Harvard Science Review

Vol. 30, No. 2 | Spring 2017

Changing Reality

table of contents

NEWS BRIEFS

FEATURE ARTICLES

COMMENTARY

DIMENSIONAL ANALYSIS

how a 'holographic universe' may be the key to understanding the space we inhabit ·

Julia Canick

Image from Wikimedia

Most people accept that reality has three spatial dimensions. But what if that is not true? Scientists are now considering the notion that we inhabit a holographic universe—that is, a universe in which we exist on a two-dimensional surface where the information on the surface is presented in three dimensions.

The Idea

The idea of a holographic universe was first conceived in the 1990s by scientists Leonard Susskind and Gerard 't Hooft.[1] While 't Hooft proposed the original theory, Susskind gave it an interpretation in the context of string theory.[2] The holographic principle likens the universe's style of encoding information to that of a black hole; black holes store information in bits of area, not volume, which suggests that they need only two dimensions to hold data.[3] Similarly, holographic theory suggests that the entire universe is a two-dimensional structure 'painted' on the cosmological horizon.[4] Therefore, a mathematical description of the universe would require one fewer dimension that it may seem.

Much like a hologram on a credit card, the universe could be an image of two-dimensional information, perceived in three dimensions. This idea has been studied in complex spaces with negative curvature, called anti-de-sitter spaces; new research, however, suggests that this concept can also hold in a flat spacetime—such as the one we inhabit.[5]

The Math

A recent paper published in Physical Review Letters fleshes out the mathematics behind this model.[6] Researchers from the University of Southampton tested algorithms provided through holographic theory against deviations in cosmic microwave background radiation left over from the Big Bang, almost 14 billion years ago. They found that the holographic theory was a good predictor of the structure of these deviations, which supports the mathematical model's legitimacy.[1]

This doesn't mean that there isn't a third dimension; rather, as Raphael Bousso of Stanford University describes it,

"The world doesn't appear to us like a hologram, but in terms of the information needed to describe it, it is one."

It is a more efficient way to explain the world than the one we currently employ.[3]

The Impact

This idea is relatively new, but could be groundbreaking. These findings help bridge quantum mechanics and general relativity. Quantum mechanics (the study of the very small) and general relativity (the study of the cosmically large) are currently at odds when it comes to describing how the universe works at every scale. Removing a spatial dimension actually helps reconcile the theories, and could be the key to a deeper understanding of the fundamentals of the universe's existence.[1] Because gravitational relativity is described in three-dimensional space, while quantum theory is described only in two dimensions, the elimination of an entire dimension would be necessary to allow the two models to coexist harmoniously.[5]

Though scientists have far from proven that we live in a hologram, the holographic principle is a significant jumping-off point for human beings attempting to define the space we inhabit. As researchers uncover more elegant explanations of the puzzling workings of the universe, the holographic theory may become increasingly relevant.

Julia Canick '17 is a senior in Adams House concentrating in Molecular and Cellular Biology.

WORKS CITED

[1] Mortillaro, N. Are We Living in a Holographic Universe? New Study Suggests It's Possible. CBC News [Online], Feb. 1, 2017. http://www.cbc.ca/news/technology/living-holographic-universe-1.3959758 (accessed Feb. 24, 2017).

[2] Susskind, L. J. Math. Phys. 1995, 36, 6377-6396.

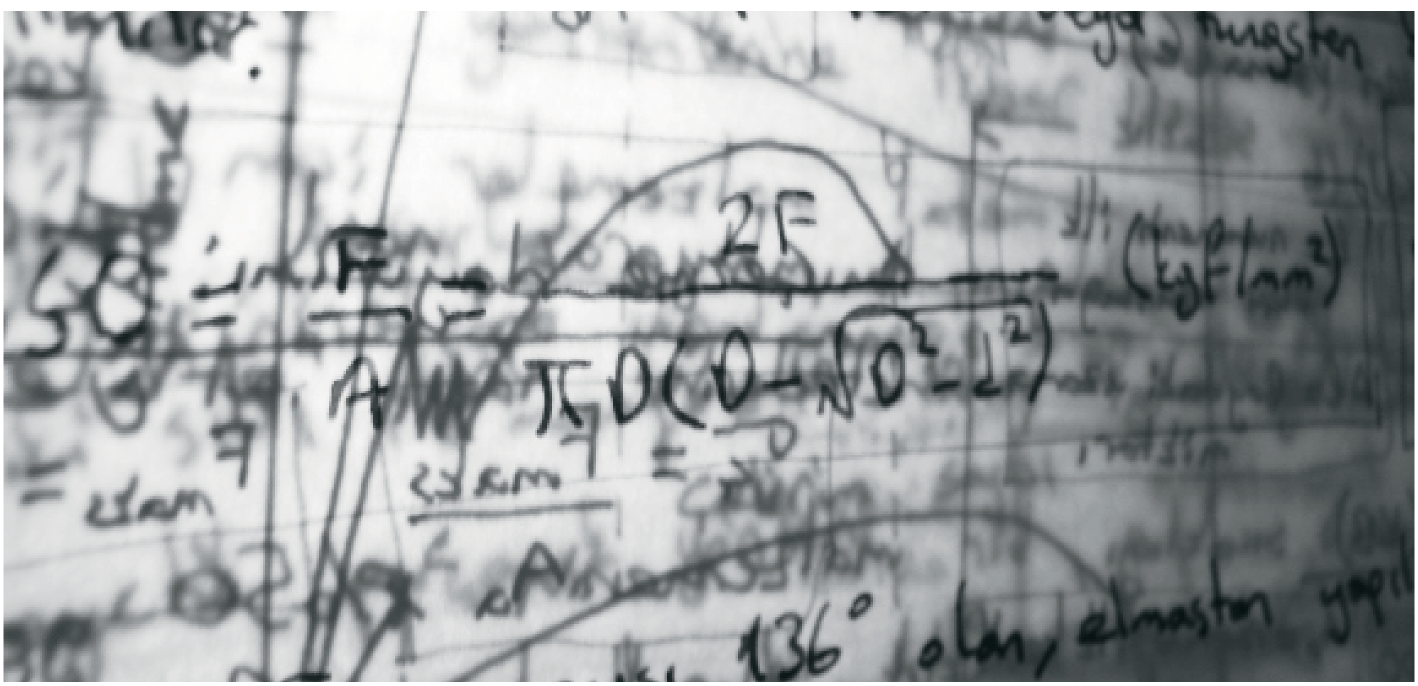
[3] Minkel, J.R. The Holographic Principle. Scientific American [Online]. https://www.scientificamerican.com/article/sidebar-the-holographic-p/ (accessed Feb. 24, 2017).

[4] Holographic Universe. ScienceDaily [Online]. https://www.sciencedaily.com/terms/holographic_principle.htm (accessed Feb. 24, 2017).

[5] Vienna University of Technology. Is The Universe a Hologram? ScienceDaily [Online], Apr. 27, 2015. https://www.sciencedaily.com/releases/2015/04/150427101633.htm (accessed Feb. 24, 2017).

[6] Afshordi, N. et al. Phys. Rev. Lett. 2017, 118, 041301.

Image from Flickr Commons



HABITAT CONVERSION:

A Major Driver of Species Loss

by Priya Amin

What causes species loss? As biodiversity has become increasingly threatened, the call to understand the impact of human activity on species around the world has become particularly urgent. Drivers of species loss include climate change, pollution, and habitat conversion. Climate change has been linked to rising levels of carbon dioxide, which are attributable to human activity.[1] Similarly, pollution is a byproduct of human expansion; undoubtedly, pollutes like fertilizer run-off and plastic waste have negatively impacted many land and marine ecosystems.[2,3] However, while climate change and pollution are key drivers of species loss, both of these factors only indirectly stem from human expansion.

Habitat conversion for human development, on the other hand, directly trades economic profit for habitat loss. Therefore, as the demand for more resources inevitably rises as a result of population growth, so will the rate of habitat conversion. In addition, habitat conversion is deeply rooted within the story of human migration and expansion. Looking toward the future, scientists' sizable estimates of habitat conversion stem from humanity's growing stewardship of Earth's land and resources. Economic activity that causes habitat loss includes urbanization, mining, water development, and agriculture. However, a leading cause of global change is likely the growing human modification of environments for agriculture.[4] To supplement the growing need for food and biofuels, it is projected that approximately one billion additional hectares of agronomic land will be developed in the next few decades.[5]

As a result of agricultural land development, an ecosystem experiences a reduction in its ability to foster biodiversity.[6] This is particularly crucial to the survival of biodiversity hotspots, which are characterized by tremendous habitat loss and a subsequent loss of endemic plant species.[7] For example, the Cerrado biome, a recognized biodiversity hotspot, is home to a variety of unique habitats, including dense woodlands, open grasslands, and dry forests; it is also the richest savannah ecosystem in the world.[8] The agricultural potential and climatic suitability of the area has led to rapid human occupation. Cattle ranching and intensive farming in the Cerrado biome have caused tremendous decline in natural habitat cover.[8]

The drastic loss of spatially consistent natural cover in the Cerrado biome denotes the decline of many endemic plant species, which is also mirrored in the Atlantic rain forest biome. The forest-grassland mosaic of Rio Grande do Sul, Brazil has been largely converted for agri- and silviculture.[9] Due to extensive logging practices, the area's Araucaria broadleaf forest is only a mere fraction of its original extension, and the Araucaria angustifolia species has been recently placed on the International Union for Conservation of Nature and Natural Resources (IUCN) Red List of Endangered Species.[9] According to a study by Hermann and colleagues, land conversion rates far outweigh preservation attempts in the area. Collecting data from satellite images, silviculture in the area was expanded by 94% over the six-year study, and grassland was the main target for agricultural land conversion. On a larger scale, this reflects global developments in temperate grasslands.[9]

An overwhelming number of studies have studied the impact of agricultural habitat conversion on birds, which are often used as indicators of biodiversity status. They play vital roles in many ecosystems, ranging from pollination and seed dispersal to insect control and nutrient cycling. It has been estimated that approximately a fifth to a quarter of pre-agricultural bird numbers have been lost due to agricultural development.[6] In particular, avian breeding success is impacted by agricultural land conversion. A study conducted by Cartwright et al. concluded that the formerly Critically Endangered Mauritius kestrel Falco punctatus experiences a decline in breeding success as the area of agriculture near a nest site is increased.[10] This may be attributable to the increasing spatial variation in the availability of native prey, which is exasperated by land conversion. In addition, loss of farmland bird populations has been observed in Europe. For example, farmland bird populations that are dependent on key aspects of these agro-ecosystems experienced a 40% decline between 1980 and 2000.[1] The status of bird populations is a crucial predictor of how other species in ecosystems will be impacted. Unfortunately, estimates based on current agricultural trends indicate that avian species, and biodiversity, will continue to decline.[6]

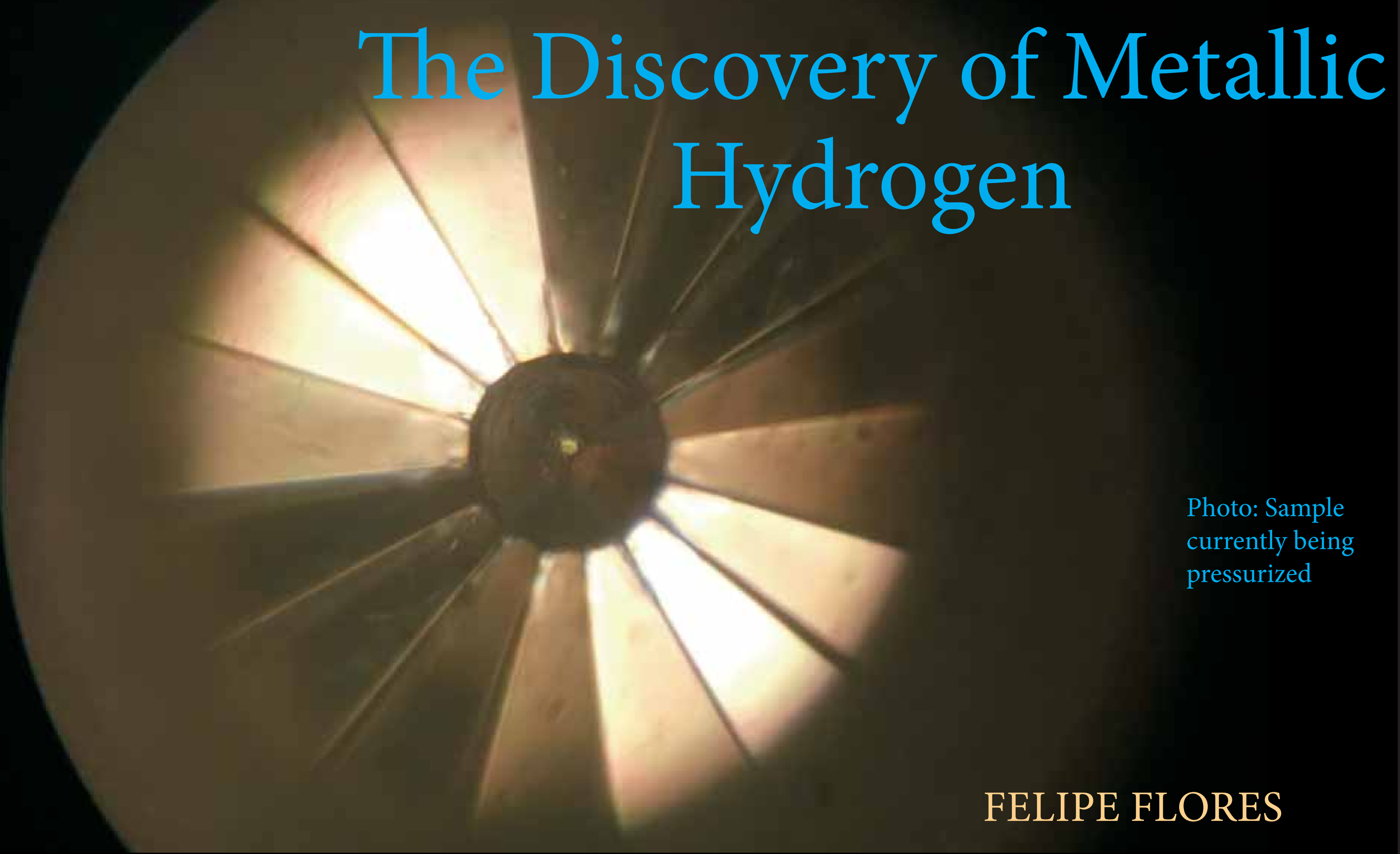
Agricultural habitat conversion has caused much biodiversity and species loss throughout the world. The impact on biodiversity hotspots is especially alarming. Agricultural land conversion of these species-rich areas has been especially detrimental to biodiversity. The startling decline in avian numbers is an ominous sign that many species are threatened by the growing trends in agriculture.[6] Thus, with an increasing human population, it is incumbent that special care is taken to protect encroached environments and endangered species.

Priya Amin ’19 is a sophomore in Pforzheimer House concentrating in Integrative Biology.

WORKS CITED

[1] Cao, L. et al. PNAS. 2010, 107, 9513-9518.
[2] Cooper P. F. et al. Water Sci. Technol. 2010, 61, 355-63.
[3] Jambeck J. R. et al. Science 2015, 347, 768-771.
[4] Keitt T. H. Ecol. Appl. 2009, 19, 1561-1573.
[5] Oakleaf J. R. et al. PLoS ONE 2015, 10, e0138334.
[6] Gaston K. J. et al. Proc. R. Soc. B. 2003, 270, 1293-1300.
[7] Myers N. et al. Nature 2000. 403, 853-858.
[8] Diniz-Filho J. A. F. et al. Sci. Agric. 2009, 66, 764-771.
[9] Hermann J.M. et al. Ecosyst. Health Sustainability 2016, 2, 1-11.
[10] Cartwright S.J. et al. J. Appl. Ecol. 2014, 51, 1387-1395.
[11] Doxa A. et al. J. Appl. Ecol. 2010, 47, 1348-1356.

Wikimedia Commons



The Discovery of Metallic Hydrogen

Photo: Sample currently being pressurized

FELIPE FLORES

The generation of metallic hydrogen by Professor Isaac Silvera and postdoctoral fellow Ranga Dias, PhD represents a crucial advance in the field of high-pressure physics. Originally theorised in 1935 by physicists Eugene Wigner and Hillard Bell Huntington, the ongoing project was finally brought to fruition at Harvard University in January 2017. Both Silvera and Dias agreed to be interviewed for this article

What was the key to the discovery?

Generating a sample of metallic hydrogen has been an ongoing project for many years in several laboratories, and the Silvera lab has finally succeeded. An essential component to Silvera and Dias' success was achieving the correct pressure to obtain a transition to a metallic state. While the necessary density of the metallic phase was predicted accurately in the 1930s, the predicted pressure to achieve a metallic phase at the time was around 25 GPa, while modern predictions placed the figures at 400-500 GPa.[1,2] Indeed this recent success was obtained with a pressure of 495 GPa, a pressure never achieved before in hydrogen experiments.[3] Achieving such pressure had its challenges: "The diamonds we use to contain the samples tend to break or allow diffusion," explained Dias; "the hydrogen sample can diffuse into the diamond and cause defects, which will weaken the diamond and make it break before reaching the ultra-high pressure needed ."[4] The key therefore, lies in modifying the diamond to make it sustain the immense force necessary for this experiment's success. Dias summarized the special technique as "adding a diffusion barrier to a very polished diamond with as little defects as possible."[4] Once the scientists achieved the ultra-high pressure and observed a phase transition,

sition, they measured the reflectivity of the sample to be consistent with that of a metal, as well as obtained a density in agreement with theoretical predictions.

Why is the discovery so exciting?

Theoretical calculations predict metallic hydrogen to be a metastable material as well as a room-temperature superconductor.[5,6] Metastability means the material would remain in the same metallic state even after the high pressure is released (just like diamond is a metastable form of carbon). If such is the case, metallic hydrogen could potentially be an extremely efficient way of storing energy, for instance to be used as a rocket propellant. Superconductivity means the material could carry currents without any resistance or energy loss. Such a property has only been achieved at extremely low temperatures in other materials, while metallic hydrogen is theorized to behave this way at 17˚C, far higher than other candidates. If both properties are confirmed to be true, we might see a revolution in electronics and transportation. For instance, magnetic levitation vehicles could become more accessible, electronics could become more efficient, and space travel could become cheaper and to farther distances.

What is the current status of the experiment?

Unfortunately, the sample was accidentally destroyed, a common fate in high-pressure physics, as both Professor Silvera and Dias explained.[7] In order to create the metallic hydrogen, Silvera and Días followed procedures necessary ensure not to break the device's compressing diamonds. Upon submitting their paper, they kept the hydrogen at a low temperature and at a high pressure until the acceptance of their work, in case the pair was instructed to perform other tests. The crystals were slowly developing defects while held under the stress of a high pressure during the evaluation of the paper, and when Silvera and Dias later shone a low-energy laser upon the sample, the diamonds broke and the metallic hydrogen was lost. "It was a surprising that the diamonds broke with such a low-energy laser,"[7] said Professor Silvera. However, it is also uncommon to retain samples compressed for such a long time. "The accumulation of defects over all that time was probably responsible," added Silvera.[7]

The discovery has not been met absent of criticism and skepticism, especially on the reproducibility of the experiment. The Silvera lab is currently reproducing their experiment, although with a few tweaks to the procedure, such as the use of a different type of diamond. Another central criticism was the pair's use of alumina to create a diffusion barrier around the hydrogen, as some thought the metallic nature of the sample could stem from the aluminium casing. However, Dias is not concerned about this possibility, explaining that even at pressures such as 400 GPa there has been no observed change in aluminium, and as such it is highly doubtful that it would be the culprit. Additionally, Silvera and Dias utilised a layer of only 48 nanometres of aluminium in their experiment, which, they say, is so thin it could not be the source of metallic properties they measured.

How do you feel about the future of the experiment?

"Hopeful," said Silvera; "optimistic," said Dias.[4,7] If their success is repeated, the scientists will transport their sample to Argon Labs, near Chicago, in order to x-ray the metallic hydrogen sample, examine its structure, and determine whether it is indeed the desired metallic phase and whether it is metastable, amongst other things. While the future of metallic hydrogen is yet to be determined, the confident attitudes of Silvera and Dias are encouraging for expectant scientists around the world as physics embraces its newest exciting discovery.

Felipe Flores '19 is a sophomore in Quincy House studying Human Developmental and Regenerative Biology and Physics.

Works Cited

[1] Wigner, E.; Huntington, H. B. J. Chem. Phys. 1935, 3, 764-770.
[2] Silvera, I.; Cole, J. J. Phys. Conf. Ser. 2010, 215, 012194.
[3] Dias, R.; Silvera, I. Science. 2017, 355, 715-718.
[4] Flores, F. Interview with Ranga Días, PhD. Apr. 4, 2017.
[5] Ashcroft, N. W. Phys. Rev. Lett. 1968, 21, 1748-1749.
[6] Brovman, E. G et al. Sov. Phys. JETP. 1972, 35, 783-787.
[7] Flores, F. Interview with Prof. Isaac Silvera. Apr. 7, 2017.

Photo: Apparatus used in the experiment

A (DIS?)HARMONIOUS UNION: CHIMERAS

By Una Choi

BACKGROUND : ANIMAL CHIMERAS

Chimeras prefigure prominently in classical and modern mythology; creatures ranging from the Greek chimera, a monster bearing lion, goat, and serpent anatomy, to the modernized hippogriffs found in popular fantasy fiction today have captured imaginations for centuries.

Biologically, animal chimeras are organisms containing two disparate genomes. Natural chimeras are commonly seen through mechanisms like fetal microchimerism, a phenomenon describing the retention of fetal cells in the mother's body for months and even years after pregnancy.[1] Chimera here refers to the deliberate transplantation of human stem cells into nonhuman animal embryos. Human stem cells were first successfully derived from adult tissue cells in 2007.[2] Pluripotent stem cells (PSC) differentiate into any cell type found in the original organism. Although initial attempts to trigger the differentiation of these stem cells into therapeutic tissues involved in vitro exposure to various chemicals, the difficulty of achieving the precise environment required for successful differentiation has led to a recent trend of transplanting stem cells of one species into embryos of another.

DIABETES AND RAT-MOUSE CHIMERAS

Dr. Hiromitsu Nakauchi of Stanford utilized rat-mouse chimeras to reverse successfully diabetes in mice.[2] Dr. Nakauchi rendered the Pdx1 gene associated with pancreas development in rats non-functional and injected these same rat embryos with mouse stem cells, forcing the rats to develop its pancreas with pure mouse cells.[2] The mice recipients originated from the same inbred strain as the donor mice, so they did not reject the transplanted organs.[3] In constructing a pancreas derived almost solely from donor mouse cells, Dr. Nakauchi decreased risk of tissue rejection, thus enhancing the likelihood of a successful transplantation of the donor-derived tissue into the donor animal.

These mouse-derived pancreases were not solely constructed from mouse cells; indeed, 10% were composed of rat cells, as the rat supplied the blood vessels. These blood vessels, however, were rapidly replaced when the pancreases were transplanted in the mice.[3]

This successful growth and implantation suggests a possible treatment for Type 1 diabetes, an autoimmune condition associated with the destruction of pancreatic beta cells.[3] When Dr. Nakauchi transplanted these formed islets into diabetic mice, the mice-derived islets normalized the hosts' blood glucose levels for over 370 days without immunosuppression, revealing the therapeutic potential of cross-species implantation.[3]

Similar attempts to knock out completely the genes associated with the development of a particular organ in a developing animal have proven successful with the murine pancreas, heart and eye.

Pig-Human Chimeras

Mice and rats, however, differ drastically from humans. Consequently, several researchers are focusing on pigs as potential sites for human organ development. Pigs' organs are similar in size to that of humans, and their metabolism also closely resembles human metabolism.[1]

While researchers have successfully blocked the generation of the murine pancreas, heart, and eye, efforts to create pigs incapable of developing the organ of interest have proven unsuccessful. Organs like the pancreas, which stems from a single kind of progenitor cell, will be more easily constructed than complex organs like the heart.

In a 2017 paper published in Cell, Wu et al. found that naïve human PSCs, which have an unlimited self-renewal capacity, successfully engrafted into pre-implantation pig blastocysts.[4] This transplantation, however, failed to contribute significantly to normal embryonic development in the pigs. The same group then injected human PSCs into cattle blastocysts. Both naïve and intermediate human PSCs survived and integrated into the cattle. Similarly, when human PSCs were injected into pig blastocysts, the blastocysts retained the human cells. These human PSCs selectively incorporated into the inner cell mass (ICM), marking the first step into successful incorporation of the donor cells into the host.[4]

When the human PSCs were later injected into pig embryos, 50 of the 67 embryos exhibiting retained human PSCs were morphologically underdeveloped. In addition, this formation of interspecies chimeras was highly inefficient, revealing the persisting challenges to constructing viable pig-human chimeras.[4]

Image: Human-Pig Chimera Developing Embryo

Ethical Implications

The incorporation of porcine, bovine, and equine biological heart valves into human patients and the use of insulin derived from porcine pancreas are widely accepted medical tools.[1] The production of a human-derived organ in a pig or other nonhuman animal, however, has been met with significant controversy.

The accidental incorporation of human cells in non-target locations in the host animal can result in ethical consequences; if human-derived cells are significantly utilized in the development of the non-human brain or the reproductive organs, the test animal may be considered excessively humanized. A 2013 study from the University of Rochester Medical Center reported that mice injected with human brain cells exhibited enhanced synaptic plasticity and learning.[2] These human glial progenitor cells outcompeted their murine counterparts, resulting in white matter largely derived from humans.

These concerns of unwanted integration have resulted in the prohibition of human stem cell transplantation into monkey early embryos, as the evolutionary closeness may result in an increased susceptibility of monkey brains to human cell-catalyzed alteration.[2]

In response to the above concerns, the National Institutes of Health (N.I.H.) instituted a 2015 moratorium on the use of public funds to incorporate human cells into animal embryos. This ban is still in place at the time of this article's writing. These efforts have delayed current chimera research dependent on public funds; Dr. Nakauchi's pancreas experiment is the result of eight to nine years of work and a 2014 relocation from Tokyo to Stanford due to Japanese regulations.

Scientists have pointed to new molecular techniques to address some of the more common ethical concerns. CRISPR-Cas9, a popular gene editing technique, might be used to direct implanted human cells to target organs in the embryo, thus preventing the accidental incorporation of human cells into the brain and reproductive tissues.[2] The injected human stem cells could also be modified to include 'suicide genes' activated upon neural differentiation, ensuring the elimination of any human-derived differentiated brain cells.[2]

In addition, primate cells divide more slowly than non-primate cells; primate neural progenitor cells go through more cell divisions.[5] A sow's gestation period, for example, is around 3 months, representing far shorter development period than that of humans.[1] Transplanted human neural progenitor cells in chimeras would only be able to achieve the same high threshold of cell divisions if they were able to somehow sense the shortened development window and divide more rapidly. This scenario, however, is unlikely, as previous studies of human/mouse blood stem cell xenografts suggest the host regulates human stem cell proliferation; the likelihood of an accidental integration of human stem cells into the murine brain and a subsequent development of human cognitive capacities is slim.

Future Implications

The discovery that human-derived stem cells were utilized in the development of tissues in pigs holds promising implications for the field of organ transplants. Around 76,000 people in the United States await transplants.[2] In Europe, over 60,000 people are on the organ transplant waiting list. Attempts to grow human-derived organs in pigs and other animals could thus address the organ shortage.

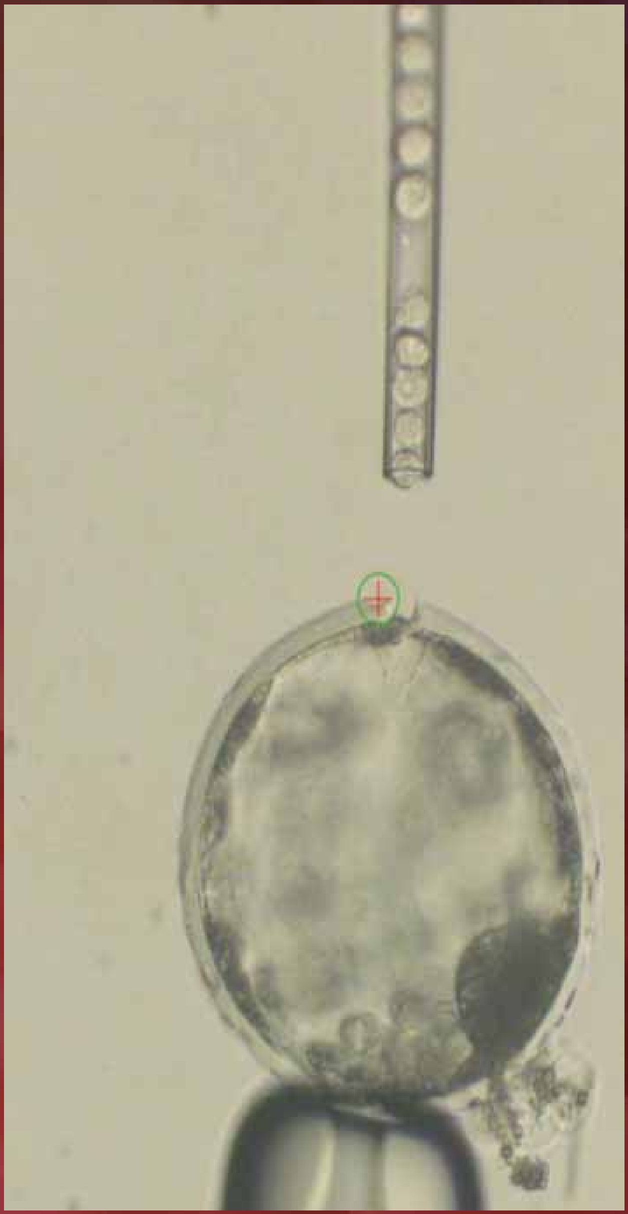
Because the organs generated in the developing embryos are derived from donor cells, transplantation of those organs into the donor or organisms closely resembling the donor can decrease risk of organ rejection. This reduces the need for immunosuppressant drugs commonly used with organ transplants today.

The ability to generate human-derived tissues in non-human embryos allows scientists to study human cell development outside of human embryos.[5]

Una Choi '19 is a sophomore in Kirkland House studying Molecular and Cellular Biology and Economics.

Works cited

[1] Bourret, R. et al. J. Stem Cell Res. Ther. 2016, 7, 1-7.
[2] Wade, N. New prospects for growing human replacement organs in animals. NYTimes [Online], Jan. 26, 2017. https://www.nytimes.com/2017/01/26/science/chimera-stemcellsorgans.html?_r=0 (accessed March 11, 2017).
[3] Kilsoo, J. et al. Stem Cells Dev. 2012, 21, 2642-2655.
[4] Wu, J. et al. Cell 2017, 168, 473-486.
[5] Karpowicz, P. et al. Nature 2004, 10, 331-335.



the new age of aging research

by eric sun

Aging. To some, this word symbolizes equality, wisdom, and progress; to others, this word represents weakness, disease, and death. To me, aging has taken on a mixed meaning. When I was a small child, I remember lying awake in bed and counting my heartbeats as if the thumping in my chest was also the ticking of my biological clock. I imagined that each person was given a certain number of heartbeats in a lifetime. Aging, to my young mind, was simply the slow and eventual countdown of these limited heartbeats. Although not many people will admit it, the fear of aging and death is extremely common.[1] Throughout history, our fascination with mortality has contributed to the rise and spread of religions and legends. Since then, scientific research has begun to shed light on one of life's greatest mysteries.

Aging Research in History

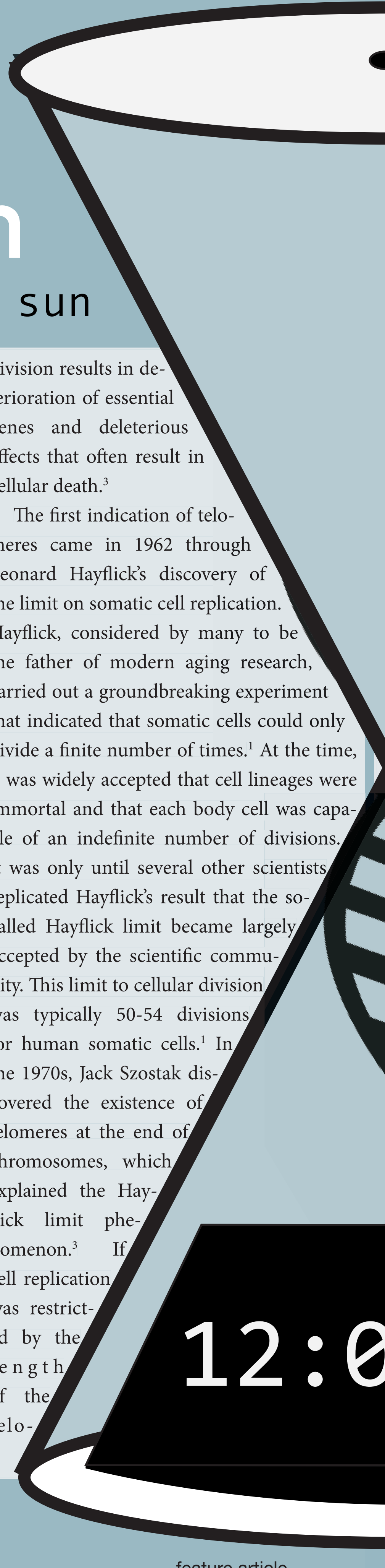
During the late Middle Ages, alchemy was a booming practice. The holy grail of alchemy was procurement of the fabled philosopher's stone—a stone that had the ability to extend the life of its wielder indefinitely.[1] Despite numerous efforts, there are no records of any successful attempts at synthesizing the object. The philosopher's stone was not the only fabled anti-aging object. After the discovery of the Americas, there was growing interest in the possibility of uncovering the fountain of youth in this uncharted territory. In 1513, the conquistador Juan Ponce de León set out on a quest to find the fabled fountain, which ultimately ended in failure.[1]

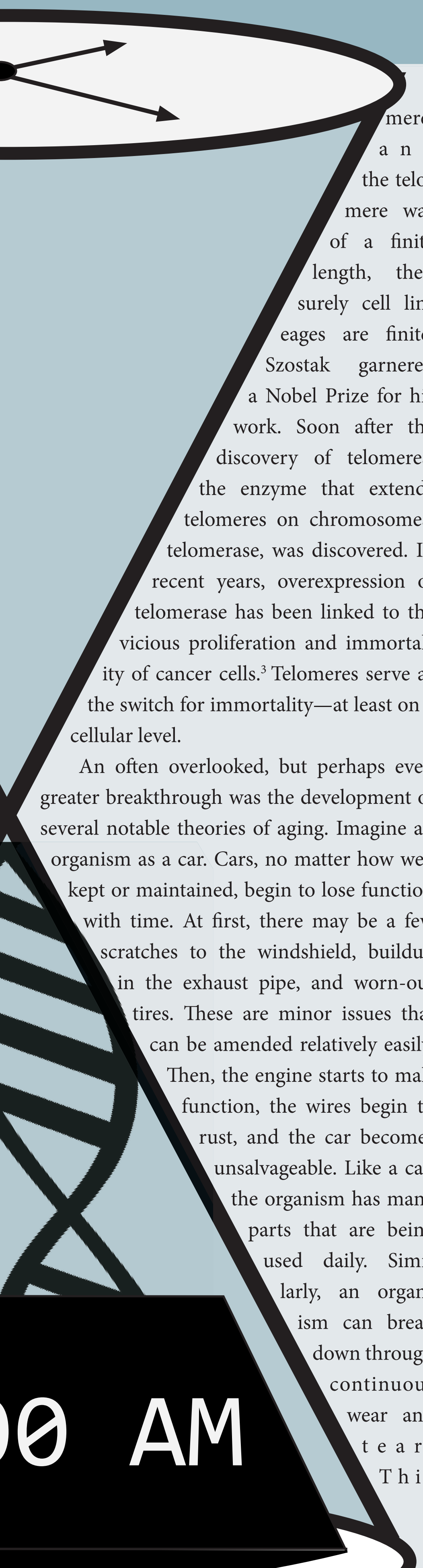
In the following decades, the interest in anti-aging 'research' faded along with its associated myths. In fact, aging research was under the public radar from the Renaissance until the 1940s when James Birren produced a theory involving what he called the "tertiary, secondary, and primary processes of aging."[1] Birren developed the field of gerontology, which is the study of aging, and expanded it firstly socially and secondly scientifically. At this time, aging research was widely considered a pseudoscience—a label that was not helped by the unscientific blood and serum transfusions championed by charlatans as anti-aging treatments. Ironically, a recent study reported that old mice that received plasma transfusions from younger mice were physiologically healthier, although this has yet to be validated in humans and although it was quite clear that these results were unknown in the early 1900s.[2] Under Birren's lead, the scientific stigma surrounding aging began to dissipate as more scientists were attracted to this young and growing field of research.

Notable Advances

In the following years, aging research underwent a series of profound, exciting breakthroughs. Perhaps the most famous discovery was that of the telomere. Telomeres are the repeating DNA sequences at the end of each of the chromosomes. Through the DNA replication mechanism, the telomeres deteriorate after each cycle of replication and the chromosomes become shorter. Although telomeres themselves do not appear to have any significant function outside of protecting other DNA sequences from degradation, when a cell exhausts its telomeres, each successive division results in deterioration of essential genes and deleterious effects that often result in cellular death.[3]

The first indication of telomeres came in 1962 through Leonard Hayflick's discovery of the limit on somatic cell replication. Hayflick, considered by many to be the father of modern aging research, carried out a groundbreaking experiment that indicated that somatic cells could only divide a finite number of times.[1] At the time, it was widely accepted that cell lineages were immortal and that each body cell was capable of an indefinite number of divisions. It was only until several other scientists replicated Hayflick's result that the so-called Hayflick limit became largely accepted by the scientific community. This limit to cellular division was typically 50-54 divisions for human somatic cells.[1] In the 1970s, Jack Szostak discovered the existence of telomeres at the end of chromosomes, which explained the Hayflick limit phenomenon.[3] If cell replication was restricted by the length of the telo-





mere, and the telomere was of a finite length, then surely cell lineages are finite. Szostak garnered a Nobel Prize for his work. Soon after the discovery of telomeres, the enzyme that extends telomeres on chromosomes, telomerase, was discovered. In recent years, overexpression of telomerase has been linked to the vicious proliferation and immortality of cancer cells.[3] Telomeres serve as the switch for immortality—at least on a cellular level.

An often overlooked, but perhaps even greater breakthrough was the development of several notable theories of aging. Imagine an organism as a car. Cars, no matter how well kept or maintained, begin to lose function with time. At first, there may be a few scratches to the windshield, buildup in the exhaust pipe, and worn-out tires. These are minor issues that can be amended relatively easily. Then, the engine starts to malfunction, the wires begin to rust, and the car becomes unsalvageable. Like a car, the organism has many parts that are being used daily. Similarly, an organism can break down through continuous wear and tear. This seemingly obvious idea has been revolutionary in the field of aging research. Contrary to other theories that proposed that humans were genetically programmed to age, the cumulative damage theory presented aging as a random process.[1] As such, it may be reasonable to conclude that aging is the byproduct of environmental effects. Surely, this would mean that after centuries of medical advancement, which included vaccines, antibiotics, and surgery among its ranks, humans have been able to increase their life spans considerably. Yet, despite significant increases in life expectancy, meaning more humans are realizing the full extent of their maximum lifespans, the actual human lifespan has stayed relatively the same.[3] A more recent theory proposed that the maximum lifespan is determined genetically and that environmental factors can only contribute to expedited biological aging. Given the saturation of human population survival curves, this theory is especially convincing.[3]

As a corollary to the cumulative damage theory of aging, aging is regarded as a holistic process—a process that is affected by a multitude of genes and environmental factors. One suspected contributor to the aging process is free radical damage.[1] Free radicals are molecules that harbor a single, unpaired valence electron and induce oxidative damage in cellular machinery. Free radicals are byproducts of cellular respiration and can damage DNA. In particular, mtDNA (mitochondrial DNA) is at risk of oxidative damage due to both its proximity to free radical formation, as cellular respiration occurs in mitochondria, and significantly lower levels of DNA repair. The free radical theory of aging has become especially popular in the health industry where antioxidants, compounds that neutralize free radicals, have become synonymous with anti-aging treatments.[3] The effectiveness of antioxidant consumption in retarding aging has not been validated. Other notable candidates for contributing to aging include protein aggregation, cross linkage, and induced apoptosis.[1]

In order to discern other contributing factors, several longitudinal studies on aging have been implemented. Longitudinal studies offer one major advantage over the cross-sectional studies traditionally employed in medical research in that they allow scientists to track an individual's health as they grow older. The Baltimore Longitudinal Study of Aging (BLSA) is the most prominent of these studies and was started in 1958 by Nathan Shock, a pioneer in the field of aging research, along with over 1,000 participants.[4] Since then, several other studies have taken root including The SardiNIA Project executed by the National Institute on Aging that includes 6,100 participants from the island of Sardinia off the coast of Italy.[3] Armed with the powerful tools of bioinformatics, these studies have become potential windows from which to understand the intricacies of human aging.

Aging Research Today

Aging research has gained steady momentum in recent years. In fact, one of the most famous aging experiments was conducted in 1993 by Cynthia Kenyon, a professor at UCSF and now vice president at Calico. Kenyon discovered that mutations in the daf-2 and daf-16 genes doubled the lifespan of C. elegans, a model organism. Her future work saw increasingly lengthened lifespans from modulating these two genes.[5] The search for homologous counterparts in humans is ongoing. A recent subset of aging research has focused on life extension treatments in more complex model organisms such as D. melanogaster, lab mice, and Rhesus monkeys.[1]

Recently, other molecular mechanisms have been implicated with aging. These include reservatrol, sirtuins, and rapamycin. Reservatrol, a compound commonly found in red wines, activates sirtuin deacetylases, which extend the lifespan of lower organisms and may also be involved in human aging.[6] Reservatrol has also been related to cardioprotective benefits. Discovery of these mechanisms and possible relations to aging have been led by pioneers such as David Sinclair of Harvard Medical

School. Treatments involving rapamycin, an immunosuppressant, have increased the longevity of mice.[7] The search for contributing molecular factors of aging is an active and promising facet of aging research.

In the past decade, the advent of computational tools for large-scale data analysis has revealed fascinating insights into aging. Computational biology and bioinformatics have expedited the search for biomarkers of aging. Traditionally, pulse wave velocity and telomere length served as the gold standards of biological age measurement, but only explained a fraction of individual variance in aging.[3] Recent research has implicated a litany of cardiovascular traits, physical and mental characteristics, and genetic mutations as potential biomarkers. In 2014, Steve Horvath, a professor at UCLA, developed a method for deriving an estimate of biological age (DNAm) from DNA methylation patterns, which was highly correlated with chronological age and seemed to explain several tendencies in both aging and disease.[8] There is ongoing research in detection of a central aging signal that explains most physiological causes of aging.

Aging research has garnered considerable public spotlight in the past several years. Aubrey de Grey, a computer scientist turned biologist and founder of the SENS foundation, gave an extremely well-received TED talk on a strategy that he has proposed to tackle the obstacle of aging. The strategy involves partitioning the aging process into several major factors: aggregates, cellular senescence and growth, cross linkage, and mutations. By targeting medical advancements in each field separately, the problem becomes more manageable and the human lifespan could potentially be elongated in small increments over a long period of breakthroughs.[9] Other social movements such as transhumanism have highlighted the potential of anti-aging treatments in the near future. Transhumanism embraces emerging technologies and their potential in bettering the human body or quality of life—including extension of the healthy lifespan.[9]

Controversies

Since the age of alchemy, aging research has been a field brewing with controversy. Today, there are two major concerns with developments in aging research and rejuvenation technology. First, critics of anti-aging research are concerned with the very real possibility of overpopulation. The current age distribution of ages in the United States is a micro-example of what an ageless population might entail. There are already concerns that the aging Baby Boomers generation may overburden the healthcare and Social Security systems.

Since the age of alchemy, aging research has been a field brewing with controversy.

Imagine this same effect but with continuous, cumulative addition to the old end of the age spectrum. Critics espousing this belief, however, do not take into consideration what current aging research implies about future anti-aging therapies. Nearly all current testing in model organisms has indicated that anti-aging treatments tend to promote extended, healthy aging. That is, the relative age of individuals would simply be stretched across a longer temporal span. Individuals under treatment who are chronologically 70 years old may instead be 50 years old biologically. As such, fears of skewing towards an elderly population are largely unfounded in a relative world. Additionally, longer healthy life spans would entail greater productivity from an individual over their lifetime.[9]

Other opponents of aging research cite religious and ethical concerns.[10] After all, if we are extending our lifespans beyond their natural limit, are we not playing God? There is no simple solution to address these concerns. There will always be advocates and critics of aging research and scientists should be attentive to these ethical concerns as they continue to pursue this line of research. In the end, if an anti-aging treatment is procured, it is only an additional opportunity that has been extended and would be by no means obligatory.

The Path Ahead

Aging research is an exciting and growing field. Developments in our understanding of the fundamental aging process are likely to proffer increased insight in related research areas such as cancer, diabetes, and Alzheimer's research. Aging is still a relatively underpopulated field of research and looks to benefit from the recent explosion of biotechnology and big data-aided research.[11] In the coming decades, one can expect to see greater innovation and progress in aging research. Perhaps one day, even the fabled philosopher's stone or fountain of youth may manifest as a product of this push for greater understanding.

Eric Sun '20 is a freshman in Hollis Hall.

WORKS CITED

[1] Hayflick, L. How and Why We Age; Ballantine Books: New York, 1996.
[2] Scudellari, M. Nature 2015, 517, 426-429.
[3] Austad, S. Why We Age, 1st ed.; Wiley: Hoboken, NJ, 1999.
[4] Shock, N. et al. Normal Human Aging: The Baltimore Longitudinal Study of Aging; NIH-84-2450; NIH: Washington, D.C., 1984.
[5] Kenyon, C., et al. Nature 1993, 366, 461-464.
[6] Baur, J. A.; Sinclair, D. A. Nat. Rev. Drug Discov. 2006, 5, 493-506.
[7] Wilkinson, J.E., et al. Aging Cell 2012, 4, 675-682.
[8] Horvath, S. Genome Biology 2013, 14, R115.
[9] de Grey, A.; Rae, M. Ending Aging: The Rejuvenation Breakthroughs That Could Reverse Human Aging, 1st ed.; St. Martin's Press: New York, 2007.
[10] Green, B. Radical Life Extension: An Ethical Analysis. Santa Clara University [Online], February 27, 2017. https://www.scu.edu/ethics/all-about-ethics/radical-life-extension/ (accessed Mar. 26, 2017).
[11] Arking, R. Biology of Aging: Observations and Principles, 2nd ed.; Oxford University Press: Oxford, U.K., 2006.

Image from PixaBay

Innocent Until Proven Free?

The Question of Neuroscience and Moral Responsibility

by Kristina Madjoska

"Plead insanity!" you might have heard Detective Cohle say to some of his interrogees in the show True Detective. Even if you have not watched True Detective, chances are you have heard of the term insanity plea. The idea that moral and legal responsibility is alleviated when a person cannot control their impulses or reason through ethically meaningful situations is fundamentally embedded in our legal understanding of insanity. This logic certainly makes intuitive sense: if someone has acted under a compulsion and hasn't been able to choose their course of action freely, then they shouldn't be blamed for having bad intentions. After all, it was not their choice. Neuroscience has consistently provided support for this reasoning, as evidence of abnormal brain structures and neurotransmitter actions in mentally ill patients has piled up. Yet in an essential way, modern neuroscience also problematizes this logic. If increasing evidence shows that our brain biochemistries are responsible for the choices we make, then are we allowed to talk about free choice? And if free choice cannot be argued for, can we rightfully assign blame to anyone?

These questions suggest that a 'pledge to insanity' should not be an exclusive privilege of the mentally ill. In certain ways, all criminal acts are a result of some malfunction of our brains, or simply said, we are all in some small ways insane. This is important to our concepts of law and morality because, when assigning blame, we typically consider whether a person has freely chosen to act in a way that deserves this negative judgment. If it is true that we have no control over our actions, then blame might be assigned purely to those who happen to have gotten the wrong combination of genes and environmental conditions which have prompted them to act contrary to the rules. There are multiple thoughtful approaches that neuroscientists have taken to study this issue. Neuroscientific literature on the topic is broad, yet two especially salient questions emerge: Does our brain biochemistry cause our behavior? And if this is true, then is it still smart or rightful to regard ourselves as responsible for our actions?

The Moral Compass

Before we begin delving into the intricacies of these two questions, it is first important to discern which parts of our brain participate in our moral decision-making. Refined neuroimaging techniques like fMRI (functional magnetic resonance scanning) have allowed us to inspect in real-time where brain activity is localized and what cognitive and behavioral responses it corresponds to. Two scientists from the University of California, Santa Barbara give an extensive overview of the current understandings of the neurobiology of ethical reasoning.[1] Synthesizing multiple findings, they posit that morality in the human brain works by a mechanism of parallel processing. This means that there are several different regions in the brain that work simultaneously to produce any ethical thought, value or conclusion. Such a division of labor reflects the plurality of human moral thought. For example, a study from the National Institute of Health has shown that social emotions, particularly disgust, play a critical role in our evaluations of morally meaningful situations. Our basal ganglia and amygdala, parts of our brain that are also associated with disgust elicited by stimuli like spoiled food, are significantly active when people are asked to think about statements that frequently elicit moral reprehension, like incestuous relationships or murder.[2] At the same time, our emotional moral responses also depend on feelings of compassion and admiration. Observed activity in the anterior cingulate cortex, a region in the frontal part of our brain involved with empathy, showed that these feelings depend on our ability to imagine ourselves in someone else's shoes.[3] However, it is critical to note that emotion is not the only important medium through which we come to understand morality. Human capacity to reason abstractly is also a crucial aspect of this process. A specific type of abstract reasoning is our belief attribution system. This system is responsible for our ability to imagine other people's intentions, even if their actions do not explicitly demonstrate them. Functional belief attribution would help us to, for example, see behind a dubious smile or party invitation. The right temporoparietal lobe, a module on the surface of our right brain, is involved in our performance of belief attribution.[4]

To date, there is no convincing evidence of centralized command integrating these multiple parallel processes. In most cases, the parallel neural mechanism manages to (at least somewhat) coherently inform our moral evaluations. Nevertheless, how effectively we act upon these evaluations also depends on how well we can control our impulses. Impulse control is the means through which we postpone momentary pleasure-seeking for long-term, objective benefits. In a significant way, impulse control affects whether we act on immediate threats or desires when they contradict our more nuanced understanding of the moral thing to do. A paper published by the International Journal of Law and Psychiatry identifies the prefrontal cortex, the part of our brain found just behind our foreheads, as the vital center for impulse control.[5] Evidence from multiple studies shows that people who have diminished gray matter in their prefrontal cortices behave more rashly, are more often violent and are more likely to have trouble with the law. Our ability to roughly correctly evaluate hypothetical moral situations is mostly independent from our ability to hold on to these considerations in the heat of the moment.

The Causation Effect

New and elegant neuroimaging technologies and the studies they have propelled have certainly contoured our understanding of how our brain thinks about and acts on right and wrong. Yet, the more we learn about these relationships, the more deeply they begin to problematize the idea of our moral responsibility. If our morally relevant actions are determined by our amygdalas and prefrontal cortices, then should we be held responsible for them? A meticulous way in which scientists have tried to study this question is through DBS, or deep brain stimulation.[6] Although DBS is not typically used to study moral behavior, it has been extremely useful in clarifying the brain-behavior relationship. The technique essentially involves a surgical transplantation of a pacemaker, which transmits electrical signals to local brain regions to stimulate activity. Given that neurons, the cells that make up our brains, communicate through electrical signals, the pacemaker can simulate this type of communication. DBS has seen some success in the treatment of depression, Parkinson's, aggressive behavior and addiction. Experiments with DBS demonstrate that, when electrical activity is altered (in this case through DBS), altered behavior follows. This evidence indicates that the brain-behavior rapport is possibly not only correlational, but also causal. An older study supporting that idea found that brain activity in regions correlated with a certain behavior preceded the conscious awareness of that behavior being initiated[7]. This means that the participants may not have exercised conscious control over their own actions. Although definitive proof of causation is still not available, these studies open up the possibility that free will may not, in fact, be as free as we would have thought.

The Question of Responsibility

Because of ethical considerations, causation experiments have not been performed specifically for moral decision-making and criminal behavior. However, if we extend the logic of DBS studies to our moral processing system, then it seems like there might not be much that we can do to control our moral behavior either. The neural determinism suggested by neuroscientific literature invites a discussion of whether freedom of choice is necessary for assigning moral blame. Two philosophical intuitions, compatibilism and incompatibilism, argue opposing sides of the issue. On the one hand, compatibilists maintain that even if our behaviors are primarily guided by the structures of our brain, the choices we make can still be called our own, because it is our brains that have initiated them.[8] Therefore, we should be held responsible for their consequences. On the other hand, incompatibilists argue that our choices must be made freely if we are to assign any sort of blame to them. Perhaps, the truth is a more nuanced version of both, and a sliding scale between what we consider insanity and health may be a better representation of it.

However, it is just as pressing to consider how neuroscience has already affected the practicalities of the justice system. Brain scans and images are increasingly finding their way to attorneys' briefs and judges' benches; they have been used to argue for juvenile criminal offenders (their prefrontal cortices and impulse control are underdeveloped) and for mentally ill patients, among others.[1] One of the most precise insights on the issue has been provided by the writers of the University of California, Santa Barbara paper. In discussing the implications of neurological determinism, they say:

"The biggest threat to our taking seriously the idea that many who commit bad, even criminal acts, are less free, less rational, less responsible, and less blameworthy than we have been thinking all along may be the following: if we take seriously that these individuals are impeded in nontrivial ways in their ability to make good choices and therefore don't deserve to be punished as harshly as they have been up until now, then what do we do with them? One answer is that we stop using the criminal justice system solely to levy punishment on wrongdoers and use it more to prevent subsequent harm from occurring."[1]

Even though it is an already existing concern in legal systems globally, this consideration may need to make its way into legal thought more quickly and more fundamentally than it has so far.

Takeaways

Although neuroscience is a vibrant and fertile field that requires much more work to be done, the implications of its findings already widely and deeply challenge our social relationships and structures. Realizing that we do not control our own actions as much as we often assume may be a little disheartening. Hopefully, however, in studying ourselves more closely, we can begin to more thoughtfully and more compassionately respond to others. Hopefully, neuroscience can inspire us to approach anyone from a substance-abusing neighbor to a lying friend not as a blameworthy criminal, but as a human in need of our help and care. Just as importantly, to begin adjusting our legal thought to the nuance of neuroscience may help our society deal with criminal behavior in a more effective and meaningful way.

Kristina Madjoska '19 is a sophomore in Lowell House concentrating in Neurobiology.

Works cited

[1] Funk, C. M.; Gazzaniga, M. S. Curr. Opin. Neurobiol. 2009, 19, 678-681.
[2] Borg, J. S. et al. J. Cogn. Neurosci. 2008, 20, 1529-1546.
[3] Immordino-Yang M. H. PNAS. 2009, 106, 8021-8026.
[4] Young, L. et al. PNAS. 2007, 104, 8235-8240.
[5] Penney, S. Int. J. Law Psychiatry 2012, 35, 99-103.
[6] Sharp, D.; Wasserman, D. Neuroethics 2016, 9, 173-185.
[7] Libet, B. et al. Brain 1983, 106, 623-642.
[8] McKenna, M.; Coates, D. J. Compatibilism. Stanford Encyclopedia of Philosophy. https://plato.stanford.edu/entries/compatibilism/ (accessed Feb. 19, 2017).

Image from Flickr

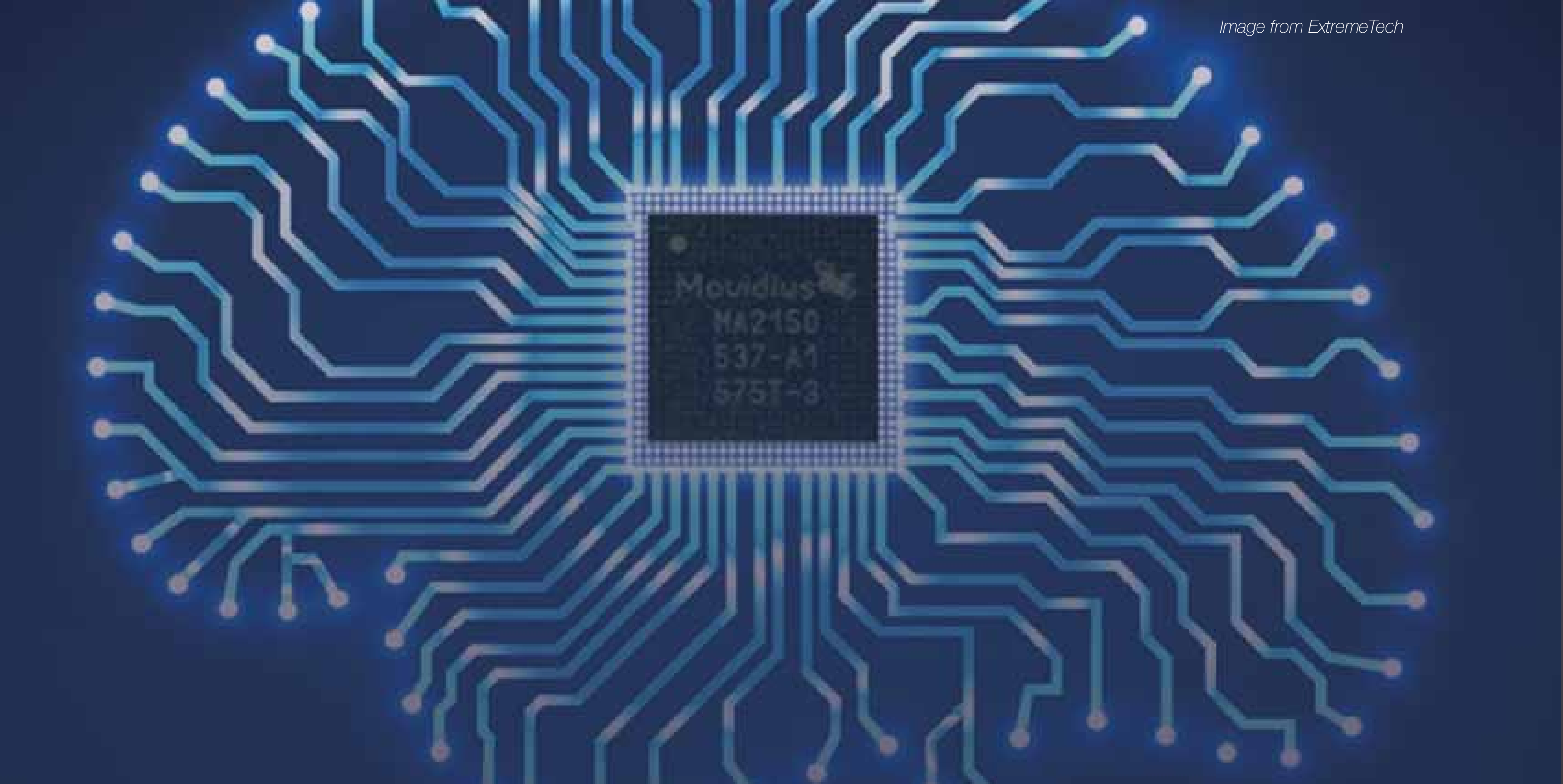


Image from ExtremeTech

Machine Learning:

The Future of Healthcare

BY PUNEET GUPTA

The U.S. healthcare system is a mess. Both the system's infrastructure, such as the role of insurance companies, and its clinical aspects, such as how care is provided, are lacking in multiple ways. Though improvements in the infrastructure are necessary, this article will primarily discuss and suggest changes to the clinical side of the healthcare system. A new movement to bring about change in private practices, hospitals, and other healthcare facilities revolves around one new innovative field of science and technology: machine learning (ML).

An Overview

Machine learning, in simple terms, focuses on developing algorithms and software based off of the machine's past experiences. A program capable of machine learning is able to perform a certain task or improve how it performs a task through previous runs and without any additional changes in the software. In the fewest terms, machine learning is the extraction of knowledge from data.

Machine learning is split into three primary categories: supervised learning, unsupervised learning, and reinforcement learning. In supervised learning, a ML model is given data that has been labeled with a certain outcome, and then learns the relationship between both (data and outcome) to make predictions regarding the outcome for future data. In unsupervised learning, a ML model is given data that has not been labeled with an outcome, so it is able to sort and separate the data into groups of its choice, unlike supervised learning, which has certain outcomes or groups that the data must fit into. In reinforced learning, the model attempts to figure out the most effective way of achieving the highest 'reward' through choosing different sets of actions. In other words, the system is rewarded when it achieves a certain outcome, and it tries to determine the best way of achieving the highest reward.[1] Overall, machine learning models attempt to adopt principles based on how humans innately learn and involves building systems that can 'think' and adapt themselves.

Machine Learning in Healthcare

In earlier decades, when walking into a healthcare setting, patients could see stacks of papers, piles of manila folders, and clutters of pens and pencils all over. Despite all the new advances in technology, at the turn of the millennium, offices and clinics are still filled with inefficient workspaces. In order to implement change, to transition into electronic health records, and to generally improve healthcare technology, the government issued the Health Information Technology for Economic and Clinical Health Act (HITECH) in 2009.[2] Though progress has been made in getting many healthcare systems to bring in new information technology (IT), there is still much room for innovation to be made to improve all aspects of patient care, including safety, patient experience, efficiency, and effectiveness. With the overall quality of care in the U.S. lacking in comparison to those of other countries, the demand for change has increased, with more people seeing machine learning as the solution. ML is currently being used in healthcare, but not to its full potential and capabilities, nor is it being applied to the extent that it is used in other industries, such as finance, where it has brought major positive changes and a variety of benefits.

ML's primary use in the near future will involve data analysis. With each patient comes large bulks of data including X-ray results, vaccinations, blood samples, vital signs, DNA sequences, current medications, other past medical history, and much more. However, we still are not able to efficiently obtain, analyze, and reach conclusions well. One of the major challenges is integrating the data obtained for each patient into one system, as that will allow for efficient communication between providers, allow for rapid data analysis, and give providers all the information they need to accurately treat their patients. However, much of the data today is encrypted and has restricted access due to the constant efforts to protect patient privacy, making this transition difficult, alongside the fact that many medical devices are not interoperable.[3] Once a single database can be established, the benefits of ML can be reaped.

One of the primary applications to healthcare for machine learning involves patient diagnosis and treatment. It is important not only in emergency medical situations, but also in general primary care and in specialized physicians as well. For example, ML can be used to predict mortality and length of life remaining using physiological patient vitals and other tools including blood test results, either in the immediate future, such as for a traumatic car accident, or in the long-run, such as for cancer.[3] Most significantly, ML models can be used to help physicians diagnose patients, especially in cases involving relatively rare diseases or when outcomes are hard to predict. For example, in a recent clinical study, several machine learning models were used to analyze data from electronic health records to predict heart failures, and the outcomes indicated that these ML systems predicted outcomes well.[4] Moreover, machine learning can be used to determine the most effective medication dosage, reducing healthcare costs for the patients and providers. ML can be used not only in determining dosage, but also in determining the best medication for the patient. Genetic variations among different races, ethnicities, and individual people in general impacts the effectiveness of certain drugs and people's response to these drugs, such as HIV medications [3]. Once more advanced ML algorithms and models are developed, they would be able to rapidly recognize these differences and reach accurate and reliable conclusions. Some technologies are being used currently for interpreting a variety of images, including those from magnetic resonance imaging (MRI), X-rays, and computed tomography (CT) scans.[5] However, more advanced ML algorithms that can effectively identify potential regions of concern on these images and then develop possible hypotheses are needed. Even in surgery, new machine learning models need to be developed for robotic surgeries to increase the probability of successful surgical outcomes, which can potentially eradicate the need for human surgeons.[6]

Many issues involving erroneous and imprecise data arise in data collection, as much data is simply wrong.[3] This is especially true in waveform data, where environmental factors and patient movement can affect the recorded signals. New and advanced algorithms need to be established that can distinguish real data from artificial and poor data, thereby improving the reliability of the data gathered and allowing the physician to make an accurate diagnosis. Even in very common electrocardiogram readings, many physicians reach different conclusions in regards to the patient's condition. Artificial data and data with poor signal quality play a major role in this analytical difference.[3] Many times, physicians are overwhelmed by the plethora of data collected, but ML algorithms that can identify and streamline the most pertinent data without leaving behind other crucial information need to be developed. Moreover, ML algorithms that can allow the AI to explain the reasoning behind its proposed diagnosis or treatment plan is necessary.

Challenges and Controversies

Adapting artificial intelligence (AI) and machine learning into all healthcare systems is unfortunately not easy. Health-care systems have been structured so that change is difficult. Much of the decision makers in healthcare systems and policies are elderly, who tend to have strong preferences for the typical 'pen and paper' and prefer simpler systems in which they have more control. ML systems are complex and need to be integrated into health care systems in the simplest yet most effective form. Moreover, many healthcare facilities are not motivated or incentivized enough to spend their budget in investing in adequate research, staff, and other support for developing these ML models. This adaptation of AI and ML is necessary not just in the United States health care system, but all across the world. However, as the U.S. is one of the leading places for innovation and development in this health information sector, the country needs to bring about a large-scale change in its system first, despite the difficulties in installing such a system, in order to start a ripple effect.

As with the rise of most new technologies, machine learning brings about a heated debate on ethics. When we train machines to 'think for themselves,' we have given up our control over them in that we don't know what the system learned or what it is thinking, thereby putting our lives in danger. Some believe that our advancements in machine learning will reach a point at which we no longer need human physicians, which would significantly hurt the economy, workforce, and patient experience in clinics. Many are afraid that when they come into a doctor's office, they will no longer have that physician-patient contact and connection, but instead must confront a machine. When building and training machine learning systems, access to large databases of patient information is needed, raising privacy concerns, for which there is still no accepted standard in regards to AI. Furthermore, advances in ML can lead to issues regarding insurance coverage. For example, some insurance companies may start demanding access to the AI that is tracking a patient's health records to see how their overall health is and determine premiums based off that. Moreover, it is possible that when future research studies show the success of ML and AI, hospitals and clinics might increase the fees associated with these services, leading to inequality based off income. How will we react if the AI gives us wrong treatment or diagnoses? What if a physician's diagnosis and an AI's diagnosis are different? It is important to consider all these challenges as we further develop and improve our machine learning systems.

Future of Machine Learning

Today, many major companies and startups, including Enlitic, MedAware, and Google, have launched massive projects focused on improving AI and ML and bringing it to the healthcare system, such as Google's DeepMind Health project and IBM's Avicenna software.[7] Moreover, IBM's Watson Health is collaborating with the Cleveland Clinic and Atrius Health in using cognitive computing in their health system, from which experts are hoping to see reduced physician burnout.[8] More recently, current ML algorithms being tested and developed include k-nearest neighbors, naive and semi-naive Bayes, lookahead feature construction, Backpropagation neural networks, and more.[9]

Artificial intelligence and machine learning are undoubtedly the future, as refined automation of data collection and replacement of jobs in all industries by machine learning systems is inevitable. Scientists and researchers must focus on developing effective, efficient, and innovative algorithms while ensuring that their functions and models do not endanger the human job market. Both Elon Musk and Stephen Hawkings foresee AI and ML not only dangerous economically, but also physically.[10] Nonetheless, it is imperative that we continue to work on transforming the quality of care and healthcare system as a whole through machine learning, a science and technology that is to revolutionize the world in all aspects of life for decades to come. The benefits of machine learning outweigh these theoretical nightmares.

Puneet Gupta '18 is a junior in Dudley House concentrating in Biology.

Works cited

[1] Introduction to Reinforcement Learning. http://www.cs.indiana.edu/~gasser/Salsa/rl.html (accessed Feb. 25, 2017).
[2] Rhodes, R. et al. Amer. J. of Hospice and Pall. Med. 2015, 33, 678-683.
[3] Johnson, A. E. W. et al. Proc. IEEE 2016, 104, 444-466.
[4] Wu, J. et al. Med. Care 2010, 48, S106-S113.
[5] Wang, S.; Summers, R. M. Medical Image Analysis. 2012, 16, 933–951.
[6] Nevett, J.; Waghorn, M. Robots 'set to replace human surgeons entirely for complex operations' potentially cutting risk of errors. Mirror, May 4, 2016. http://www.mirror.co.uk/news/world-news/robots-set-replace-human-surgeons-7897465 (accessed March 3, 2017).
[7] Simonite, T. IBM's Automated Radiologist Can Read Images and Medical Records. MIT Technology Review, Feb. 4, 2016. https://www.technologyreview.com/s/600706/ibms-automated-radiologist-can-read-images-and-medical-records/ (accessed Feb. 27, 2017).
[8] Slabodkin, G. Caradigm takes end-to-end enterprise approach to population health. Health Data Management, March 2, 2017. https://www.healthdatamanagement.com/news/caradigm-takes-end-to-end-enterprise-approach-to-population-health (accessed March 3, 2017).
[9] Kononenko, I. Artif. Intell. Med. 2001, 23, 89-109.
[10] Cellan-Jones, R. Stephen Hawking warns artificial intelligence could end mankind. BBC News, Dec. 2, 2014. http://www.bbc.com/news/technology-30290540 (accessed March 1, 2017).

Image from Pixabay

CLIMATE CHANGE

What Sweden's Doing that Trump Isn't

By Jia Jia Zhang

Imagine living in a greenhouse-gas emission and rubbish free environment. Hard to envision? Not for Sweden. The country's revolutionary recycling system works so efficiently that Sweden has been importing rubbish from other countries for several years to sustain its recycling plants.[1] Even better, as of February 2, 2017, the progressive nation plans to cut fossil fuel use every four years until it reaches its goal of eliminating greenhouse-gas emissions by 2045.[2] Any remaining emissions will be offset by forests that the government intends to plant.[2] This promising new law passed with a majority vote in the Swedish Parliament and takes effect in 2018.[2]

Meanwhile in America, moves to counter climate change have only been following a regressive trend. President Trump and his Environmental Protection Agency head Scott Pruitt continue to express skepticism towards the impact of human activity as a major factor in inducing climate change. In fact, any mentions of "climate change," Obama's Climate Action Plan, or climate negotiations with the United Nations were removed from the official White House website shortly after Trump's inauguration ceremony.[3] In addition, a media blackout was issued in January for the Environmental Protection Agency and the United States Department of Agriculture.[3] Trump is not only denying the reality of climate change, but suppressing the information from United States citizens.

Under the Obama administration, the Climate Action Plan and the 2015 Paris Agreement set the nation on a path towards reducing carbon pollution, increasing energy efficiency, and expanding upon renewable and other low-carbon energy sources.[4] However, Trump has taken several steps backwards, promising to not only reduce regulations for U.S. oil and gas drilling and coal mining industries, but also to back out of the 2015 Paris agreement to cut greenhouse gases—which was agreed upon by nearly 200 countries.[5]

Trump's disbelief in climate change does not change its pervasive existence. If you have been out and about recently and noticed the remarkably warm winter weather, you can thank climate change for that. Of 17 hottest years ever recorded, 16 have occurred since 2000.[6] Although the world's oceans are experiencing a small incremental increase in temperature, this seemingly insignificant shift causes a string of deleterious consequences. The coral reefs are particularly sensitive to temperature change; consequently, millions of polyp-colonies are dying. Huge populations of fish rely on coral reefs for survival, so in accordance with the food chain, a dissipating coral reef population leads to a dissipating seafood population. In coming decades, people will need to start preparing for an increase of 20 or more hurricanes each year and mega-droughts that will last for up to 10 years.[7] Food prices will inevitably rise and living conditions will dramatically fall.

To prevent a slew of natural disasters from occurring, we as humans, as instigators of climate change, need to mitigate the damage we have done and stop ourselves from further exacerbating the situation, just as Sweden is attempting to do. Putting environmental policies at the forefront of politics does not discount other prominent issues, rather it prevents an increasingly threatening issue from eclipsing all others.

Jia Jia Zhang '20 is a freshman in Pennypacker concentrating in Human Developmental and Regenerative Biology.

Works Cited

[1] Sheffield, H. Sweden's recycling is so revolutionary, the country has run out of rubbish. http://www.independent.co.uk/environment/sweden-s-recycling-is-so-revolutionary-the-country-has-run-out-of-rubbish-a7462976.html (accessed Feb. 20, 2017).
[2] Doyle, A. Sweden sets goal to phase out greenhouse gas emissions by 2045. http://www.reuters.com/article/climatechange-sweden-idUSL5N1FN6F2 (accessed Feb. 20, 2017).
[3] Abbott, E. Donald Trump Signing Executive Order Declaring Climate Change A Threat Is Fake News. http://www.business2community.com/government-politics/donald-trump-signing-executive-order-declaring-climate-change-threat-fake-news-01769494#d4zAX5rkBaaPmBq3.97 (accessed Feb. 20, 2017).
[4] Center for Climate and Energy Solutions. President Obama's Climate Action Plan. https://www.c2es.org/federal/obama-climate-plan-resources (accessed Feb. 20, 2017).
[5] Fortune. President Trump Prepares to Withdraw from Groundbreaking Climate Change Agreement, Transition Official Says. http://fortune.com/2017/01/30/donald-trump-paris-agreement-climate-change-withdraw/ (accessed Feb. 20, 2017).
[6] Patel, J. How 2016 Became Earth's Hottest Year on Record. https://www.nytimes.com/interactive/2017/01/18/science/earth/2016-hottest-year-on-record.html?_r=0 (accessed Feb. 20, 2017)
[7] CNN. 11 Ways Climate Change Affects the World. http://www.cnn.com/2014/09/24/world/gallery/climate-change-impact/ (accessed Feb. 20, 2017).

WHAT TO DO WITH VIRTUAL REALITY

BY JEONGMIN LEE

Innovators have gone out of their way to open up a new dimension we all can experience as virtual reality; however, one of the greatest questions regarding this technology can be summed in two words: what now? Virtual reality utilizes computer technology to immerse a user into a simulated world. It takes the user "out of the physical reality to virtually change time, place and (or) the type of interaction."[1] While this may sound like science fiction, virtual reality devices immerse players simply through goggles covering one's eyes to display the simulated world, and in some models, users have hand-held devices they can use to interact with other objects in that virtual reality. Now that this technology exists, people from multiple fields of expertise are coming together to figure out how virtual reality can be useful.

Simulations and games through virtual reality can serve not only as time-wasting entertainment but also as art, stories, and education. Drawing programs and basic entertainment games have been released with some of the earliest virtual reality headsets. Some entertainment systems try to increase physical activity through a virtual tennis match, while others take advantage of the technology's ability to immerse the player. With virtual reality, other detailed simulations have been made by HumanSim to train surgeons and dentists on virtual patients.[2] Doctors can practice with the virtual world to hone their skills without harming physical patients. In addition to medical education, general education is also looking to bring virtual reality into their classrooms.

Some professors are considering integrating virtual reality into their lectures. As virtual reality is known for its powerful immersion, educators consider this technology an opportunity to better engage students with the course material. The newest technologies have been often used in classrooms, but their usage was not always necessitated.[3] For example, once the touch-screen tablet was made, uses of the tablets in class were limited due to the fact that writing down or selecting answers of an activity can be easily done on a regular computer or even pencil and paper. Some classrooms even implemented smart screen white boards, but again, a regular whiteboard could accomplish the same tasks.[4] The newer technology did not seem to bring significant benefits compared to past inventions. However, virtual reality may prove to be different.

As virtual reality allows one to generate another world that follows a different set of physical laws, the technology can directly show students what a world with less gravity would look like or help them visualize how large dinosaurs are imagined to be by allowing the users to fly around the model while they are still in their seats. Dr. Der Manuelian, Director of the Harvard Semitic Museum, employs virtual reality to recreate the past of Egyptian pyramids in the classroom.[5] Through the immersion, one can experience the different chambers of the pyramids and look around to see not only the color and artifacts that might have existed in that time period but also how large the tombs were and how narrow the hallways leading to the tombs were. This same experience cannot be replicated by a mere video as one must use considerable spatial thinking to imagine the proportions when looking at a stationary screen, but through virtual reality, students can experience what they are learning.

Virtual reality has a lot of potential in its future. Virtual reality can instantly engage players more effectively than many other media by capitalizing on the players' sight. This immersion, when mastered, can paint experiences and tales more clearly than ever before. Additionally, the technology can have selective use in classrooms where virtual reality labs can be used to aid those who learn best spatially. However, surrounding any user can help them visualize certain scenarios and possibly allow the user to make some theoretical mistakes without harming anyone physically such as surgeons who can practice and make mistakes before operating on a real patient. Virtual reality offers strong involvement of the user into a different world more easily than any other medium has. Through artists, technicians, professors, students, and the general consumer, virtual reality has many uses and can fill many roles in the near future.

Jeongmin Lee '19 is a sophomore in Lowell House concentrating in Chemistry.

WORKS CITED

[1] Fuchs, P., et al. Virtual Reality: Concepts and Technologies; CRC Press: Boca Raton, FL, 2011; pp. 3-7.

[2] Virtual Reality Society. https://www.vrs.org.uk (accessed Feb. 4, 2017).

[3] Minshew, L.; Anderson, J. CITE Journal 2015, 15, 334-367.

[4] Brodkey, J. Larry Cuban on School Reform and Classroom Practice. https://larrycuban.wordpress.com/2010/03/20/we-dont-need-smart-boards-we-need-smart-people-jerry-brodkey/ (accessed Mar. 31, 2017).

[5] Rajan, G. S. Giza 3D: Harvard's Journey to Ancient Egypt. YouTube [Online], Oct. 2, 2016, http://www.youtube.com/channel/UCASIa29X_S1YdFyeRHijW1A (accessed Feb. 4, 2017).

A warm 'Thank You!' to our sponsors:

lifesciences undergraduate education

THE COOP HARVARD/M.I.T.

HARVARD UC UNDERGRADUATE COUNCIL

HARVARD School of Engineering and Applied Sciences