classical laws of cats and boxes reach their limits, are we forced to adopt a theory with tremendous experimental success even if it can only describe these ensembles? The answer is no.

In the early 1920s French physicist Louis de Broglie conceived Pilot Wave theory by unifying two principles: Maupertuis' principle of least action in classical mechanics and Fermat's principle of least time in optics. The theory states that particles — which we will assume are point particles — are always accompanied by a "guiding wave" like a surfer riding an ocean wave. Schrödinger published the equation that the guiding wave obeyed in 1926, but, abandoning trajectories, reinterpreted its meaning in the "Wave Mechanics" he developed. With this theory, de Broglie predicted that the electron should exhibit wave-like properties. This prediction was experimentally confirmed by Davisson & Germer's scattering experiment. He presented Pilot Wave theory at the 1927 Solvay Conference, historic for the major discussions on quantum theory. Despite the clarity and successful predictions, scientists did not devote the extensive amount of research on this theory as they did for its counterpart — the "Copenhagen" interpretation grounded in the work of Niels Bohr and Werner Heisenberg.

It wasn't until 1952, when American physicist David Bohm published a non-local "hidden variable" interpretation of quantum mechanics, that ideas similar to de Broglie's reemerged. A "hidden variable" is a degree of freedom that exists, but cannot physically be known to the experimenter. This is in contrast to the probabilistic interpretation which states that the universe is fundamentally random. To illustrate this, imagine closing your eyes and throwing a ball. To determine the final position, we require the initial position and velocity of the ball. The Copenhagen interpretation would imply that before you open your eyes and measure where it is, the position doesn't exist - it is a nonsensical question to ask where the ball was before you looked. All you can know is the probability distribution of potential positions where the ball will be found once you measure it. But the instant after you open your eyes, you will see where the ball is. According to this interpretation, the act of opening your eyes and performing a measurement causes the ball to assume a random, yet well-defined, final position. The ambiguity of when the measurement occurs and reduces the ball to a well-defined position is known as the 'measurement problem.'

A hidden variable theory would imply that the ball has a well-defined position before you looked, but because of your uncertainty of the initial position and velocity, you find the same probability distribution of final positions. Bohm's goal was to show that it is in fact possible to have a deterministic hidden variable theory that agrees with all of the predictions of quantum mechanics, yet is free of the measurement problem. Similar to Pilot Wave theory, there exists a guiding wave, or wavefunction, that deterministically guides the motion of point particles. In addition, Bohm provided a theory of how measurements works by treating the measurement apparatus as a quantum object as well as the measured system. We are made up of particles after all, and those particles should also obey the laws of quantum mechanics.

There are three postulates in Bohm's theory: (1) the wavefunction evolves according to the Schrödinger equation for all times, (2) the particle momentum moves in a deterministic way determined by the wavefunction, and (3) the initial distribution of particle positions is given by the magnitude squared of the wavefunction. Going back to our analogy, we have an equation for how the ocean wave changes, another equation for how the wave guides the surfer, and an assumption that most of the surfers are located where the ocean wave is the biggest. The theory is not fundamentally probabilistic, but our ignorance of the initial conditions only allows for predicting a probability distribution. Over the years, the theory has assumed names such as Bohmian mechanics, the causal interpretation, and de Broglie-Bohm Pilot Wave interpretation. Distinctions can be made, but I personally think "Pilot Wave theory" suits it best, as it makes some reference to the content of the theory itself (i.e what is a "Bohmian"?). Either way, Bohm's work in 1952 emphasized that the foundations of quantum mechanics are far from settled.

So what is the difference between the Pilot Wave theory and the Copenhagen interpretation? First, in Pilot Wave theory, there is no mention of "measurement" in the postulates. Measurement is viewed as just another interaction between some articles and other particles.

Particles are assumed to actually exist, and they are guided along actual trajectories by a wavefunction. There is no question of behaving like a particle at some times, and like a wave at others; rather, there is always a particle, and there is always a guiding wave. But what doesn't change? As an "interpretation," all the predictions must be in agreement with the standard quantum mechanics—this is guaranteed by the 3rd postulate.

While anything we actually "measure" can only be predicted up to the probability distribution, the theory would mean that there are radically different events occurring when we aren't looking. For example, the ground state of the hydrogen atom describes the electron at rest some distance away from the proton. The reason individual photons behave like waves in the double slit experiment is also clear; the ocean wave travels through two narrow slits, but the surfer goes through one. The distribution of where the surfers end up looks like a wave because they were guided by one, and not moving in straight lines. More technically, the wavefunction travels through both slits and interferes with itself, while the particle passes through one slit and is guided along a non-trivial trajectory to one of the interference fringes, as predicted by de Broglie. Schrödinger's cat is either dead or alive, but you don't know until you check because both the state of the system and the wavefunction evolved deterministically. Still, you can never have 100% accurate initial conditions, as in the case of throwing a ball.

While viewing these examples in the context of Pilot Wave theory may seem to suggest some sort of intuition that could not possibly be accessed through the Copenhagen interpretation, Bell's theorem (1964) elegantly showed that local hidden variable theories cannot agree with the experimental predictions observed in quantum mechanics. As an example of non-locality, measuring the position of a particle in the Milky Way galaxy instantaneously fixes the momentum of a twin particle in the Andromeda galaxy. Pilot Wave theory is indeed in agreement with Bell's theorem once we consider quantum systems of two or more particles. It can be stated simply: a particle's momentum depends instantaneously on the position of all other particles in the universe. It might initially seem hopeless to calculate anything if shaking a particle in the Andromeda galaxy alters the trajectory of particle in the sun. But, it is more subtle than that.

Known since Schrödinger's time, the wavefunction is defined over a higher dimensional space called the configuration space. This makes the wavefunction a completely different type of field from the ones we are used to, such as the electric and magnetic, for example. The configuration space for an N particle system is N copies of 3-dimensional space pasted together to form a 3N-dimensional space. It is in this configuration space that the wavefunction (ocean wave) guides the configuration point (or surfer), which is a higher dimensional point representing the positions of every particle. If we are given the position of this configuration surfer point, then the 2nd postulate would tell us which direction the ocean wavefunction guides it. It is the same situation as before, but in a much higher dimensional space. Since the point represents the positions of all the particles, no matter how far apart they are, there is a non-local connection between them in 3-dimensional space.

At the end of the day, as in any interpretation of quantum mechanics, Pilot Wave theory has its criticisms. Pilot wave theory is at odds with Einstein's theory of relativity, since non-locality defines a unique reference frame which contradicts the relativeness of the laws of physics under certain changes of coordinate systems. The existence of particle trajectories can be viewed as adding unobservable structure to the theory, which goes against Occam's razor. To this objection, the price of shaving off the unobservable should be considered: quantum paradoxes about measurement, wavefunction collapse, and cats in dark boxes. The fact that we could have some quantum intuition about the microscopic realm, where particles actually exist at definite locations in between measurements, isn't a scientific argument in favor of Pilot Wave theory. But it might help one sleep easier at night. We have also seemed to abandon the action-reaction principle where every force has an equal and opposite force. There is an equation for how the wavefunction affects the particles, but not one for how particles affect the wavefunction in a dynamic fashion. This lack of an action-reaction principle is not so much a criticism as it is a part of a theory that agrees with stringent experimental tests.

When de Broglie formulated Pilot Wave theory, there was no motivation to solve a measurement problem; his goal was to unite two principles of physics, and use the union to explain the unexplainable phenomena and new predictions of his time. With the addition of Bohm's work, the theory became a full description of non-relativistic quantum mechanics as a non-local, hidden-variable theory that circumvented the measurement problem. As seen through some of the canonical examples, there is an intuitive explanation for quantum phenomena acting in a deterministic manner after accepting the existence of a particle's unobservable trajectories. Perhaps this intuition can be applied to different fields of research that rely on quantum mechanics. In the future it might help guide physicists to more advanced theories—only time will tell. Feynman could safely say that nobody understood quantum mechanics. But by looking at things from another perspective, we may be able to see the universe in a different light without stripping down to our raw.

Video Game Addiction

The Hidden Danger of Winning the Game

Article and Illustration by
Kimberly Shen

Have you ever had a friend or sibling who would spend hours upon hours attached to his or her Xbox, playing "Call of Duty" (2003)? Maybe you dismissed these somewhat obsessive gaming habits as mere quirks, thinking they are just what he or she does. However, for some gamers, this pastime could become a serious addiction. This is most apparent in the many youths who retreat into the world of video games and lose all interest in their friends and family. At times, this addiction has even proved fatal. With the global spike in heavy gamers, there has been much controversy surrounding this addiction, which raises an important question—can video game addiction be labeled as a mental disorder?

The history of video games dates back to the 1940s, when Thomas T. Goldsmith and Estle Ray Mann filed a patent for what they described as a "cathode tube amusement device." Yet, video gaming did not attain widespread popularity until the 1970s when arcade games, game consoles, and computer games became accessible to the public. Since then, video games have become an integral part of modern entertainment and youth culture in many parts of the world, especially the United States, Europe, and Asia. Unfortunately, the increased number of heavy gamers has signified an increased number of fatalities. For example, in 2011, 20-year-old United Kingdom resident Chris Staniforth died after a 12-hour gaming session with his Xbox 360 game console from deep vein thrombosis, a condition caused by sitting in a single position for an extended period of time. Similarly, in 2005, Seungseob Lee, a 28-year-old South Korean resident, died from heart failure after playing "Starcraft" (1998) almost continuously for fifty hours. In the last six weeks before his death, Lee had been fired from his job due to his tendency to skip work to indulge in video games. Lee's girlfriend had also broken up with him, demonstrating the toll that his obsession took on both his professional and social life.

Unfortunately, in spite of the potentially devastating effects of video game addiction, this problem has not yet been officially recognized as a mental disorder. In 2007, the American Psychiatric Association deemed that there was not enough evidence to add it to the Diagnostic and Statistical Manual of Mental Disorders released in 2012. Recently, however, there has been discussion among experts whether video game addiction may indeed be one. After all, other addictions, particularly substance dependence, are widely considered mental illnesses in the medical world. In light of both past gaming-related fatalities and the continued omnipresence of video game addiction in today's society, heavy gamers share some notable similarities with the more commonly acknowledged drug addicts: both experience symptoms like withdrawal, which brings about feelings of anger, tension, and/or depression when the object of addiction is unavailable, and tolerance, which incites a need for more use to attain the same high, which, as defined by medical experts, is generally an artificially induced state of euphoria and excitement.

Certainly, many scientists believe video game addiction to be a serious mental disorder and have likened it to addiction to powerful drugs such as heroin. For instance, in 2008, several researchers led by Dr. Chih-Hung Ko conducted a neuroimaging study at the Kaohsiung Medical University Hospital in which they examined the differences between the brain activity of ten gaming addicts and ten non-addict control subjects. During the experiment, the participants were presented with gaming pictures as they underwent fMRI scanning. To evaluate brain activity, the scientists calculated the blood-oxygen-level dependent (BOLD) signals of the


VS
MUST WIN...

participants' brains in response to the gaming stimuli. Compared to the control group, the addict group generally showed greater activation in the right orbitofrontal cortex and the medial cortex—two brain regions that also contribute heavily to substance dependence. Consequently, such results suggest that the cue-induced gaming urge in online gaming addiction is quite similar to that of the cue-induced craving in drug addiction.

Meanwhile, in 2012, Dr. Haifeng Hou, a researcher at Second Affiliated Hospital of Zhejiang University of Medicine, performed a study in which he compared the dopamine transporter levels of five addicted gamers and those of nine healthy age-matched controls. A neurotransmitter that helps control the brain's reward and pleasure centers, dopamine plays an important role in addiction. PET scans have shown increased release of dopamine during video gaming. Because the increased levels of dopamine are linked to reward (in this case, a high), addicted individuals experience temporary euphoria during their gaming sessions. However, in the long run, excessively high concentrations of dopamine cause serious damage to the dopamine terminals, as evidenced by the finding that the dopamine transporter levels of the addicted Internet gamers were lower than those of the controls. Indeed, similarly low levels of dopamine transporter levels can also be found in drug addicts, signifying that lowered dopamine transporter levels are indicators of addiction.

Such studies seem to reinforce results from an experiment led by Simone Kuhn, a psychologist from the University of Ghent in Belgium. In 2011, Dr. Kuhn and her fellow researchers observed 154 fourteen-year-old video gamers. About half were frequent gamers who played at least nine hours a day while the others did not play as frequently. Using fMRI scanning, the scientists found that the frequent gamers have a greater amount of gray matter in the region of the brain known as the ventral striatum. An area rich in dopamine cells, the ventral striatum plays a significant role in reward and addiction. Like the experiment led by Dr. Hou, Dr. Kuhn's research also implies that significant changes occur to the brain's pleasure centers during video game addiction. Such results are similar to brain comparative studies on drug addicts and non-drug addicts alike.

Unlike other substance dependence, video game addiction has yet to be officially recognized as a serious health problem. However, video game addiction undeniably has serious impact on both individuals and society at large. The sedentary lifestyle that comes with spending hours upon hours each day playing video games certainly is not healthy. Like drug addicts, video game addicts often neglect their friends, family, and work obligations due to their continuous preoccupation with seeking the high that comes with their obsession. Video game addicts also tend to have trouble socially interacting with others outside their games and are at greater risk for health problems like obesity and diabetes. At times, this addiction can lead to death. Unfortunately, many addicts have trouble breaking free from their unhealthy gaming habits, for addicts frequently exhibit preoccupation with their games even when they are not playing. Such fixation creates an unending cycle of dependence, rendering the players unable to separate themselves from the virtual world of their video games.

Thus, in response to this increasingly widespread problem, many countries, including South Korea, Canada, and the United States, have opened treatment centers for addicts. Some of the most effective treatments currently in use comprise of psychopharmacology and psychotherapy. Nevertheless, because video game addiction has not yet received the acknowledgment given to other health problems like drug abuse, research for its treatment is still in its preliminary stages. Fortunately, there are a number of organizations dedicated to raising awareness of the consequences of video game addiction. Some examples include Mothers Against Videogame Addiction and Violence, Kiwi Seminars, and Canadian Psychiatric Research Foundation. To further curb video game addiction, some countries have attempted various preventive measures to counteract this problem. For example, in 2005, China introduced an online gaming restriction that limited playing time to three hours, after which the player would be expelled from whatever game he/she was playing. Meanwhile, in the 1980s, the British Labour Party Member of Parliament George Foulkes tried to ban the arcade game, "Space Invaders" (1978), for its "addictive properties." Although the bill was narrowly defeated in parliament by a 10-vote margin, the proposal was an indicator of increasing government awareness of and concern towards the effects of video game addiction. Ideally, the combination of these organizations' efforts and individual governments' actions will spark an international movement to bring gaming addiction greater acceptance in the medical world as a serious psychiatric disorder.

The Food Allergy Conundrum

By Diane Wang
Illustration by Gemma Gené

An increase in food allergies may be traced back to the development of antibacterial drugs, a sacrifice made for over-protecting our immune systems.

For most people, it isn't news that food allergies are on the rise. More restaurants have extended menus catered towards those with allergies, offering soy-free, wheat-free, gluten-free, or nut-free options, among many others. Most people know of at least one other person who suffers from a food allergy. But why have so many businesses and restaurants taken notice all of a sudden?

According to the Center for Disease Control, the prevalence of reported food allergies increased 18% in children under the age of 18 years from 1997 to 2007. The most common allergens in children are cow's milk, egg, peanut, soy, wheat, tree nuts, fish, and shellfish. In adults, they are peanut, tree nuts, fish, and shell fish. Peanut allergy has more than tripled in children under the age of 18 years over the past decade, going from 0.4% to 1.4%. It now affects 0.6% of the population and is the most common cause of fatal food-induced anaphylaxis, a life-threatening allergic reaction. Given these statistics, the rise in food allergy is no casual topic.

So why, exactly, are food allergies becoming more and more common?

An easy answer points to awareness. More people are becoming familiar with the symptoms of food allergies, leading to an increased number of patients seeking medical care for them. In other words, because there is an increased level of knowledge about food allergies in the general population, we tend to look out for them more. However, it is important to note that many people nowadays are conflating true food allergies with food intolerance. While food intolerance is caused by problems in the digestive system, such as an enzyme deficiency, a food allergy involves an immune response. For example, when a certain type of food is ingested, the proteins enter the bloodstream and an allergic person will produce immunoglobulin E (IgE). IgE is an antibody that will react to the specific food protein, attaching itself to blood and tissue cells. This will then set off allergic reactions such as coughing, hives, or swelling. Clearly, this biological mechanism is different from food intolerance, which does not engage the immune system. However, the overlapping symptoms that manifest in both food intolerance and allergy often lead to misdiagnosis, rejecting the milder former case for the latter.

This increased awareness of food allergy is not the only factor in its rise—the increased movement of people and foods around the globe also contributes to the trend. Hugh Sampson, a professor of pediatrics and immunobiology at the Mount Sinai School of Medicine, describes the kiwi fruit as a classic example: "We never used to see kiwi allergy, but no one ever ate kiwis. Now everybody eats kiwis and we have lots of kiwi allergies."

By adopting more exotic diets (eating things like kiwis) people are becoming exposed to foods that they never would have encountered historically. The United Kingdom, Australia, and other European nations exemplify this trend perfectly. Peanut allergies have risen dramatically since the introduction of peanut butter, a staple of the American diet.

Another contributing factor is the way in which we now manufacture our food. Within the United States, peanut allergies in children doubled from 1997 to 2002. The most common preparation of peanuts in the US is dry-roasting, which increases allergic reaction compared with boiling or frying peanuts. While people in China consume the same amount of peanuts per person as people in the United States, their method of boiling peanuts results in very low rates of peanut allergies.

The differences in food preparation across different parts of the world may cause the digestive systems of their inhabitants to vary significantly. In a study in Proceedings of the National Academy of Sciences, the gut bacteria of fifteen children from Florence, Italy were compared to those of fourteen children from a rural village in Burkina Faso, Africa. Researchers found that the type of flora in these two groups was distinct. The children from Burkina Faso eat a mostly vegetarian diet consisting of food that the community grows itself—reminiscent of how humans ate 10,000 years ago. On the other hand, Italian children's diets consisted of more sugar and animal fat. The study concluded that less diversity in the diet decreases the richness of gut bacteria in the European children. This may be related to the increase in allergies in industrialized countries, where diets are less varied and consist of more processed foods.

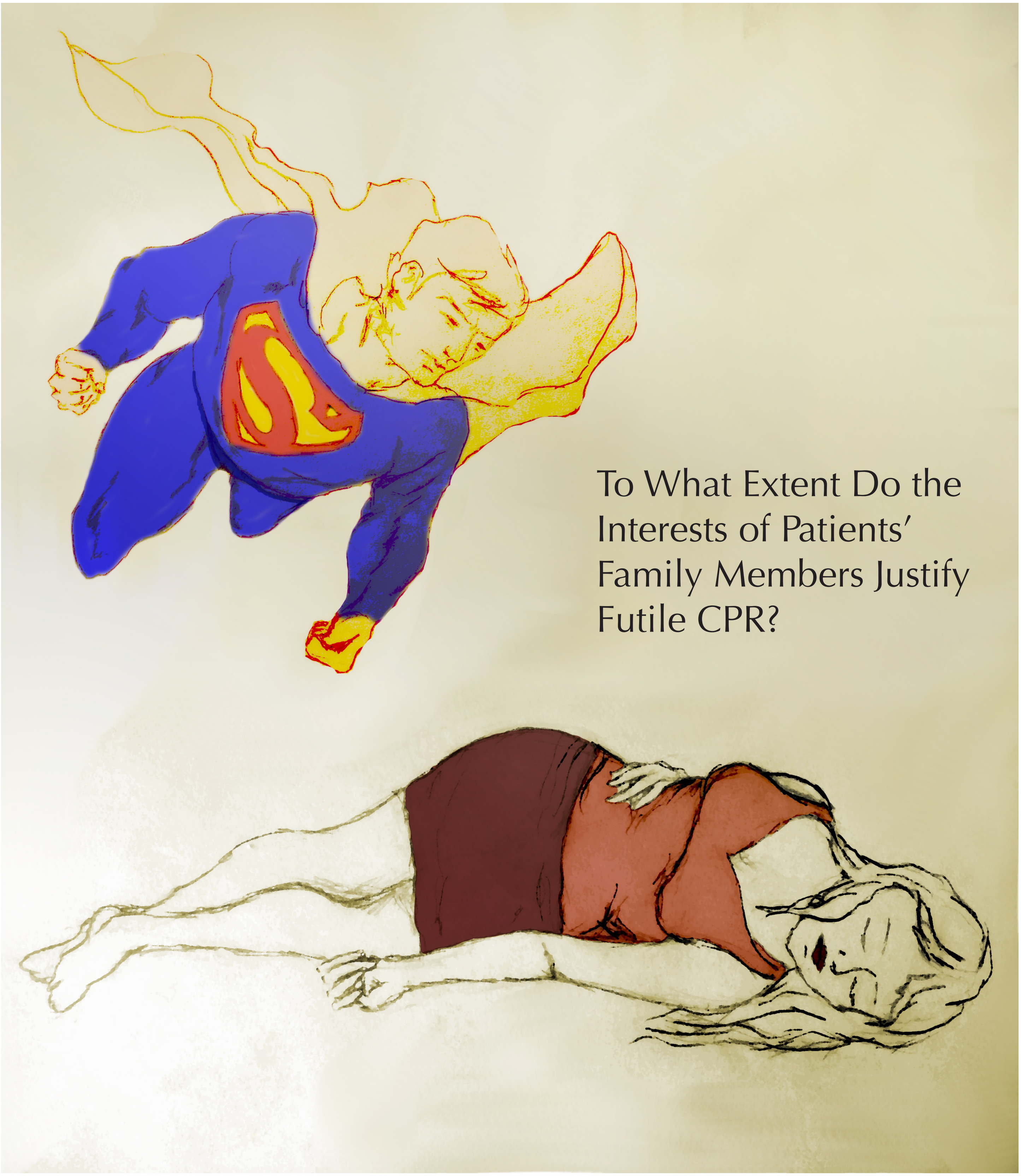
Ultimately, perhaps the most fascinating answer to the allergy question is the hygiene hypothesis. This hypothesis suggests that extreme cleanliness has made the humans' immune systems more sensitive to benign substances in developed countries. A McGill University study examined the effects of having a cleaner environment and fewer infections as a young child on the immune system. They found that overreliance on antibiotics has curbed the development of the immune system, making people more susceptible to allergies. Basically, our "advanced" lifestyles have protected our immune systems from exposure to different types and quantities of germs. Initially, this seems beneficial, but it leads to unwanted consequences when certain people are eventually exposed to various substances. While these consequences certainly were not on scientists' radar when they developed antibacterial drugs, a trade-off eventually had to occur. The increase in food allergies serve as the probable cost for overprotecting our immune systems.

Whether it is due to an increase in awareness, adopting new foods, or being too "clean," the high prevalence of allergic reactions to food is a trend that shouldn't be ignored. Children with food allergies are at an increased risk for asthma or other allergic conditions, and the number of hospitalizations due to allergies in children under 18 has more than doubled since 2003. But before you go out purposefully exposing yourself to germs in order to boost your immune system, remember that the scientific propositions in this article are merely hypotheses to the question of why food allergies are on the rise. The definitive answer remains one to be solved, so the best thing to do for now is to stay aware and get tested.

Do Everything You Can

By Alyssa Ehrlich

Illustration by Esha Maharishi



To What Extent Do the Interests of Patients' Family Members Justify Futile CPR?

Administered outside of the hospital, cardiopulmonary resuscitation (CPR) is effective less than 30% of the time. For hospitalized patients, the success rate drops to 15%. If the patient is elderly and has multiple medical problems, the chances of survival are even lower, with 5% being the highest estimate.

Unfortunately, on average only 5 to 10% of people who receive CPR will actually be revived by the procedure.

This is not to say that CPR is not valuable as a life-saving tool—I am inclined to believe that the value added by a single successful resuscitation is immeasurably great—but rather that CPR is not nearly as effective as many of us imagine. Popular television shows and movies give the impression that CPR is an overwhelmingly successful emergency intervention, one that has miraculously brought countless victims back to life: in these media, CPR is portrayed as effective over 75% of the time. This undoubtedly skews our perception of CPR: we often overestimate its expected value.

I had shared in this overly idealistic impression of CPR until this past February, when I attended a bioethics talk on CPR given by Dr. Craig Blinderman, the director of the Adult Palliative Medicine Service at Columbia University Medical Center. As Dr. Blinderman led a group of undergraduates in a discussion of ethical problems associated with the use of CPR, I learned not only that the procedure is much less effective than I had originally thought, but also that CPR's status as a default response to cardiac arrest is inherently problematic. Dr. Blinderman explained that if patients or their next of kin do not actively opt-out of CPR, it will be performed in response to any cardiac arrest, regardless of cause. Without a do-not-resuscitate order (DNR), CPR will often be performed on terminally or otherwise intractably ill patients whose hearts stop in the natural course of the dying process.

These considerations reminded me of the common request "Do everything you can" made by patients' family members, imploring doctors to take any and all possible measures in order to save their loved ones. Yet given its effectiveness, there must be some cases in which CPR is futile that doctors are aware of. But if they are certain that chest compressions will only serve to bruise a patient in his or her dying moments without any chance of recovery, why would physicians acquiesce to demands for CPR? If the patient has nothing to gain, I wondered, perhaps in these instances CPR serves to comfort the family, a physical embodiment of the doctor's reassurance: "We did everything we could."

In early 2010, Dr. Robert Truog of the Harvard University Division of Medical Ethics published an article on this topic in the New England Journal of Medicine (NEJM) titled, "Is It Always Wrong to Perform Futile CPR?" Dr. Truog argues that performing futile CPR is justifiable in a small minority of cases, which meet certain conditions: (1) the patient is incapable of feeling any physical suffering that might result from CPR, (2) the family members stand to gain a significant psychological benefit from knowing that CPR has been performed, and (3) the use of the hospital staff and resources for CPR does not endanger the health of other patients. Put simply, so long as there is no possibility of CPR causing harm to any patients, whose interests must be considered first and foremost, it is morally permissible for doctors to perform CPR in order to lessen the psychological distress a dying patient's family will inevitably experience. Instead of wondering if something more could have been done, and living with the associated guilt, doubt, and regret, family members can be rest assured, knowing that the patient's death was unavoidable despite the best efforts of clinicians.

Although I find Dr. Truog's arguments very persuasive, many disagreed with his position. One Letter to the Editor criticized Dr. Truog for "inviting us to violate Kant's second maxim—that persons should be treated 'as an end and never merely as a means to an end.'" I find this remark troublesome. Kant's second formulation of the categorical imperative is derived from the notion that it is wrong to violate another's autonomy—his or her power of free will—by using it as a means to an end. Yet how exactly does one violate the autonomy of incapacitated patients, patients who cannot currently exercise free will in any meaningful sense, in their dying moments? If clinicians or family members suspected that a patient would object to futile CPR were he or she able to voice an opinion, or the patient expressly rejected the procedure in a directive such as a DNR, then such a counterargument would be relevant; otherwise, it is unfounded.

Moreover, the clinical experiences that led Dr. Truog and others to believe that futile CPR can be psychologically beneficial for family members have been supported by recent research findings. One such study titled, "Family Presence During Cardiopulmonary Resuscitation," was published in NEJM this March. The study found that relatives of cardiac arrest patients suffered 1.7 times fewer symptoms of depression and anxiety, particularly symptoms of Post-Traumatic Stress Disorder, if CPR was performed. The chance of anxious or depressive symptoms was even lower if relatives personally witnessed CPR being performed. Notably, the presence of family members during CPR did not impact the effectiveness of CPR or the stress experienced by the attending medical team.

While it seems that the conditions that justify futile CPR would rarely be met, perhaps much less often than the procedure is actually performed, the value of saving grieving families from additional psychological duress cannot be denied. In those very special cases in which performing CPR can do no harm—either directly to the ailing patient, or indirectly to other patients due to resource scarcity—I believe that clinicians ought to make an effort to respect relatives' wishes, and grant them a peace of mind.

The Surgery that Forever Changed the Game of Baseball

Zachary Morrow
Illustration by Allison Cohen

In 1974, Dr. Frank Jobe, an American orthopedic surgeon, performed a revolutionary surgery that changed the game of baseball forever. Tommy John, a left-handed pitcher on the Los Angeles Dodgers baseball team, had been pitching in the major leagues for eleven years when he tore his ulnar collateral ligament (UCL), which at the time was considered a career-ending injury. Baseball players who permanently damaged their UCL were said to have a "Dead Arm," and the player can do nothing except retire. This all changed when Tommy John was the first pitcher to have his UCL surgically repaired by Dr. Frank Jobe. Even though John was given less than one percent chance of a successful return, he spent the entire 1975 season recovering, determined to make a comeback. When he returned for the 1976 season, he stunned the world and pitched 207 innings. This was a miraculous feat for a player returning just one year after a "career-ending injury." The surgical repair of his UCL ultimately extended his career another 14 seasons during which he won 174 games out of his career 288 wins: 7th most among left-handed pitchers.

The surgical repair of the UCL, now referred to as "Tommy John surgery," is becoming more common among pitchers in major league baseball. This injury is now becoming a turning point for some pitchers' careers. After undergoing this surgery, many pitchers return to previous, or sometimes improved, levels of performance. This revolutionary medical procedure has changed the careers for many professional pitchers and athletes of all ages.

This surgery targets the UCL, located on the inside of the elbow and connecting the humerus bone to the ulna bone. Its main purpose is to provide stabilization for the flexed, or bent, elbow joint. When the UCL is injured, pitchers lose their ability to throw at full velocity and fail to accurately control the ball. The injury can be very painful and involve tenderness, swelling, inability to straighten the elbow, and numbness in the ring

and little fingers of the hand. Physicians are able to detect tears in the UCL through the use of MRI.

The original surgery performed by Dr. Jobe involved replacing the damaged UCL with a harvested autograft. An autograft is a tendon taken from a different part of the patient's body, such as the arm, leg, or foot. The physician would drill holes into the humerus and ulna, weave the autograft in a figure-eight formation, and attach the tendon to the bone. The most commonly used tendon is the palmaris longus tendon, which is taken from the patient's own forearm. This is primarily due to its biomechanical similarity in length and diameter to the UCL, as well as minimal consequence from its absence. Surprisingly, about 14% of the population does not have a palmaris longus tendon. In this case, surgeons harvest an autograft from a different part of the body, such as the leg or the foot. Over the years there have been many modifications to the original surgical technique, but with proper rehabilitation regimens, this new tendon can become just as strong as the original ligament.

The remarkable success of this surgery has a lot to do with the post-operative rehabilitation process. The operation takes about an hour, but rehabilitation requires almost a full year. During this time players follow an arduous rehabilitation regimen that requires gradual and protected exercises. Essentially the body must train the tendon to start working as a ligament, which connects bones to bones while a tendon attaches muscles to bones. Pitchers undergo exercises to strengthen not only the elbow, but also the shoulder and forearm as well.

To understand how the UCL is injured, we must be able to understand the physics of pitching. There are six phases: wind up, early cocking, late cocking, acceleration, deceleration, and follow through. The most stress is put on the elbow during the late cocking and early acceleration stages. The average stress on a pitcher's elbow during the acceleration phase is 64 Newton-meters per pitch. Newton-meter is the unit for torque, which is the tendency of a force to cause an object to rotate about an axis. Due to the fact that the measured strength of the UCL in cadavers is less than 64 Nm, the forces associated with pitching motions have the potential to exceed the tensile strength of the UCL and lead to its rupture. Tensile strength is the maximum stress a material can experience before breaking. However, protection from the arm muscles, internal rotation of the shoulder, and proper pitching mechanics greatly reduce the excessive stress on the UCL.

Glenn Fleisig, research director of the American Sports Medicine Institute, has conducted many studies on breaking pitches and its effect on arm injuries. A breaking pitch is a specific pitch type, such as a curveball, that does not travel in a straight line as it approaches the batter. For years it has been believed that these types of pitches were one of the leading causes of arm injuries. There are many factors that contribute to the risk of injury among pitchers, but recent studies now show that one of the greatest threats to a pitcher's arm is the number of pitches thrown in a single game. Given the repetitive motion in throwing, pitchers are predisposed to elbow injury. Pitching biomechanics are shown to deteriorate over the course of a game as fatigue sets in, which further increases risk for injury. Baseball organizations at all levels, ranging from Little League all the way up to the Major Leagues, have enforced strict rules to combat this finding. Five years ago, Little League baseball implemented a per-game pitch limit of 85 pitches and required four full days of rest before a pitcher could return to the mound. Recently, the World Baseball Classic, an international baseball tournament where professional baseball players compete for their home country, imposed similar rules on pitching limits. Pitchers are limited to 65 pitches per game in the first round, 80 in the second round, and 95 in the semifinals and finals. In addition, a pitcher cannot pitch for four days if he threw 50 or more pitches.

Over the past ten years more than 75 major league pitchers have had Tommy John surgery. A study published by the American Journal of Sports Medicine and conducted by the Department of Orthopedic Surgery at the University of Pennsylvania examined 68 major league pitchers who pitched in at least one major league game before undergoing Tommy John surgery. They compared the mean innings pitched per season (IP), earned run average (ERA), and walks and hits per inning pitched (WHIP) before and after each player's surgery. Fifty-six of the pitchers returned to play with no significant change in their IP, ERA, and WHIP. This is an incredible accomplishment based on the fact that Dr. Frank Jobe originally gave Tommy John only one percent chance of avoiding retirement.

Roughly 12 million children and young adults play baseball annually, and recent studies suggest that an increased frequency of UCL reconstruction surgeries is being performed. Due to the surgery's high rate of success and effective rehabilitation regimens, athletes of all ages are returning to pre-injury levels of performance.

Although a tear in the UCL was once a career-ending injury, Dr. Frank Jobe's revolutionary medical procedure changed the careers for many professional pitchers and athletes of all ages. Continued development and evolution of surgical techniques and rehabilitation programs have made it possible to return to previous or higher levels of competition. Advancements in sports medicine are changing the course for sports related injuries for athletes in all levels of competition. Hopefully, as technology continues to advance at such a rapid rate, athletes will no longer have to worry about the possibility of a career-ending injury.

Article continued from page 9

or 1. But while a bit may only be either 0 or 1, a qubit may be 0, 1, or a superposition of both. Basic vectors notated as |0> and |1> measure qubits and can represent a pure qubit state as a linear superposition of both. To visualize this, imagine a Bloch sphere, which is a sphere whose north and south poles correspond to |0> and |1>. While a classical bit could only be represented on either pole of the sphere, a pure qubit state may be at any surface point of the sphere, or even as a point inside the Bloch sphere. Multiple qubits may be entangled, allowing a set of qubits to express higher correlation than would be possible in a conventional bit system.

Entanglement permits multiple quantum vectors to be acted on simultaneously, unlike bits that may only have one value (0 or 1) at any given time. This is a necessary ingredient for quantum computation that allows for most of the predicted quantum leaps of quantum computation, including teleportation and super-dense coding.

Recently, the Vienna Center conducted an important experiment deciphering entanglement that was led by Xiao-song Ma and her colleagues who produced two entangled pairs of protons. One photon of each pair was sent to a measuring device named "Victor." Of the two remaining photons, one was sent to another measuring device "Alice" and the other to a third measuring device "Bob" (the names of the devices are the ones used by Peres' original thought experiment that they set out to prove). Victor had two options for measurement. It could measure its two photons in a way that would force them into an entangled state. If this is done, the photons sent to Alice and Bob—each a part of another entangled pair—will become entangled with each other as well. If, on the other hand, Victor measures its two particles separately, then the photons measured by Alice and Bob will likewise be in a separable state.

But now Ma's team proceeded to delay Victor's decision and measurement until such time as Alice and Bob had already completed their measurements. They did this by creating optical delays for Victor's photons and by using a high-speed tunable bipartite quantum state analyzer that was controlled in real time by a quantum random number generator. Delay as well as randomness are necessary to rule out the possibility of the photon pairs through some unknown effect, somehow "knowing" in advance which setting will be implemented once they are registered, which could allow them to produce results of a definite entangled or definite separable state. This set-up enabled Ma and her researchers to decide the quantum state of photons measured by Alice and Bob (i.e., whether Alice's and Bob's photons would be entangled or separable) only after Alice and Bob had already completed their measurements. Thus they showed that this decision could even be made at a time when the photons measured by Alice and Bob no longer physically exist, proving Peres' conjecture made in 2000.

The significance of this experiment for anticipated quantum computing lay in its potential use for "quantum repeaters," a system that extends the range of a quantum link. These could be used to link quantum computational devices so that a quantum computer could perform calculations on a problem whose input only exists in the future. It also means that the question of whether or not two particles are entangled is an objective fact of reality that cannot be answered definitively. Just as there is a wave-particle duality for single particles, there is an entanglement-separability duality for multiple particles. The experiment's practical significance may correlate with our ability to delay the time differential between past and future—in the case of the Vienna experiment, the ability to delay photons which, assuming measuring mistakes can be reliably ruled out, still is nominal within a minute range of nano-retardation at best. But there have always been barriers thought to be unbreakable. Mach 1.05 is still beyond the speed of sound. Traveling only a fraction of a second into the past or future by exceeding the speed of light only marginally, at $c^{1.000058}$, would relegate to the reach of future research our liberation from a once insurmountable challenge for technology. Breaking the barrier of directionality of time and causation was one small step on the exciting yet still arduous road to quantum computing, but it was a giant step across an axiom of physics believed immutable. Special Relativity and more specifically the conceptual evolution of Quantum Theory may have predicted the possibility of Ma's experiment. However, its manifestation under relatively modest laboratory conditions in the 21st century rendered the enormity of "effect before cause" all the more tangible.


NOW THAT I HAVE LIVED ALMOST MY ENTIRE LIFE, I CAN SAY WITH ALL CERTAINTY THAT INTEGRALS ARE WORTHLESS...
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