ISSUE 41 Fall 2019

NU SCI

ROOTS

TABLE OF CONTENTS

LETTER FROM THE EDITOR

"There is no such thing as a new idea. It is impossible. We simply take a lot of old ideas and put them into a sort of mental kaleidoscope. We give them a turn and they make new and curious combinations. We keep on turning and making new combinations indefinitely; but they are the same old pieces of colored glass that have been in use through all the ages."

-Mark Twain, a Biography, 1910

Every idea you can think of, no matter how original you may believe it is, can be traced back to a previous idea, an inspiration, that can be traced back to another, and another, and on and on. The same goes for science. New fields are simply more specialized versions of old fields, and novel theories are truly nuanced versions of the archaic. Atomic theory isn't a modern discovery; it's been evolving since the days of the ancient Greeks in the fifth century B.C.E. And doubtless it hasn't finished transfiguring yet.

This was our thinking behind NU Sci's 41st issue: Roots. We challenged our writers to tell the origin stories of the ideas, endeavors, and cultural phenomena that interest them most. And once again they've astounded us with what they've produced. Read about the history of vaccines and climate change, the inspiration behind the human genome project, even such topical subjects as the genesis of meme culture; and, of course, the occasional article about actual tree roots.

And be sure to also check out our website, nuscimag.com, to read even more content from Issue 41 in our Online Exclusive section.

Lastly, I want to specifically highlight the work of our photography and design teams—who have put together four spreads of original work this issue and have imbued each page with their creativity and talent.

A special thank you to everyone who has been involved in the chronicling of these stories. I'm incredibly proud of our writers, some of whom we've seen grow considerably in ability and experience over the years, others who have been brave and are being published for the very first time. This year being our tenth anniversary of publication, we hope you enjoy our largest-ever issue and all the creative liberties we've taken with it.

Lucas Principe
Editor-in-Chief

STAFF

Cover Design by Lillie Hoffart

OPINION:

GROUNDED IN FICTION

THE CASE AGAINST ASTROLOGY

BY LUCAS PRINCIPE, PHILOSOPHY AND ENVIRONMENTAL SCIENCE, 2019
DESIGN BY KATIE GREEN, BIOENGINEERING, 2022

Astrology is certainly experiencing a renaissance in American popular culture—especially online. Ask a millennial or a Gen Z'er, the denizens of internet culture, and I bet you they'd more likely than not be able to tell you their zodiac sign. This phenomenon is by no means a new one: astrological belief in some form can be traced back since before Common Era. Today, however, the main thread being popularized entails the provision of horoscopes, predictions, and life advice based off of the astronomical minutiae surrounding the precise date and time a person was born. It is this type of data, astrologers claim, that allows them to predict a person's future, explain his personality traits, and help him to realize his full potential. Astrology.com even claims to be able to tell someone if "you and your love interest are meant to be," based on birth signs alone.

It's easy to laugh at that kind of nonsense from a position of skepticism. Because, of course, it's 2019—who could believe that this type of information could actually be predicted by the positions of the celestial bodies at birth? But you'd be surprised: according to Pew Research Center, over 29 percent of Americans did express a belief in astrology in 2017.

There is no shortage of empirical research that leaves astrology floundering; some of the most famous studies on the topic include Carlson, 1985, Dean and Kelly, 2003, and Forer, 1949. However, one study in particular does a wonderfully simple job at deflating the practice. A 1990 study conducted out of Indiana University Bloomington asked six "expert" astrologers to correctly identify the birth chart for 23 individuals after being provided with each subject's life history, photograph, and score on various personality tests. The result, unsurprisingly, was that the astrologers did no better than chance or than non-astrologer control subjects at matching birth charts to personal data. Even more damningly, the astrologers generally failed to agree with one another's predictions.

These types of tests demonstrate that astrology isn't a science at all. And nor is it a silly, innocent belief system either. It's an industry: one, when combined with other psychic services, that is valued by market research firm IBISWorld at over two billion dollars annually. Furthermore, as any industry, its goal is to make money—which, in the astrologer's case, can come from birth chart analyses, personalized horoscopes, tarot readings, compatibility forecasts, and an abundance of other services grounded by nothing other than fiction.

All these services do, in reality, is provide scientifically-inaccurate information to people seeking insight into their natures and futures. Even worse, the industry seems to relish the vulnerability of others. There is no shortage of astrological advice for people in despair. A simple Google search of wretched problems paired with the word "astrology," such as: "my ex left me astrology," "why am I so depressed astrology," "why does nobody love me astrology," or "how to pay my bills astrology," yields endless diagnoses about how your sign has gotten you into such a situation, and how your sign can get you out of it.

I will concede that not all astrology "believers" completely adhere to the faith. I have often heard, in conversation or in eavesdropping, a dubious claim along the lines of, "I don't really believe in astrology. It's just fun to read my

horoscope and compare with my friends," which is usually followed by, "Why do you care if it's not hurting anyone?" I sincerely do not doubt you if you express this sentiment too. Though, I might ask, would you also see nothing wrong with pretending to believe ideas like blood-letting, alchemy, anti-vaccination, and flat Earth?

Unfortunately, if you, as much as you may truly not believe in astrology, are simply partaking in its cultural moment because it's "fun," what you're really doing is providing validation to countless charlatans throughout the world who make their money off of spreading false hope, false dread, and complete misinformation. These people may be giving vague, uncouth answers to individuals with little money who are desperate for a solution to their grim real world problems.

There have been enough con artists throughout history. Astrologists, in one way or another, just seem to be America's new televangelists. There may always be these types in the world—those who promise fantastical information that neither dull everyday life nor rigid science could ever supply. My advice to you is simple: you have no rational reason to listen to a word they say.

Journal of Scientific Exploration (1990), "A Scientific Inquiry into the Validity of Astrology"

We asked a local astrologer, who explained "much of the basis of astrology comes from the idea that the positioning of the moon and planets affects a person's mood. Though every person has their unique moon sign determined by when exactly they were born, everyone is still affected by the moon's cyclical effects."

PHOTOS BY MUHAMMED ELARBI, COMPUTER ENGINEERING, 2022

TRENDING IN TEXTILES

BY TORI MARKIN, BUSINESS ADMINISTRATION, 2021
DESIGN BY HEATHER WELCH, ENVIRONMENTAL SCIENCE, 2020

When you are looking to buy a new shirt, you may be looking for style and affordability. Though, how often do you consider the actual textiles used to produce that shirt?

With 16 million tons of textile waste in 2015 alone, consumers need to take a hard look at what companies use to manufacture their clothing. Beyond thrifting and second-hand buying, ensuring that new clothing is produced responsibly needs to be a major focus for both companies and consumers.

Currently, cotton and polyester are the most commonly used textiles, but both have their own negative implications. Cotton production is incredibly water intensive, and accounts for 16 percent of worldwide pesticide use. In addition to large bodies of water, these pesticides also pollute the minimal resources in regions with water scarcity. Polyester is also incredibly problematic, given that washing polyester textile releases thousands of plastic microfibers into the environment, which pollute ecosystems and taint natural food chains. Polyester also has a drastic carbon footprint, and produced 706 billion kilograms of carbon dioxide in 2015 alone.

What are the other options? Clothing companies continue to delve into the world of sustainable textiles to curtail their environmental impact, and attract the attention of the increasingly conscious consumer market.

Cellulose-based fibers have the potential to transform the garment industry. The textile industry regards Tencel, also known as Lyocell, as the environmentally friendly textile of the century. Tencel has similar qualities to cotton, such as high levels of durability and moisture absorption. If anything, Tencel wrinkles less and many people consider it to be softer than cotton.

Tencel, made from wood cellulose, is naturally biodegradable. The production of Tencel has no harmful emissions, and the chemicals used in its production are also biodegradable and recyclable. The eucalyptus trees used for Lyocell pulp require no chemicals nor irrigation, making Lyocell significantly more sustainable than polyester and cotton.

Producing Tencel is currently more expensive than producing cotton or polyester, which hinders the market growth of Tencel. However, garment companies often respond to consumer demands. Next time you go shopping, take a moment to look at the tag, and consider what is used to make your clothes.

Engineering and Technology Research (2017). DOI: 10.12783/dtetr/apetc2017/11079

PHOTO BY PEXELS

What prescriptions are in your garden?

BY HEATHER WELCH, ENVIRONMENTAL SCIENCE, 2020

When I was very young and complained to my mother about a sore throat, she would give me tiny white pebbles that looked vaguely like Dippin' Dots and tasted like weird sugar. Their primary ingredient was echinacea, a purple flower that has long been used as an immune stimulant. Echinacea, and hundreds of other plants, function as a treatment for many ailments. These plants can be processed and applied in many different forms: whole herbs, essential oils, ointments, tinctures, tablets, and more. This system of herbal medicine, which is one facet of the broad spectrum of traditional medicine, may be mysterious to a young child, but it has been a significant part of culture and medicinal history since ancient civilizations populated the Earth.

Experts speculate that the use of herbal medicine began in prehistoric times when humans ate whatever plants they could find and ended up expressing physiological reactions based on whether the plants were toxic or beneficial. From that point on, the knowledge of herbal medicine expanded and blossomed into several systems of traditional medicine including Ayurveda, Kampo, Unani, and traditional Chinese medicine. Most of these systems emphasize the holistic evaluation of a person with respect to body and spirit (or energy), rather than treating a symptom.

Although herbal medicine began as an ancient practice, it extends into modern times. Until the 20th century, when a doctor trained in modern medicine overthrew the last Qing emperor, traditional Chinese medicine remained the primary method of healthcare in China. Modern health practices are now prominent in China, but traditional medicine remains a large part of the Chinese healthcare system. The same can be said for other countries and cultures. Even in America, disillusioned consumers turn to traditional medicine, including herbs and acupuncture. Scientists and researchers use the opportunity in this new 'golden age' of traditional medicine to analyze the scientific basis of the remedies used, as well as to discover new uses for plants in modern medicine. In fact, scientists estimate that plants are the basis for 25 percent of drugs prescribed around the world.

Not all of these plants are readily available to the general population; however, a fair few of the herbs and plants used in traditional medicine may be found in the average person's backyard or kitchen. The next time you are having stomach pains, you could try drinking some boiled yam water as an alternative to Pepto-Bismol™.

Molecules (2016). DOI: 10.3390/molecules21050559
The American Journal of Cardiology (2008). DOI: 10.1016/j.amjcard.2008.02.007
Fitoterapia (2010). DOI: 10.1016/j.fitote.2010.02.001

PHOTOS BY ADOBESTOCK

The Roots of MeME cULtuRE

BY SANJANA MISHRA, COMPUTER SCIENCE, 2023

DESIGN BY ANANYA DHANDAPANI, UNDECIDED, 2023

Many of us have experienced scrolling through social media, pausing on a meme, smirking, double tapping, then carrying on. Memes have become ubiquitous on almost every social media site, fueled by globalization, the information age, and access to thousands of images at our fingertips. But where did "the meme" begin? How did we get here, laughing at screen grabs of Spongebob or sharing videos of Blinking Man?

In the past five years, meme accounts have become the fastest growing accounts on Instagram, proving that the power of the meme is unparalleled in today's day and age, when information exchange is rapid and omnipresent. Memes have further evolved to take on more controversial issues through the use of multimedia and "humor," turning pictures into mediums for hateful ideologies and political propaganda. The iconic Pepe the Frog meme was denounced as a hate symbol by the Anti-Defamation League for this reason after being adopted by the alt-right movement as a kind of ideological mascot. In terms of political propaganda, memes regarding political leaders, like Donald Trump, have become a normal part of the memescape.

> "A prominent result of the information age we've all grown up in, meme culture is here to stay."

Memes have become so pervasive in our culture that researchers now engage in memetics, the study of memes. Essentially, memetics is the study of going viral—researchers study how "little bits of culture spread among us," according to a 2018 paper from the Internet Measurement Conference. In "On the Origins of Memes by Means of Fringe Web Communities," researchers from all over the world studied memes in different "fringe communities," such as 4chan, Reddit and Gab. They aimed to "detect and measure the propagation of memes across multiple Web communities, using a processing pipeline based on perceptual hashing and clustering techniques." Using 160 million images taken from 2.6 billion posts on Twitter, Reddit, 4chan's Politically Incorrect board (/pol/), and Gab over 13 months, the researchers attempted to recognize patterns across the different communities. They found that communities within the fringe communities were using memes to spread "hateful and racist content." These same fringe communities were considered to be "influential actors in the meme ecosystem."

Although memes are now used as vehicles of hate at times, the meme begins its story with a smile. On Sept. 19, 1982, American computer scientist Scott E. Falhman used a " :-) " text-based emoticon in a Carnegie Mellon blog, and the rest is history. Widely considered the first recorded instance of a meme, the smiley face revolutionized online communication, and became part of a family of emoticons.

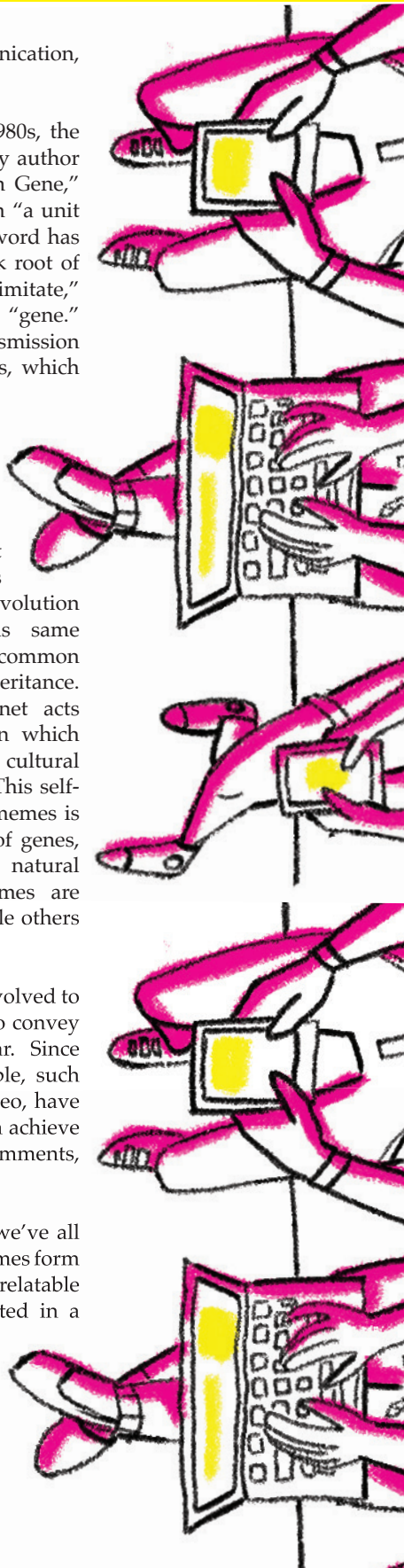
While the first meme was created in the 1980s, the term "meme" was coined a decade before by author Richard Dawkins. In his book, "The Selfish Gene," Dawkins created the word "meme" to mean "a unit of cultural transmission or imitation." The word has its roots in evolutionary biology—the Greek root of the word is "mimema," which means "to imitate," and was supposedly made to rhyme with "gene." Genes are biological units that aid in the transmission of hereditary information, similar to memes, which transfer cultural information.

Human culture is based on tradition and inheritance. However, modifications and evolution also play a crucial role in our cultural phenomenon. If traditions were unchanging, many of them would die out due to lack of adaptation—much like humans if the laws of evolution didn't exist. In this same way, memes rely on common conventions and inheritance. Essentially, the internet acts as an environment in which individuals can select cultural elements to pass on. This self-replication aspect of memes is just like the concept of genes, and the environment they exist in allows natural selection to be performed—the best memes are forwarded on to the meme hall of fame while others fall by the wayside.

True to its biological origins, the meme has evolved to include images, text and captions in order to convey meaning, employing multimodal grammar. Since then, pets, such as Grumpy Cat, and people, such as the kids in the Charlie Bit My Finger video, have become infamous. Now, ordinary people can achieve fame on social media through funny comments, videos or multimedia creations.

A prominent result of the information age we've all grown up in, meme culture is here to stay. Memes form an international common ground, where relatable experiences and funny stories are distributed in a humorous way. This online creativity is now fostered by millions of people around the globe, and the best part about memes is that everyone is in on the inside joke.

Proceedings of the Internet Measurement Conference (2018). DOI: 10.1145/3278532.3278550



BREAK A MIRROR?

Psychology says not to worry

BY MAYA KRAUSE, ENVIRONMENTAL SCIENCE, 2022
DESIGN BY KATIE GREEN, BIOENGINEERING, 2022

Any Boston Red Sox fan will tell you about the superstition that led the baseball team to fail to win the World Series championship for 86 years. According to "the Curse of the Bambino," the action of the Red Sox selling future superstar Babe Ruth (also known as the Bambino) to the Yankees in 1919 was the source of repeated seasons of losses for Boston and, more importantly, no championship. While this curse was broken in 2004 with the team winning the World Series, many superstitions around sports teams persist, as well as superstitions around animals, mirrors, salt, numbers, dates, and more. Where did these superstitions come from, and why are humans prone to believing them?

There is evidence of superstitions having roots as early as 5,000 years ago in Ancient Egypt. Egyptians believed that the shape of a triangle was sacred, which is why they buried their royalty in pyramids. When a ladder leans against a wall, it creates a triangular shape, and to walk through that shape would break the sacred power—hence where the superstition of walking under a ladder bringing bad luck is derived from. Another common superstition, the idea that a broken mirror will bring seven years of bad luck, originated in Ancient Rome. Its roots began with the Greek foretelling strategy of catoptromancy, where a person would look into a mirror or bowl of water to reveal their soul. If the reflection was broken, it symbolized that the person's soul was damaged. The Romans took this symbol a step further, combining the superstition with their belief that a person's health changes in seven year cycles.

But why do we believe in these superstitions? In 2011, psychologist Daniel Kahneman wrote in his book *Thinking Fast and Slow* about the theory that humans have two "systems" in which their minds think. The first, System 1, is the "Thinking Fast" system—it represents our initial reactions to the world. This is where superstitions start. System 1 tries to come up with the simplest explanations for what is going on, and often that explanation is not the most logical one. Initially, it may make more sense that the reason for the lack of success of a baseball team is a decades-long curse, and not more complicated factors such as poor management or player injuries. System 1 is also prone to confirmation bias, so initially a person is more likely to think about the times that the superstitious behavior worked, and not the times that it didn't.

System 2 is the slower, more logical part of the brain—the part that counteracts superstitious thought with facts. However, Jane Risen, a psychologist at the University of Chicago, wrote in *Psychological Review* in 2015 that people will often recognize that their superstitious behavior is illogical but continue to perform the behavior anyway. Risen argues that humans do this because, most of the time, the cost of not completing the action, and being wrong, is far greater than the cost of completing the action. That is, the risk of walking under the ladder and having bad luck for the rest of the day is worse than the few extra seconds it takes to walk around the ladder.

Don Saucier, associate professor of psychology at Kansas State University, has another theory as to why people believe in superstitions. He says people perform these actions in an attempt to restore control to situations that may feel out of control. By performing ritualistic behaviors, such as wearing a pair of lucky socks for an important event, a person can alleviate some anxiety or simply feel a little better about the future. Saucier also explains that if a ritualistic behavior is repeatedly shown to not be connected to the occurrence of an event, then that superstition can disappear.

So no need to avoid stepping on cracks, walking under ladders, or opening an umbrella indoors—science says the correlation with bad luck is all in your head.

PHOTO BY MAXPIXEL.NET

Psychological Review (2015). DOI: 10.1037/rev0000017
Thinking Fast and Slow (2011): ISBN 978-0374275631.

On the basis of race

BY SYEDA HASAN, BEHAVIORAL NEUROSCIENCE, 2020

In 1995, the first human genome was sequenced by chief private scientist Craig Venter and his colleagues at the Human Genome Project. Five years later, after having analyzed the genomes of people of five different ethnicities, Venter was definite that race has no genetic or scientific backing. Since then, the science behind gene expression has been questioned. What has been found is that all humans have almost an identical set of genes within their genomes, but the extent to which a gene is expressed may vary.

We also now know that gene expression can increase or decrease as a result of environmental changes. Studies have indicated at least three biological pathways that may play a role in the regulation of gene expression—the neuroendocrine system, the disruption of transcriptional capabilities, and via microbial symbionts. Evidently, none of these factors are "race".

However, despite scientific principle, many individuals still believe that race is biological. So where does this notion come from? The idea that there are five distinct "races" (Caucasians, Mongolians, Africans, Malayans, and Americans) is one that has been pushed and probed since the 18th century.

These "human varieties" were proposed by a renowned German physician and anthropologist, Johann Friederich Blumenbach. Blumenbach thought the shape of the skull and other physical differences were hugely impacted by environmental and cultural factors. His biases became evident when he and fellow naturalist Georges-Louis Leclerc, Comte de Buffon, upheld the "degeneration theory". This was the notion that all races had a single origin, and environmental factors, like food and sun exposure, brought about other races. Since this "degeneration" could be reversed, Buffon and Blumenbach believed that humans of any race could revert "to the Original Caucasian"—in reference to their belief that Adam and Eve were white.

Evidently, the hypotheses of race have deeply problematic roots. The theorists who propelled the assumption that one race is biologically inferior to another also paired with these assumptions their social and religious predispositions. Importantly, the turn of the 18th century marked the point in history when Americans began searching for human classifications to justify the trans-Atlantic slave trade. American anthropologists Audrey Smedley and Brian Smedley note, "in an era when the dominant political philosophy was equality, civil rights, democracy, justice, and freedom for all human beings, the only way Christians could justify slavery was to demote Africans to nonhuman status." The works of Blumenbach and others like him were the perfect vehicles for this kind of justification.

Today, the human genome has been studied thoroughly enough to conclude that as our ancestors migrated, some random mutations proved to be beneficial and were passed on. The further apart humans migrated, the more distinct these mutations appeared. Still, geneticists have found that there is more diversity (both phenotypic and genotypic) within the continent of Africa than there is on all the other continents combined. There are no fixed traits for specific geographic locations and every notion that we have historically upheld concerning race can only continue to move further from the truth as humans globalize.

Considering all of this, the way race and racialism have been weaponized seems like a harsh reality. Many of the racist ideologies of the 18th century still persevere. When asked about the outcomes of racialism, Dr. Richard Wamai, Associate Professor of Cultures, Societies and Global Studies at Northeastern University, says, "Recently—in 2016—a study… showed that there is a large belief among white physicians—whether they are in medical school, whether they are practicing physicians—that black people don't feel pain, or feel less pain as it were. Because of that, the type of prescription practices that are perpetuated then mirror that belief. Where does that belief come from? That belief comes from history…But you wonder, these are highly educated people who've studied anatomy, biology…How would they not know?"

> "Still, geneticists have found that there is more diversity (both phenotypic and genotypic) within the continent of Africa than there is on all the other continents combined."

The study that Wamai was referring to clearly states that, to this day, many professionals in the field of healthcare, research, and medicine hold false beliefs about biological differences between black and white people which continue to shape the way we perceive and treat people of different races and, in turn, influence health disparities. So race is not a branch of biology, yet the residual impact of scientific racism can still be felt. Perhaps if the scientists of tomorrow have a better idea of what race truly is, we can uproot the ways in which it bleeds into scientific development.

Journal of Biosciences (2005). DOI: 10.1007/bf02705151
Discourse and Society (2004). DOI: 10.1177/
BMJ (2007). DOI: 10.1136/bmj.39413.463958.80
The American Psychologist (2005). DOI: 10.1037/0003-066X.60.1.16
PNAS (2016). DOI: 10.1073/pnas.1516047113

DESIGN BY ESHA AGGARWAL, COMPUTER SCIENCE, 2022
PHOTOS BY PIXABAY

Engulfing cells

The origin of multicellular life

BY RYAN BRADY, CHEMICAL ENGINEERING & BIOCHEMISTRY, 2022
DESIGN BY LILLIE HOFFART, ENVIRONMENTAL SCIENCE, 2022

Humans represent the pinnacle of organized life, with trillions of cells working together to enable complex thought and interaction with the environment. Both of these processes require a great deal of organization and energy production. On a cellular level these attributes can be traced back to the same change which led to the evolution of all multicellular life on Earth. This change was the evolution of simple prokaryotic cells into complex eukaryotic cells. Prokaryotic cells are generally just a single membrane with DNA (lacking a nuclear membrane) and proteins inside, whereas eukaryotes have internal organelles and DNA contained within a nucleus. Although this change occurred almost 2 billion years ago, most scientists agree that the change was caused by the infolding of membranes and the mutualistic engulfment of smaller cells to form organelles. This theory has since been named the endosymbiotic theory.

The earliest life on Earth fell into two categories: archaea and bacteria—two types of single-celled life. A series of changes occurred that led to the advent of multicellular life. One of the first changes was the adaptation of phagocytosis, which is the ability to engulf and consume other cells for nutrients. The ability to consume other cells placed foreign matter into the intracellular space allowing for the rapid accumulation of nutrients. The competitive advantage this provided allowed for its proliferation and provided an avenue for which endosymbiosis could occur.

> "The word endosymbiosis literally means a symbiotic relationship with one organism living inside of another."

The word endosymbiosis literally means a symbiotic relationship with one organism living inside of another. Because of the prevalence of phagocytosis in early cellular life, it became common for organisms to find themselves inside of each other. Two theories exist that detail the possible order of events that early cellular evolution occurred. The first states that the intake of prokaryotic cells, which eventually became the mitochondria, served as the keystone event that propagated the immense reorganization of cells' inner structures and led to the development of eukaryotic cells. The concept is that the cell's ability to produce energy through a more efficient process led to the development of secondary organelles from internal membranes such as the nucleus and the Golgi bodies—eventually resulting in the eukaryotic cell structure that exists today. The alternative theory is that the development of early eukaryotic cells occurred alongside the symbiotic intake of prokaryotic cells for usage as mitochondria. The key distinction between these two theories is that the first theory posits that the development of mitochondria was the keystone evolutionary event which led to the development of eukaryotic life. On the other hand, the second points to a variety of contributing developments happening simultaneously, such as the development of the nuclear envelope and the formation of chromosomes. Because of how long ago these changes occurred, it is impossible to deduce the exact order of events that led to the formation of eukaryotic life. However, significant evidence supporting the existence of an endosymbiotic event has been uncovered.

The evidence that supports the endosymbiotic theory is mainly derived from the biochemistry of modern mitochondria. The smoking gun that led to the postulation of the theory is the presence of a discrete set of DNA located in mitochondria. This set of DNA contains 27 unique protein-coding genes that are not found in the nuclear DNA and code for proteins that are only expressed in the mitochondria. The organism with the most similar DNA to the mitochondria is a genus of bacteria called Rickettsia, which are a group of parasitic bacteria. Their genomes are significantly larger than that of the mitochondria. This relative size difference has been characterized by genetic reduction the mitochondria underwent because of their integration into eukaryotic cells. Another piece of evidence is the conservation of the ATP synthesis process between many prokaryotes (such as members of Rickettsia) and the methods of production used within the mitochondria.

While mitochondria were the first organelles that evolved through endosymbiosis, they are most likely not alone. It is generally accepted that chloroplasts developed in a similar manner. Genomic similarity between chloroplasts and cyanobacteria (photosynthetic prokaryotes) provide strong evidence for a relationship between these organisms. Further, some scientists point out that the high energy cost of the creation of the endomembrane system points to an extracellular origin for this structure.

Overall, the endosymbiotic theory provides evidence of the early evolutionary events that led to the development of complex life. The ability to effectively produce energy by this special type of cellular specialization paved the way for the evolutionary proliferation that led to the variation of life seen today.

Journal of Theoretical Biology (2017), DOI: 10.1016/j.jtbi.2017.08.001
Annual Reviews (2013), DOI: 10.1146/annurev-ecolsys-110411-160320

THE DIRT ON DIRT: INVESTIGATING SOIL'S SCENT

BY SAGE KUMAR, BIOLOGY, 2023

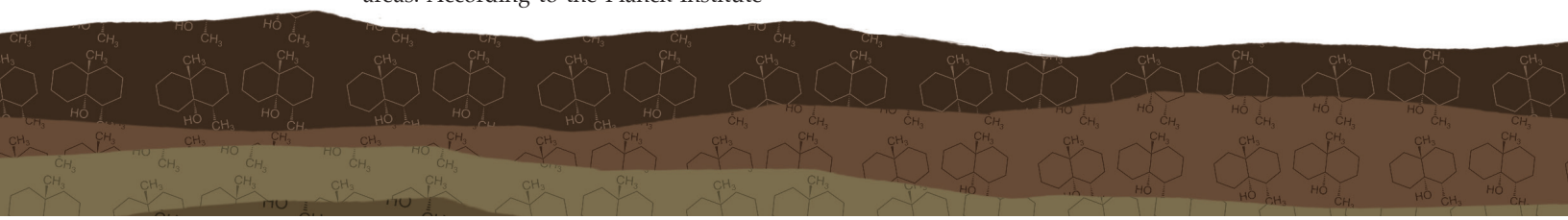
DESIGN BY MARISSA KEESEY, ELECTRICAL ENGINEERING, 2022

Dirt. Soil. Earth. It goes by many names and often unnoticed. Lying silently, it constantly absorbs the blows of our daily routines. Despite its understated nature, dirt wields one distinct attribute that refuses to be ignored: its smell. Geosmin, an organic compound derived from farnesyl diphosphate (FPP, 2) by an enzyme that is encoded by the SCO6073 gene in the soil organism Streptomyces coelicolor is responsible for the unmistakable pre- and post-precipitation scent known as "petrichor". Humans are undeniably sensitive to this scent, but why? Why are we able to detect this one compound at a level of five parts per trillion, putting us 200,000 times more sensitive to geosmin than sharks are to the scent of blood?

According to a series of studies conducted by faculty at the Max Planck Institute for Chemical Ecology in Jena, Germany, the answer lies within the common fruit fly, Drosophila melanogaster. One neuron type in the fly, labeled ab4B, carries the receptor Or56a, which reacts only to geosmin. This dedicated neural pathway enables the fruit fly, which subsists on a diet of rotting food, to distinguish good microbes from bad ones. This example of olfactory genetics even informs females on where to lay their eggs, suggesting the reproductive significance of avoiding geosminic areas. According to the Planck Institute studies, female Drosophila lay eggs on areas occupied by ordinary yeast while completely avoiding cultures that house Streptomyces coelicolor: a highly toxic, geosmin-producing bacterium which would otherwise kill the new larvae.

In the context of humans, geosmin is a contributor to the muddy taste and odor of certain kinds of farmed fish. Off-flavors (muddy or funky undertones) in farmed fish have roots in geosmin, as they can be generated by rotten remains or offensive compounds transferred from the surrounding environment. Our sensitivity to geosmin also helps us avoid dangerous drinking water, which will tend to taste "dirty," as the compound is also produced by cyanobacteria found in poisonous algae blooms that can propagate in large reservoirs. Heightened geosmin detection has also aided in setting distillery and winery health standards to levels which keep us from consuming rogue microbes present in funky-smelling ingredients. The evolutionary advantage to being able to detect this definite, earthy scent is made clear, both by Drosophila's encoded response to it and by the negative effects associated with it. In regards to geosmin, the nose knows best.

Nature (2007). DOI: 10.1038/nchembio.2007.29
CELL (2012). DOI: 10.1016/j.cell.2012.09.046



VACCINES THROUGH THE AGES: THE VEXING HISTORY OF VACCINATION

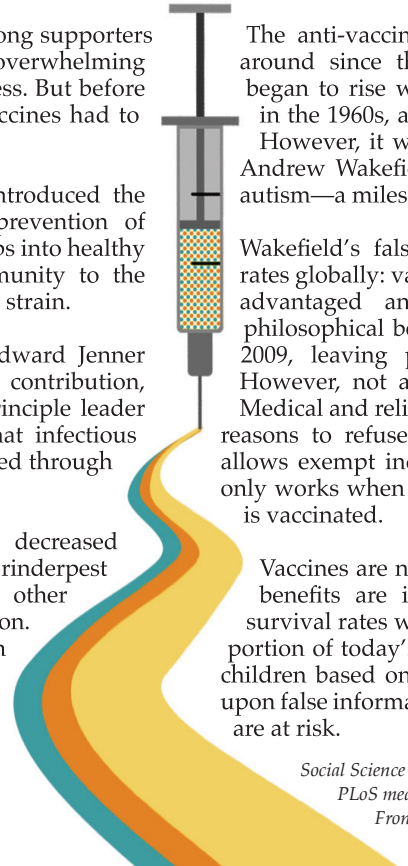
BY CHRISTINA MCCONNEY, BIOLOGY, 2021

Vaccines are a loaded topic today—with strong supporters on both sides of the argument, despite overwhelming scientific evidence backing their effectiveness. But before there could be anti-vaccination sentiments, vaccines had to be created.

Early China and India (roughly 1500 BCE) introduced the practice of inoculation, a method for the prevention of smallpox, involving blowing crushed, dried scabs into healthy children's nostrils. This helped build an immunity to the disease through exposure to an attenuated (live) strain.

In the late 18th century, English physician Edward Jenner invented the smallpox vaccine. Despite this contribution, it was Louis Pasteur who was crowned the principle leader of immunology through his demonstration that infectious microbial diseases could be prevented and treated through immunology.

Since Pasteur's contributions, vaccines have decreased disease related mortality rates. Smallpox and rinderpest have even been eradicated globally, while other diseases like polio are on the verge of eradication. Despite evidence of documented success through vaccination, with reduction of mortality rates in diseases covered by the DTP3 vaccine cited most often, there has been a recent decrease in vaccination rates and a re-emergence of diseases.



The anti-vaccine movement isn't new; opposition has been around since the 1700s. In the US, anti-vaccine sentiment began to rise with the enforcement of "no shots, no school" in the 1960s, and echoes of resistance could be seen globally. However, it wasn't until 1998 that British gastroenterologist Andrew Wakefield announced "evidence" linking measles to autism—a milestone in the modern anti-vaccine movement.

Wakefield's false findings irreversibly impacted vaccination rates globally: vaccination rates decreased in both economically advantaged and disadvantaged populations, and "non-philosophical belief" vaccination exemptions have risen since 2009, leaving populations more susceptible to outbreaks. However, not all vaccine exemptions are based on distrust: Medical and religious exemptions exist and are viewed as valid reasons to refuse administration of vaccines. Herd immunity allows exempt individuals to be protected from disease, but it only works when a minimum percentage of the able population is vaccinated.

Vaccines are not new, nor is their opposition. However, their benefits are indisputable: they have increased childhood survival rates worldwide since their introduction. With a large portion of today's anti-vaccine supporters refusing to vaccinate children based on a mistrust of doctors and continued reliance upon false information, the health and safety of millions of people are at risk.

Social Science & Medicine (2018), DOI: 10.1016/j.socscimed.2018.08.032
PLoS medicine (2018), DOI: 10.1371/journal.pmed.1002578
Frontiers in Immunology (2012), DOI: 10.3389/fimmu.2012.00068

Cosmic cuisine

BY ANUSHKA BISWAS, CELL AND MOLECULAR BIOLOGY, 2023
DESIGN BY IAN PROULX, BIOENGINEERING, 2022

Day 152. Shifting through rations, you're faced with the nightly dilemma: freeze-dried tofu with mustard or nutritional wildberry slurry? Every fibre of your mind and body longs for a carrot.

Welcome to life in space.

For astronauts aboard the International Space Station (ISS) or eagerly awaiting a six-month mission to Mars, many sacrifices must be made. Yet, the quality of food can be spared, if not improved, with space agriculture.

The ability to grow fresh vegetables in space provides copious merit for spaceflight. While it is completely possible to transport pre-packaged meals on space expeditions, packing food is both expensive and energy-intensive. Astronaut ice cream is by no means a long-term solution. Over time, the nutritional composition of food degrades and, for extensive journeys lasting upwards of five years, rations are shipped far in advance. Given the reduced gravity in spacecrafts, fluids within the astronauts' bodies travel upwards and begin to accumulate—a phenomenon called fluid shift. The effects of fluid shift feel a bit like the common cold, causing heads to swell and a reduced sense of smell. Our intergalactic voyagers, in turn, lose their sense of taste and, eventually, weight from skipped meals. Even with a healthy diet, space flight comes with the qualms of spending months on end in isolation. The comforts of caring for another living organism suggest that growing plants can have a multitude of psychological benefits for astronauts. Being able to mark the passage of time on a seemingly endless, static expedition undoubtedly offers solace.

> "The comforts of caring for another living organism suggest that growing plants can have a multitude of psychological benefits for astronauts."

While there is significant incentive to cultivate crops amongst the cosmos, researchers struggle to bypass the environmental constraints of astronomic farming. Major concerns for astrobotanists include the thinner atmosphere of Mars and reduced plant yield in microgravity. Lunar and Martian soils are coarse and low in nutrients. The sharp angles of the soil particles themselves may pose a threat to the roots of the crops. Soil on Mars is extremely varied and high in metallic composition, full of iron oxide and perchlorates, capable of potentially stunting the growth of otherwise successful plants.

From the 1997 Mir Space Station to the current project Veggie, NASA has been fine-tuning the process of aeroponics to support plant growth in space. Aeroponics encompasses the process of growing plants suspended in air without soil or media. When well-implemented, aeroponics enables plants to grow faster and more sterile, without pesticide residue or contamination. The ISS Vegetable Production System is compact for accessible therapeutic gardening.

Guowei Liu, of the Institute of Plant and Microbial Biology at the University of Zurich, recently published a study on the use of strigolactone, a plant hormone, in the presence of microgravity and nutrient deficiency. Plants were genetically edited to exude high levels of strigolactone to promote increased branching of their roots. Meanwhile, extraterrestrial conditions were simulated using a growth medium of synthetic lunar soil with mycorrhizal fungi. Mycorrhiza, a unique symbiotic relationship between plant and fungus, can greatly improve the viability of crops in nutrient-poor space by allowing plants to enlarge their root system. Microgravity was then mimicked via the use of a clinostat, a continuously rotating equipment that holds and positions the plants randomly. Results were promising, as the genetically edited plants displayed extended branching even under microgravity and were generally taller with greater biomass production. Inducing excess strigolactone may allow for more reliable growth of sustainable plants in space.

Currently, astrobotanists are pursuing the growth of salad crops, which grow quickly and efficiently while being easily influenced by light therapy. Being able to consume vegetables without extensive cooking or cleaning is a significant advantage in a limited environment. Specific crops of interest include herbs, radishes, and lettuce strains—more specifically red lettuce. Weiger Wamelink of Wageningen testifies that, compared to other crops, red romaine lettuce has selective properties that aid in repairing DNA damage from solar radiation, to which astronauts are prone, as well as a low microbial count. The long-term goal, however, is to prioritize stable crops like potatoes. Potatoes, high in energy and essential nutrients, tell us The Martian might have had the right idea after all.

It is said that once you grow crops somewhere, you colonize it. With recent developments making astrobotany an up-and-coming discipline, we are one branch closer to extending our roots and settling in on Mars.

Nature (2018). DOI: 10.1038/s41526-018-0054-z
Plant Physiology (1971). DOI: 10.1104/pp.47.6.756

PHOTO BY PIXABAY

HUBBLE TROUBLE, AND MAKE IT DOUBLE

DISAGREEMENT OVER ONE OF THE UNIVERSE'S MOST IMPORTANT CONSTANTS

BY ISABEL KAIN, PHYSICS, 2021
DESIGN BY HEATHER WELCH, ENVIRONMENTAL SCIENCE, 2020

In the beginning, all that would become the universe was concentrated into an extremely small, dense, high-energy speck of space. In the fractions of seconds that followed, this singularity exploded: one hundred decillionths (10-35) of a second after, it expanded to nearly the size of a soccer ball; after one nonillionth (10-30) of a second, it reached the width of a city block. 13.8 billion years later, the universe stretches perhaps to infinity, and the expansion that characterized its explosive origin is still stretching it apart.

But how fast is this expansion? It turns out that finding this value is much trickier than expected, and differing results are causing scientists to question our understanding of the physics of the universe.

One way to measure expansion is to look at "standard candles," objects with luminosities so well-known that we can measure their distance from Earth by how much dimmer they are than we expect. Scientists divide the speed with which these objects are being pulled away from us—measured using their redshift, or how much their light gets stretched out as they recede—by the object's distance from the observer. This relation, velocity over distance, calculates the Hubble Constant, a famous parameter in cosmology that describes universal expansion.

The Hubble Constant, or H0, has been measured using a second method to verify these results. Cosmologists made very precise measurements of the cosmic microwave background (CMB), the electromagnetic afterglow of the beginning of the universe. This faint wash of radiation left over from the Big Bang provides a snapshot of what the Universe looked like millions of years (mere moments in cosmic time) after it was born. Telescopes like Planck and WMAP have created detailed maps of the CMB that have allowed cosmologists to determine the exact characteristics of the universe, such as temperature and composition. Cosmologists then plug these values into physical models that include all the parameters we have to describe the Universe—including H0—and tweak the knobs until the predictions of what the CMB should look like match observations.

> "Until the Hubble tension is resolved, cosmology will continue to be pulled apart."

There's only one small problem—these methods produce very different results.

Redshift measurements taken with the Hubble Space Telescope (HST) in 2019 place H0 at 74.03 (km/s)/Mpc. (These weird units give the speed of a galaxy one megaparsec or ten quintillion kilometers away). Measurements of the CMB taken with the Planck telescope arrive at a value of 67.66 (km/s)/Mpc. This disagreement may seem small, but it amounts to a 4.4σ or 99.9989174912% discrepancy. This means there's less than a 1 in 100,000 chance that this discrepancy is a fluke—and further physics research depends on this tension being resolved.

One theory that might resolve this tension challenges our understanding of cosmic distance. To calibrate redshift measurements of Type Ia supernovae, a type of standard candle that are some of the farthest, oldest, and most quickly receding targets, astronomers have to use a closer standard candle for reference. In this case Cepheid variables are used, which are stars that pulse with clock-like dependability. To calibrate these distances, even closer standard candles are used. Astronomers continue to step down the "cosmic distance ladder" until they have solid estimates of distance. But if one rung is broken, then the whole structure—and all the science that relies on it—will come toppling down.

An even more concerning possibility is that our physics is wrong. Values derived from detailed maps of the CMB are used to make physical predictions of what the Universe should look like – predictions which rely on our current understanding of physics. We rely on a physics model called Lambda-CDM (where CDM stands for cold dark matter and Lambda represents the cosmological constant, which describes how quickly the rate of cosmic expansion is changing). If this model is incomplete, even by some small amount, then predictions produced by the model are incomplete as well.

This profound disagreement over one of the most fundamental characteristics of the universe is troubling. Either methods we have trusted and used to do science for decades is wrong, invalidating enormous swaths of results, or there is mysterious new physics that we have not yet seen. Until the Hubble tension is resolved, cosmology will continue to be pulled apart.

PHOTO BY PIXABAY

UTTER CHAOS:

Tracking the dispersion of airborne pollutants

BY ANNABELLE MATHERS, CIVIL ENGINEERING, 2022

DESIGN BY MARISSA KEESEY, ELECTRICAL ENGINEERING, 2022

Many processes in the natural and humanistic worlds are extraordinarily complex and seemingly random. However, in systems defined by Chaos Theory, this apparent randomness is actually not random at all, but governed by hidden patterns. Computer algorithms, biological responses, and weather are a few of the chaotic systems that express a constantly changing, never entirely predictable state of organization rooted in patterns. Likewise, the global dispersion of airborne pollutants consists of particle routes that are chaotic, or more specifically, deterministically chaotic.

A subset of Chaos Theory, deterministic chaos intrinsically links order and disorder, claiming that initial conditions in a constantly changing system result in the exponential growth of the number of future scenarios. Each scenario has nuanced characteristics and events that create countless cascading outcomes. The particular combination of events and characteristics causes future scenarios to exponentially diverge from and become semi-unique. Thus, a disordered picture forms from a series of ordered events. An example of such chaos is the Butterfly Effect, described by Edward Lorenz, where the wind from an Amazonian butterfly's flapping wings causes a sequence of seemingly unrelated events that includes a tornado in Texas.

In a 2019 study, Tímea Haszpra of Eötvös Loránd University applies this concept to atmospheric aerosol particles. Volcanic ash and industrial air pollutants make up these particles, which form colloidal suspensions in the air that do not readily settle. Research data for wind and atmospheric conditions enabled Haszpra to create maps, using principles from Chaos Theory, that predict global particle dispersion. According to Haszpra, the initial altitude of a particle does not necessarily affect its escape rate from the atmosphere to the ground, but particle size has a quadratic influence on the escape rate. When paired with geographic location, this illustrates global areas most affected by the accumulation of airborne pollutants.

In order to reach these final locations, particles must travel along an atmospheric 'chaotic saddle' created by a combination of wind, atmospheric conditions, and particle size. The saddle itself functions as a boundary between stable and unstable states. Particles which congregate inside the saddle remain in stable colloidal suspension for a longer period of time; particles which exist outside or on the outskirts of the saddle are more unstable and scattered in their quicker descent to Earth. All particles within the saddle eventually fall to the ground, meaning the chaotic saddle is transient, or impermanent, by nature.

Using particle trajectories calculated by a tracking program, RePLaT (Real Particle Lagrangian Trajectory), Haszpra reinforces the idea of locational stability and instability by estimating that the saddle can exist where stable particles maintain the greatest atmospheric lifetime and smallest escape rate. The tracking program relies on the principles of deterministic chaos, where circumstances and environmental nuances surrounding each particle over time all factor into the particle's eventual behavior. A particle of a greater elevation at emission does not necessarily remain in the atmosphere, nor travel as far, as a particle of a lesser elevation. Then again, because of the sheer number of later events and characteristics that factor into the particle's destiny, the previous statement does not always hold true. One characteristic that appears to maintain a more 'predictable' outcome is that particles with a larger radius will have a greater escape rate. This may seem like a simple application of gravitational principles, but when the idea of predictability in chaotic systems is not truly viable because of their infinitely complex nature, it is a significant recognition.

Because meteorological conditions are time-dependent, the chaotic saddle's geographical location fluctuates over time. The saddle most often falls over equatorial tropical regions, which experience the highest concentration of persistent air pollutants from worldwide emissions. Converging southeast and northeast trade winds in the Intertropical Convergence Zone, along with atmospheric convection enabled by the warm equatorial surface, correlate with the saddle's densest regions. Each condition affecting an individual particle has an exponential effect on its divergence from the paths of the other particles, meaning pollutants emitted in close proximity to one another can travel different paths toward extremely different locations. It may seem like the particles' initial location and conditions become obsolete and detached from its final trajectory. However, it is now known through Chaos Theory that the origin story, and the origins of the innumerable factors affecting the particles along the way, are more important than ever.

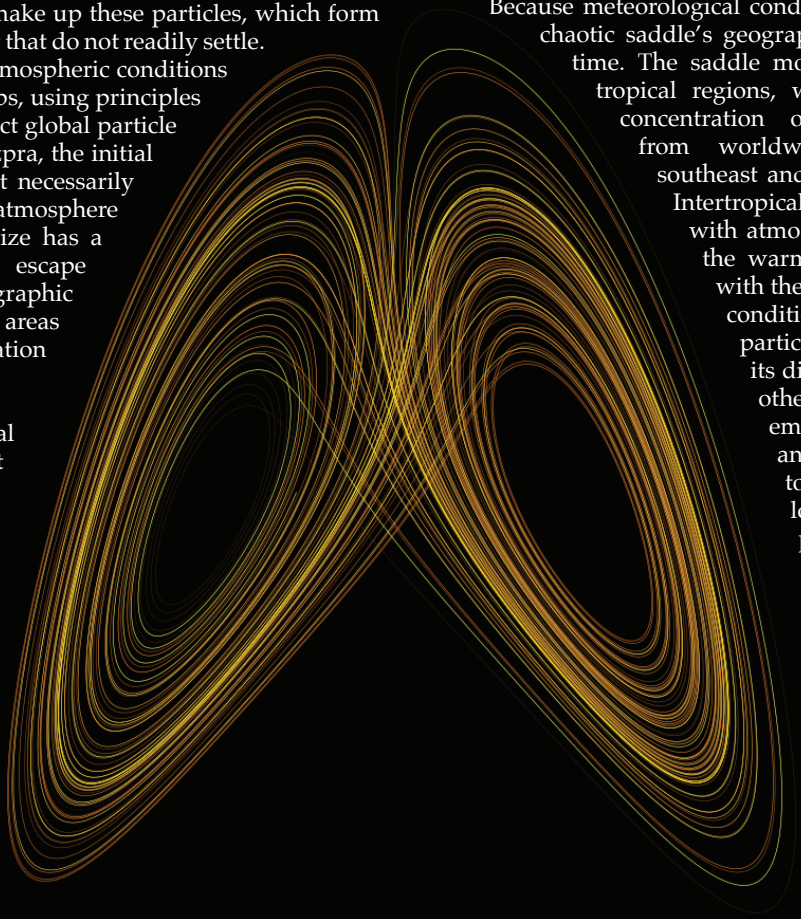


PHOTO BY WIKIPEDIA

DISCOVERING OUR ROOTS

BY RACHEL LINES, BEHAVIORAL NEUROSCIENCE, 2023

Humans share a DNA code that is 99.9 percent identical among all individuals. Encoding physical traits, instructing development, and containing information about probability of disease, DNA tells the story of humanity's past, and individuals' connections to one another. In order to advance the understanding of the human genome, which is the complete compilation of human genes derived from over three million DNA base pairs, the Human Genome Project began to analyze the human recipe in 1988.

Robert Sinsheimer was one of the first individuals to realize the potential of sequencing the human genome. Walter Gilbert, who developed the technique for genetic sequencing, enlisted the help of James Watson, a scientist famous for discovering the double helical structure of DNA. Originally, the strategy to understand the genome involved utilization of bacterial artificial chromosomes, which contain fragments of human DNA. To identify disease-related genes, scientists performed sequencing that utilized clones of these artificial chromosomes. As the project evolved, the Celera approach emerged, thus sequencing the whole genome through the cloning of random chromosomal fragments. Finally, technological development allowed sequencing to rely on algorithms and computer processing.

Although the idea was fascinating, many people doubted the scientific merits of the Human Genome Project. The estimated price of the project was a daunting three billion dollars. Additionally, the majority of DNA does not actually code for genes—so, was it worth the cost to map the entire genome? Consequently, scientists used model organisms to reduce the price tag. Sequencing simpler organisms enabled researchers to observe a preview of the human genome.

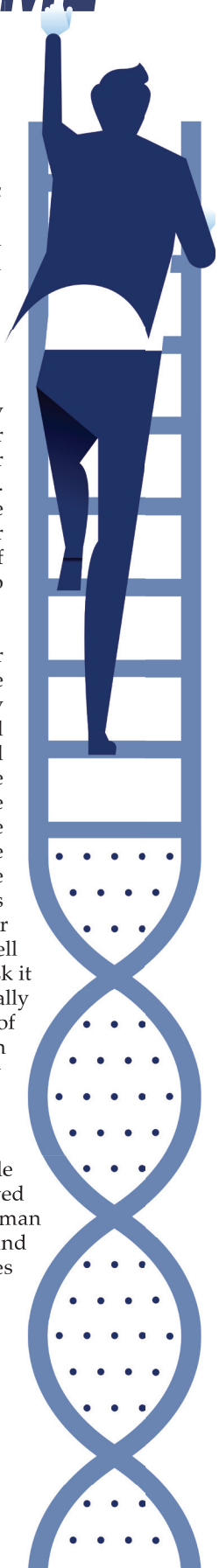
Although knowledge of the human genome provided many medical benefits, issues arose due to consequences of privacy, consent, and genetic testing. The Ethical, Legal, and Social Implications (ELSI) Program played an essential role in preventing conflicts. Individual privacy and fairness were carefully protected, especially considering the use of individuals' genetic information. Informed consent was also essential, as humans were the genetic research subjects. Furthermore, knowledge of the human genome became increasingly controversial because of the developing potential for genetic testing of embryos during pregnancy.

In April 2003, the International Human Genome Sequencing Consortium released a high-quality sequence of the human genome. Through the use of model organisms, researchers also sequenced the mouse genome, and the genomes of several other organisms. The development of this sequence resulted in the formation of techniques which currently allow for the study of thousands of genes at one time.

GRAPHIC BY SHUTTERSTOCK

DESIGN BY YECHAN YANG, BIOLOGY AND PSYCHOLOGY, 2021

THE ORIGINS OF THE *HUMAN GENOME PROJECT*



Knowledge of the human genome allows for better understanding of familial disease, genetic disorders, and even susceptibility to addiction. The Chesler Lab within the Jackson Laboratory in Bar Harbor, Maine is a prime example of a team currently working on advancing knowledge of the human genome. In this lab, experts use mouse models to analyze impulsivity, response to novelty, and drug abuse.

Initially, the mice used at the Jackson Laboratory began as a collection of cute, pet mice. The founder of Jackson Labs, Clarence Cook, studied whether the traits in these fancy mice were heritable. Using systematic crossing of inbred mice, the laboratory developed mouse variants bred for specific traits and lineages. Through definition of the mice genomes, the sequence data was able to be correlated with complex traits.

Humans and mice share around 95 percent of their genes, meaning research on the mouse genome can be compared to human research. A 2016 study performed by the Jackson Laboratory revealed genes related to cocaine sensitization, and suggested mechanisms that drive human cocaine use. Elissa Chesler, the principle investigator at the Chesler Lab, explained that studies such as these can help define what good recovery from drug use looks like, and how to replicate it. Additionally, she said it can be controversial to study mental illness in mouse populations. In an interview, Chesler explained, '"some people argue that you cannot tell whether or not a mouse is depressed; you can't ask it how it feels."' However, these mice can be genetically modified to express the biological aspects of depression similar to those of humans, and can then be studied. New research includes the study of vulnerability to drug abuse, and the study of biological changes resulting from addiction.

The Jackson Laboratory is only one example of researchers working towards an improved understanding of genomics. Although the Human Genome Project ended in 2003, the knowledge and understanding of the human genome continues to evolve.

Nature (2018). DOI: 10.1038/d41586-018-05462-w
Science (2001). DOI: 10.1126/science.291.5507.1218
Psychopharmacology (2016). DOI: 10.1007/s00213-015-4147-z

The origin of the penis:

Where did it come from?

BY CERINA KARR, BIOLOGY, 2023
DESIGN BY LILLIE HOFFART, ENVIRONMENTAL SCIENCE, 2022

According to fundamental evolutionary principles, traits are likely to get passed onto offspring if they contribute to one's fitness, i.e., the ability to survive and reproduce. Therefore, it is essential that genitalia are kept intact so that organisms may produce offspring. Why, then, is human male genitalia so vulnerable?

What are the options?

An important distinction to make is that while the penis is an external organ, fertilization itself is an internal process in humans.

Tailless amphibians, such as frogs, fertilize externally. The male frog grips the female in an embrace known as amplexus. The female expels her eggs at the same time males release sperm, and the result is an external gelatinous mass of joined eggs.

Amphibians with tails undergo internal fertilization. The male lays down small masses of sperm called spermatophores. The female collects one through the cloaca, which is the opening for both reproductive and excretory processes in reptiles, amphibians, birds, most fish, and monotremes. In fact, the word "monotreme" comes from the Greek words "monos" and "trema," which together mean "single hole."

In reptiles, male genitalia is kept inside the body until intercourse stimulates erectile tissues to bring it to the outside. This keeps the genitals protected until they are truly needed.

After the first animals began living exclusively on land, external fertilization (the frog method) would no longer suffice; the egg would be prone to desiccation (drying out). Consequently, the amniotic egg emerged as a new means of provisioning the embryo with moisture and nutrients. In humans and most other mammals, the fertilized egg is retained within the mother during development.

External genitalia

The evolution of male genitalia in amphibians and reptiles and fertilization methods have been well-established. However, it is still unclear why external male genitalia evolved in mammals. What possible advantage could there be to having genitals so unprotected?

One theory is that there is no room for internal storage of the penis in mammals. Perhaps there is some advantage to using extra abdominal space for the digestive and excretory systems. Space does not seem to be a huge issue, however, since males don't have to fit a uterus and occasionally an entire human baby inside of them.

Another theory is that external male genitalia provide a means of female selection in wild mammals. Sexual selection occurs in many species of primates. Males have to compete with each other for the fertile females. This usually occurs through fighting, and females typically select males of higher status rather than males with better physical attributes. However, if the appearance of genitalia has some relevance to sexual selection, having external genitalia would be logical. Some primates, such as chimpanzees and bonobos, may have evolved long penises to ejaculate at more advantageous locations within the female reproductive tract. Therefore, sexual selection regarding penis size would make evolutionary sense. Some claim this would not apply to humans, however, due to a propensity to often select mates based on factors such as personality.

An additional theory has to do with female pleasure. Having external genitalia introduces the concept of foreplay, which can increase the chances of female orgasm. Although female orgasm is not necessary for fertilization, it is speculated that the evolutionary purpose of female orgasm is to leave females immobilized after copulation. Studies have shown that remaining horizontal after intercourse could increase sperm retention in the vaginal canal, improving chances of pregnancy. This theory has more to do with the evolutionary purpose of female orgasm, though, and not with external male genitalia.

Perhaps having external genitalia somehow enhances its position in the vaginal canal to improve fertilization. A study headed by Maxi Richmond from the University of Connecticut was conducted on scarab beetles and suggests that the main structural goal of male and female reproductive organs is to allow them to lock tightly together: "The male and female genital morphology in Phyllophaga thus appears to function to enhance the mechanical fit between the sexes as the male hangs from the female." Of course, it is difficult to apply a beetle study to humans, as there are fundamental differences in fertilization methods.

The mammalian penis is ostensibly a very mysterious organ. Do the benefits described above really compensate for its vulnerability as an external organ? Regardless of its origins, it can be agreed upon that the penis has its reasons for being external, for evolution always does its job.

PHOTOS BY WIKIMEDIA COMMONS

Animal Behaviour (1993). DOI: 10.1006/anbe.1993.1272
Annual Review of Sex Research (2001). DOI: 10.1080/10532528.2001.10559796
Journal of Evolutionary Biology (2016). DOI: 10.1111/jeb.12955
BMJ (2009). DOI: 10.1136/bmj.b4080

DNAGE OF CONSENT

BY EMILY CHEN, DATA SCIENCE AND BIOCHEMISTRY, 2023

The distribution of a revolutionary piece of DNA testing technology has changed the world of ethics and information gathering. A genomics company, 23andMe, has commercialized a device that reveals an individual's ancestry when provided with only a sample of saliva. If only things stayed this simple...

23andMe began with the goal of providing genetic information to as many people as possible by supplying its devices at reduced rates. However, in a world that prizes monetary success, this company moved closer and closer to the line dividing privacy and security. The scientific community, specifically the sector that involves human testing, revolves around informed consent; a volunteer agrees to treatment with knowledge of procedural details, whether it is in the instance of giving a urine sample, or undergoing surgery.

In May 2012, 23andMe announced that it obtained a patent for a method of determining predisposition to Parkinson's disease. Instead of celebration, this achievement increased the tensions surrounding clinical research using such large data bases. The question arose: did every person participating in this experiment give informed consent? According to customers on the company's blog, the answer was no. Participants repeatedly expressed their increasing concern with the company, specifically in regard to data privacy. They exclaimed how their decision would have been affected if they had known how their data was going to be used. Other participants questioned the ethics of such an ordeal. Data collection is a common step in research, but, in this case, the public believed it was not notified in an efficient nor effective way. When a corporate misunderstanding occurs, it is not necessarily on purpose. However, some parts of the public still have reservations about 23andMe.

> "The scientific community, specifically the sector that involves human testing, revolves around informed consent."

With its status as a for-profit institution, there is pressure on 23andMe to produce profitable research discoveries. Thus, this company could be inclined to take certain steps to bring in revenue despite the ethical consequences. In contrast, nonprofit institutions receive the majority of their funding from the government. Technically, when someone submits her DNA to 23andMe, the company reserves the right to utilize the subject's personal information to tailor advertisements for products and services. The debate unfolds when participants in the genetic research aspect of this company question if their knowledge of these procedures serves as informed consent to 23andMe. There is a fine line between privacy and health security, and some people believe 23andMe remains dangerously close.

Trends in Biotechnology (2013). DOI: 10.1016/j.tibtech.2012.11.007

WHY CARROTS ARE ORANGE: The domestication of your favorite healthy snack

BY JASON M. DENONCOURT, CHEMICAL ENGINEERING AND BIOCHEMISTRY, 2023

The common name for wild carrots is Queen Anne's Lace. With its illustrious, white summer flowers and pale, branching root systems, this subspecies hardly resembles everyone's favorite healthy snack. Yet, over numerous generations of human influence, wild carrots, essentially ornamental flowers, transformed into one of the most common vegetables in the world.

There are two types of root systems in plants: taproots and fibrous roots. While fibrous plants form a spider web of thin, spindly roots, taproots anchor plants deep in the soil with one primary root branching into thin strands. All carrots are a specific subcategory of taproot known as storage roots, which are reservoirs of starch and water. To increase yield and revenue, cultivated carrots have been selected for larger, starchier taproots. By breeding the plants with the thickest taproots and highest volume of starch together, scientists and farmers have transformed the carrot plant from a spindly network of roots to its characteristically dense, singular root.

So, it is economically beneficial for farmers to artificially select for larger taproots. But, if carrots in nature are typically a pale, whitish color, what would be the benefit of selecting for the color orange?

The popularization of the orange carrot dates back to the Habsburg occupation of the Netherlands in the 16th century. William the Silent of the House of Orange-Nassau organized a Dutch revolt against Spanish imperial rule, resulting in the reclamation of half the nation's territory. In tribute to the House of Orange-Nassau's involvement in the war, the color orange became a symbol of royalty and freedom for the Dutch people. Even today, Dutch orange pride is still evident in parades, athletic competitions, cultural events, and even carrots.

Agricultural scientists had long been breeding deep yellow carrots together over numerous generations to create orange carrots. They were qualitatively selecting for what scientists today have identified as the chemical β-Carotene. In addition to its bright pigment, this chemical has substantial health benefits. Scientists today continue to select for β-Carotene for its nutritional content and distinctive orange color.

Due to artificial selection over thousands of years, carrots have been transformed from an invasive, wild species into the vegetable we are all familiar with today. Though the most significant genetic change of carrots took place in the Netherlands, scientists today continue to alter the genetic makeup of carrots, in search of that perfectly sweet, vivid orange crunch.

DESIGN BY ESHA AGGARWAL, COMPUTER SCIENCE, 2022
PHOTOS BY GABRIEL MZAOUAKK, HEALTH SCIENCE, 2023 AND WIKIMEDIA

Survival of the friendliest:
The evolution of dogs

BY LAUREN VOSO, BIOLOGY, 2023

DESIGN BY KYLA VIGDOR, DESIGN, 2021

Dogs are known as man's best friend for a reason: their wagging tails, aggressive licks, and silly personalities combine to make the perfect recipe for a loyal and trusted pal. But, would you feel the same about adopting a wolf into your family?

Typically, we think of wolves and dogs as two completely-separate entities. In reality, wolves and dogs are still considered closely-related species. Then, what makes dogs so different from their biological siblings?

The answer is obvious to most: dogs are nice! For scientists studying the evolution of dogs, the question has become: why?

> "Friendliness became an advantageous trait for wolves, leading to the evolution of the modern dog."

Brian Hare, the director of the Duke Canine Cognition Center, and Vanessa Woods, a researcher at Duke University, hypothesize that friendliness became an advantageous trait for wolves, leading to the evolution of the modern dog. The two theorize in their book, *The Genius of Dogs*, that humans would only let the friendly, non-aggressive wolves scavenge through their scraps. So this "friendliness" trait would have been naturally selected for as the relationship between humans and these wolves strengthened.

Several studies have looked at the genomes of dogs to identify which genes differentiate them from wolves and produce this friendliness. Researchers have found that a combination of genes produce these differences, including genes relating to brain function and physical structure. Interestingly, Bridgett vonHoldt and her team from Princeton University found that dogs share genetic similarities to humans with Williams-Beuren syndrome—a disorder characterized by hypersocial behavior—which contributes to their affectionate personality. The team concluded that as dogs were domesticated, this trait probably became more widespread in the population.

Another study, led by Amanda Pendleton from the University of Michigan, discovered several genetic differences between dogs and wolves, including facial features. Comparing the genomes of dogs and wolves revealed that physical traits such as floppy ears and smaller jaws were naturally selected for in dogs, probably because these traits gave them a less intimidating appearance. The team also investigated genetic differences in the neural crest of dogs and wolves and how these influence their behavior; dogs, they discovered, have lessened aggression and "fight or flight" reactions due to these neural crest changes.

As more information about the evolution of dogs is gathered through genetic sequencing, we get to learn more about what makes our pets best-friend material. Next time your dog attacks you with cuddles instead of claws, be grateful for evolution!

BMC Biology (2018), DOI: 10.1186/s12915-018-0535-2
Science Advances (2017), DOI: 10.1126/sciadv.1700398

PHOTO BY GUS MUELLER, BIOENGINEERING, 2022

A WALK ON THE WILDLING SIDE

BY THEODORE FISHER, BEHAVIORAL NEUROSCIENCE, 2020

DESIGN BY KRISTI BUI, COMPUTER SCIENCE, 2021

This past August, researchers from the National Institute of Health published a study in Science aimed at improving translational immunology. Their findings demonstrate a crucial variable leading rodent laboratory research astray, which may bear responsibility for several failed human clinical drug trials.

In 2006, six volunteers experienced near-death inflammatory symptoms after being given a drug, Theralizumab. This drug aimed to stimulate T cells, which are responsible for recognizing and responding to immune challenges in the body. It had demonstrated a possible treatment for specific types of Leukemia in mouse models, yet it failed as soon as it was administered to humans. Both humans and mice had similar health conditions and share mostly parallel immune systems, making them good translational models. Nevertheless, this and other immunological studies have proven useless or dangerous in clinical trials. So how might these oversights happen?

Let's take a step back. We as humans are hosts to an entire ecosystem of microbiota, or microscopic organisms that we have evolved to share symbiotic relationships with. In fact, our body provides nutrients and shelter to over 10 trillion microbial cells. Symbiotically, they aide us in digestion, metabolism, vitamin production, behavior, and especially the support of our immune system. Around the time we are born, we acquire these microorganisms such as bacteria, archaea, and fungi altogether known as flora. They come from everywhere; the food we eat, the air we breathe, and largely from our mothers. It can be said that as a whole, our microbiome is at the will of our environment.

The microbiome is currently in the research spotlight, given its implications in many functions essential to life itself. Many recent studies have uncovered striking data suggesting its role in priming and preserving the immune system to sufficiently respond to challenges. Our immune systems are composed of many different cell types and subtypes, all of which must maintain an intricate landscape of gene expression. This so-called "landscape" serves to provide a fine balance of reactivity to what is meant to be in our bodies versus what is not.

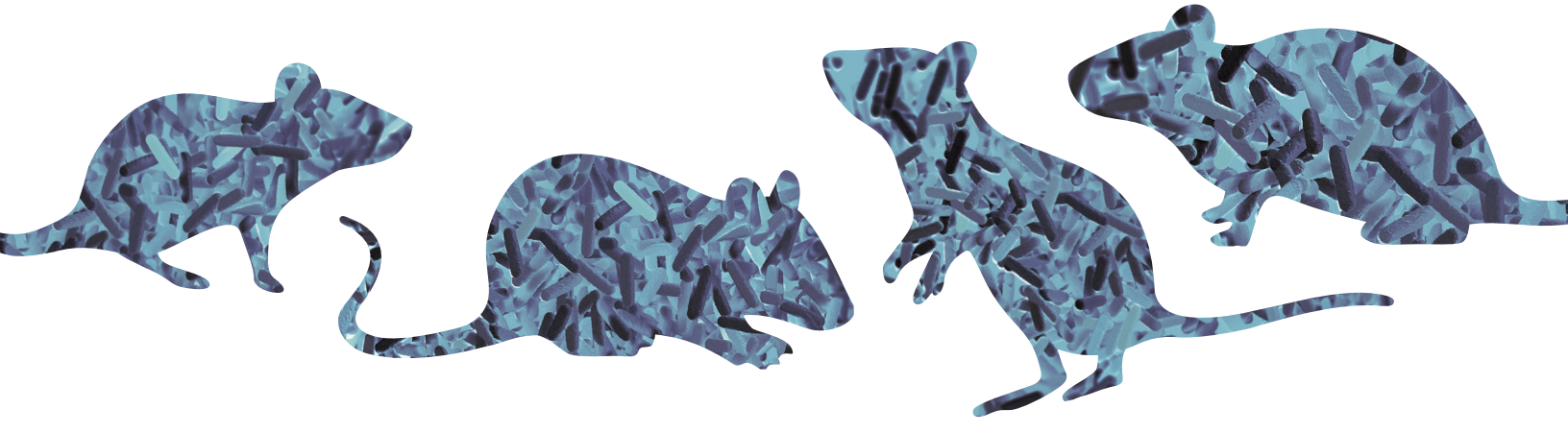
NJEM (2006) DOI: 10.1056/NEJMoa063842

Even in a mouse, both the symbiosis of our microbiome and complexity of our immune system represent just how complicated it is to study animal systems. Further, many challenges are posed when we must translate rodent research to human treatment. This study sets out to explain how the developmental environment may be to blame.

Laboratory mice are born in a sterile, nearly germ-free environment. This is drastically different to wild-mice, who run freely in fields or sewage and acquire any flora they encounter. Because humans are also at the will of our natural environment, we too are exposed to a large amount of flora daily. Imagine the differences seen between city-goers and farmers or a pregnant mother on antibiotics. To investigate this variability, scientists used humane traps and peanut butter to catch dozens of wild mice from horse stables in Virginia. They then created a maternal transfer model in which laboratory-bred embryos were transplanted into wild female mice. Coined "wildlings," these mice represent an intermediate model in between the lab and wild mice. The scientists then sequenced the microbiomes and immune cells residing in the gut, skin, and vagina, all considered to be high exposure areas. The differences were drastic. Not only were the colonies of bacteria, viruses, fungi, protozoa different, but the landscape or gene expression seen amongst immune cell populations had been completely reshaped by the environment.

Laboratory and wildling mice, each with drastically different immune landscapes, were treated with Theralizumab. As previously reported, the laboratory mice remained healthy, but the wildlings responded with similar inflammatory responses to the human volunteers. Although there is no true mechanistic explanation for this response, it can be said with certainty that the environment played a large role and may be at the center of these translational differences.

Rosshart et al. provides an eye-opening explanation for the root of a massive problem in translational immunology. But, they also provide a possible answer. This study shows the utility of a "wildling" model in that it is able to more closely represent human immune landscapes, but can also be kept in a laboratory setting. It is the hope of these scientists and many others that the environment will be considered in immunology, possibly saving more lives in the future.



THE ORIGINS OF THE CLIMATE CRISIS:

LEADING TO AN UNCERTAIN FUTURE

BY JULIA HINES, CHEMICAL ENGINEERING, 2021

DESIGN BY KAI GRAVEL-PUCILLO, ENVIRONMENTAL SCIENCE, 2021

The Climate Crisis has filled the news lately with the rise of Greta Thunberg, a sixteen year old climate activist, and many youth-led protests across the globe. Thunberg's insistence of action has reverberated around the world. She has made Europe and the United States listen, proclaiming during one rally that "adults keep saying we owe it to the young people to give them hope. But I don't want your hope. I want you to panic". However, this raises the question: how did we get into this position?

The greenhouse gas effect has been mentioned in scientific literature since the late 1800s. However, the connection between human-generated carbon dioxide emissions and the greenhouse gas effect wasn't made until the early 1900s. Before this time, it was commonly assumed that humans could not change the heat balance or climate of the earth because the total power from all human activity (8 trillion Watts) is insignificant next to the power of the sun's radiation (80 quadrillion Watts). During the Industrial Revolution, cities started to develop a thin layer of smog that hung overhead. Of course, this is climate change, but it is regional climate change. The effects of this smog did not reach all the way across the globe.

To fully understand climate change, one must first understand the greenhouse effect. It's caused by carbon dioxide, methane, water vapor, and several other trace gases—together known as greenhouse gases—that absorb infrared (IR) radiation. As the sun's light hits the Earth's surface, some IR radiation is reflected off Earth and back into space. These greenhouse gases prevent some reflected radiation from escaping to space which, in turn, warms the lower atmosphere and the surface.

The first mention of this in scientific literature was by Jean Baptiste-Joseph Fourier in 1824. In 1864, John Tyndall scientifically proved that water vapor and carbon dioxide could absorb IR radiation, meaning atmospheric conditions could change the Earth's temperature. Finally, at the turn of the century, Swedish scientist Svante Arrhenius calculated that doubling the then current carbon dioxide levels in the atmosphere would raise the average surface temperature by five to six degrees Kelvin. Despite all of these discoveries, there was still no acknowledged link between human activity and the increase in carbon dioxide emissions or global temperature.

> "The effects of climate change are coming faster, and more intensely, than any scientists predicted."

In the 1950s, the ideas of anthropogenic climate change and the need for "climate control" were introduced by scientists John Von Neumann, Roger Revelle, and Hans Seuss. It wasn't until 1965 that the President's Science Advisory Committee addressed air and water pollution, making it the first time the U.S. government publicly acknowledged climate change. In 1970, a group of scientists formed the Study of Critical Environmental Problems (SCEP). This produced a dire warning that the potential long-term consequences of CO_2 on the climate are extremely serious and need to be researched and monitored more. This warning worked: in 1972, the UN had its first meeting on the "human environment". And in 1995, the Intergovernmental Panel on Climate Change (IPCC)—backed by the World Meteorological Organization and the United Nations Environmental Program—stated, "the balance of evidence suggests a discernible human influence on global climate."

Flash forward to today: 24 years later, little action has been taken. The effects of climate change are coming faster, and more intensely, than any scientists predicted. Major changes in weather—in addition to larger, more powerful storms—have already started.

Flash forward to today: 24 years later, little action has been taken. The effects of climate change are coming faster, and more intensely, than any scientists predicted. Major changes in weather —in addition to larger, more powerful storms—have already started.

In 2013, the first large international treaty, the Paris Agreement, was agreed upon to combat climate change. The general goal of this agreement was to strengthen the global response to climate change to limit the global temperature rise to below a 2 degree Celsius rise from pre-industrial levels. 196 countries have signed the agreement, and 183 countries have ratified this agreement.

Some, like Thunberg, believe that the world isn't doing enough. Despite the unprecedented Paris Agreement, some countries are not actively taking steps to combat climate change. The US pulled out of the agreement and has rolled back many environmental protection policies in recent years. However, some countries are doing more than their part; smaller countries like Tunisia and Peru have started cracking down on dumping hazardous waste. With the speed of the effects of climate change being disputed, the future seems uncertain. However, without major action from large countries, there is little that can be done to solve the crisis.

Nature (2016), DOI: 10.1038/nature19082
The Royal Society Publishing (1864), DOI: 10.1098/rstl.1864.0005

PHOTO BY SHUTTERSTOCK

Elephants in your backyard:

Megafauna could return to the great plains

BY BINH DANG, ECOLOGY AND EVOLUTIONARY BIOLOGY, 2022

DESIGN BY KYLA VIGDOR, DESIGN, 2021

Humans have largely affected the natural world to the point that almost no species or ecosystem can accurately be studied without considering some sort of anthropogenic activity. Even 13,000 years ago during the Pleistocene epoch, humans heavily influenced other organisms from woolly mammoths to giant armadillos. The greatest influence they had on the animals of this era? Extinction. The Pleistocene extinctions of this time are largely credited to both humans over-hunting the fauna in North America and the rapidly changing climate, which marked the end of the Ice Age.

A movement in conservation biology—motivated by restoring ecological potential and making amends for past human excess—hopes to rectify this overexploitation through Pleistocene rewilding. Typically, rewilding is a management tool used to restore a damaged or lost ecosystem to its previously wild state by introducing apex predators or keystone species. One example of this is restoring a riverine ecosystem by reintroducing beavers that build dams, which create a micro ecosystem for other organisms to inhabit and thrive. Pleistocene rewilding takes this approach one step further: Rather than introducing recently extirpated, or locally extinct, species, it aims to introduce species that are modern-day ecological equivalents or descendants of extinct Pleistocene species.

> "Although the idea of an elephant roaming the fields of Kansas seems far fetched, the science behind it isn't."

Thirteen thousand years ago in North America, woolly mammoths, saber tooth tigers, and giant ground sloths roamed the continent. These megafauna (large animals) lived in the last period before humans began significantly impacting the globe. Using the principles of rewilding on a larger time scale, this would mean introducing similar species to North America. Woolly mammoths and saber tooth tigers have long been extinct, but some of their relatives have not yet succumbed to the same fate.

Proponents of Pleistocene rewilding endorse introducing species such as elephants, lions, and camels back into the North American wilderness. The idea is that, like the aforementioned riverine ecosystem, the ecosystems of North America have not functioned optimally in the absence of these keystone species. Although the idea of an elephant roaming the fields of Kansas seems far-fetched, the science behind it is not. Woolly mammoths lived in the Great Plains of North America long before humans ever stepped foot on the continent. Elephants, modern descendants of the woolly mammoth, knock down and trample vegetation, and this environmental change allows other species to thrive in the newly altered habitat. It is not a stretch to assume woolly mammoths filled the same ecological niche in their own time.

The introduction of these proxy species would meet several conservation goals, the first being the restoration of North American ecosystems. The niches of the Pleistocene megafauna have remained vacant since their extinction. Considering the beneficial species interactions among apex predators, large herbivores, and smaller animals in Africa and Asia, the fauna and flora that coevolved to interact with the Pleistocene varieties would also benefit from a similar species presence and increase the ecological potential of the region.

Another conservation goal being touted by rewilding is the conservation of extant megafauna. It is well known that elephants and tigers are endangered—with humans playing a major part in that. By introducing these animals back into the Americas, they would be allowed to flourish without threats of poaching or habitat destruction. Swaths of land would be sectioned off, so these introduced species could thrive and interact with the natural environment without fear of encroachment by humans.

The aims of rewilding are intuitive, but there are some caveats to consider before loading up boats with lions and tigers. Pleistocene rewilding operates on the assumption that ecological processes haven't changed since then, but there isn't a large body of evidence to support or refute this. Another concern is the potential to introduce new diseases or pathogens to native or imported species, which is difficult to assess in advance. Lastly, there are the social and practical concerns. The two strategies for introducing novel species are in a fenced off area or simply in the wild. The issue with the former is that the fenced enclosures needs to be very large to accommodate the large animals. The issue with the latter is obvious: People don't want a wild tiger finding its way into their backyard.

While this novel strategy needs some development, it isn't as implausible as it seems. With more data on the impacts of introducing extant megafauna, Pleistocene rewilding could be on the cutting edge of future conservation practices. Maybe one day you can look out your window and see cheetahs dashing across the prairie.

Philosophical Transactions of the Royal Society B (2018). DOI: 10.1098/rstb.2017.0432
Trends in Ecology and Evolution (2007). DOI: 10.1016/j.tree.2007.03.001
The American Naturalist (2006). DOI:10.1086/508027
Biological Reviews (2018). DOI: 10.1111/brv.12432
Philosophical Transactions of the Royal Society (2018). DOI: 10.1098/rstb.2017.0440
Biological Conservation (2006). DOI:10.1016/j.biocon.2006.04.003

PHOTOS BY UNSPLASH AND SHUTTERSTOCK

Rewilding could be used as a climate change mitigation strategy since introduced species can maintain current vegetation composition and prevent plant encroachment from lower latitude species.

There was no ecological succession after the extinction of the Pleistocene megafauna, so their niches were never filled again.

Woolly mammoths and elephants share the niche of eating small trees and shrubs to maintain grassland ecosystems.

Saber tooth tigers and cheetahs share the niche of controlling populations of small herbivores via predation to prevent overgrazing of grasses.

Polluted in the womb

BY THERESA CHUNG, HEALTH SCIENCE, 2023
DESIGN BY KATIE GREEN, BIOENGINEERING, 2022

In recent centuries, the burning of fossil fuels has dramatically increased the amount of pollutants in the air. Coal, one of the most used fossil fuels in the world, is very toxic. It releases dangerous compounds, including carbon monoxide molecules, particulate matter (or soot), mercury, and more. In areas where fossil fuels are being burned regularly, the population is forced to continually breathe in these substances. This can lead to severe damage to humans' respiratory systems, nervous systems, and cardiovascular systems. In addition to affecting the directly exposed population, even those who have not yet been born are being affected by pollution--a mother can actually present a danger to her baby still in the womb, as the pollutants inside her body can reach the fetus itself.

A 2019 study done by researchers at Hasselt University in Belgium found that samples of placenta after birth showed accumulations of black carbon (BC) particles on the side that faces the fetus. These BC particles arise from the emission of burning fossils fuels, such as gasoline, diesel, and coal, and remain in the environment as air pollutants. The study found that in women who had less exposure to air pollution, there was an average particle count of 9,500 BC particles in the placenta. For women who were highly exposed, there was an average count of 20,900 BC particles present. The researchers concluded that higher amounts of air pollution correlated with higher amounts of BC present in the placenta.

The universal understanding of the placenta's purpose is that it is a temporary organ that serves as a barrier between the fetus and the mother during pregnancy, in order to protect the fetus from any harmful things present in the mother's body. However, it turns out that the placenta is not impenetrable enough to prevent the permeation of pollutants. Previous research has shown that pollutants such as alcohol and therapeutics have crossed through the placenta and made it to the fetus. Thus, there is little reason to doubt the idea that pollutant particles such as BC could not make it past the placenta and cause severe damage to the fetus.

The study found that these BC particles have already accumulated on the placenta during the early stages of pregnancy. The fetus undergoes development in a stage known as the "critical window," during which the fetus is most likely to be affected by environmental exposure. Prior research done in 2007, 2011, and 2013 by Beate Ritz, Carole B. Rudra, and Dr. Marie Pedersen in the United States and the European Union has shown that particulate matter that has reached the fetus during the critical period is "associated with lower birth weight, preterm birth, and intrauterine growth restriction." Fetuses exposed to pollutant particles, including BC, are often born prematurely, or are smaller than they should be because they were not able to grow fully in the womb.

As we continue to use fossil fuels that release toxins into the air we breathe, the amount of people who start off their lives already subject to the harmful effects of pollution will continue to increase. Particulate matter present in air pollutants can easily be breathed in and kept in the body for as long as pollution remains an issue. As more and more fossil fuels are being burned everyday, studies are more frequently coming out to show that humans are suffering due to the pollutants present wherever they go. Breathing in polluted air is causing asthma in some, while others are suffering from lung cancer due to the carcinogens present in these pollutants. If we continue to burn fossil fuels at this rate, we can expect that most people will have already have accumulated so many toxins inside our bodies that it will be rare for us to not be plagued by a pollution-related health issue early in life.

Nature Communications (2019). DOI: 10.1038/s41467-019-11654-3

Duckweed: A plant for humans, water, and… well, ducks

BY CARA PESCIOTTA, PHYSICS, 2022

Duckweed is hailed as a miracle plant, claiming to be a panacea for sustainability issues. The name is appropriate—it is a weed-like plant eaten by ducks. Duckweed is the smallest known flowering plant and grows quickly in still water, often covering the surface.

Rutgers University's Lam Lab proposes duckweed may act as carbon neutral biofuel, animal feed, and treat wastewater —helping solve a rising renewable resource crisis. Rutgers currently owns the largest collection of duckweed in the world, putting them at the forefront of the plant's technological development.

Duckweed's speedy reproduction makes the plant practical, particularly in price. In addition to ordering duckweed yourself for just $1 on eBay, "oil would have to cost only about $72 per barrel for larger duckweed refiners to be cost-competitive" as a biofuel source, according to the American Chemical Society. Oil prices last reached this threshold in 2018. The current oil price sits between $50 and $60.

Other biofuels, such as corn and wheat, are more sustainable than oil. However, they still present issues. These sources take up to eight months to harvest and already double as human food sources. Duckweed eliminates these issues as a minimal-effort crop, reproducing asexually and being able to cover a pond in one day. It is also considered carbon neutral since it absorbs the same amount of CO_2 while growing as it releases when its ethanol derivative is burned.

The plant also feeds on other pollutants such as nitrogen and phosphate, making it a promising water purifier. A University of Jordan study cited an average decrease of 40 percent in nitrate and 35 percent in phosphate in irrigation ponds, as well as decreases in many other minerals. This could help communities that cannot afford costly standard water treatment plants, as they require long-term business models and many resources.

The University of Jordan study then used duckweed-treated water to research its effect as a food source on laying hens. Hens' weight, egg weight, and production rate were not impacted when duckweed replaced 10 percent of soybean feed, showing hopeful results in use as sustainable feed. It is high in protein and has no indigestible material, while corn and soybeans have less protein and 50 percent indigestible material.

Duckweed's versatile qualities make it very attractive for practical uses. As a staple in energy, waste management, and agriculture industries, duckweed is a plant for more than just ducks.

DEStech Transactions on Computer Science and Engineering (2016). DOI: 10.12783/dtcse/mcsse2016/10943

PHOTO BY SHUTTERSTOCK

TRIPPING OUR WAY INTO CONSCIOUSNESS

BY CLARA BILS, BEHAVIORAL NEUROSCIENCE, 2023

DESIGN BY KYLA VIGDOR, DESIGN, 2021

At some point between 2,000 and 2 million years ago, *Homo sapiens* diverged from their closest relatives as our neocortex nearly doubled in size. Recent research has discovered that the ARHGAP11B gene may have played a role in this expansion; the gene was detected in our hominid cousins, the Neanderthals and Denisovans, but not in ape genomes. When the gene was placed in embryonic mouse brains, folding in the brain, or gyrification, occurred, which correlates to an expansion of the neocortex.

The study concludes that the gene possibly contributed to our grand evolution long ago, leaving room for other explanations. One of these explanations comes from renowned mycologist and psychonaut Terence McKenna, who coined the "Stoned Ape Theory" in 1992. McKenna claims that "the synergy of the psilocybin in the hominid diet brought us out of the animal mind and into the world of articulated speech and imagination." Psilocybin is the psychoactive compound in magic mushrooms. That's right, McKenna claims that we tripped our way into conscious, higher-level thinking.

In a nutshell, the theory presents that *Homo erectus* was forced into grasslands as the African climate got drier. There they stumbled upon scat-fostered mushrooms containing psilocybin and had multiple community-wide psychedelic trips—ultimately resulting in the expansion of the neocortex. Specifically, McKenna claimed that shrooms increased sexual drives, heightened clarity while hunting, and induced the genesis of speech. Some psychedelic users experience glossolalia (also known as "speaking in tongues"), which is the production of sounds that resembles a language unknown to the user. McKenna claims this phenomenon may explain how *Homo sapiens* began using language as a means of communication.

In 2017, Paul Stamets, a modern-day mycologist who produces medical applications derived from various mushrooms, expounded the hypothesis further. Stamets specified that the likely source of the psilocybin was the fungus *psilocybe cubensis*, whose psychedelic properties incite a process known as "epigenetic neurogenesis." In this case, epigenetic neurogenesis is the process in which psilocybin replaces serotonin as a neurotransmitter, initiating neurogenesis and creating new pathways in the brain. Stamets suggests that psychedelics also reduce fear and increase empathy, explaining how the species became better hunters and communicators. A study conducted in 2013 found that small doses of psilocybin increased neurogenesis within a mouse population and heavily reduced classically conditioned fear responses.

As more evidence arises, we hone in on the neurological and mental adaptations of those who walked before us. Yet indisputably, there is not enough evidence to support the Stoned Ape Theory or to conclude that one gene alone is responsible for our species' ascent into consciousness.

Current Biology (2017). DOI: 10.1016/j.cub.2017.01.020
Experimental Brain Research (2013). DOI: 10.1007/s00221-013-3579-0

GRAPHIC BY SHUTTERSTOCK

Little *sod* house on the prairie

BY LILLIE HOFFART, ENVIRONMENTAL SCIENCE, 2022

With the passage of the Homestead Act in 1862, the Plains region, or "Great American Desert" was parceled out in plots. After paying a fee, farming, and living on the land for five years, the homesteader became the land's owner. With the passage of the Homestead Act in 1862, the Plains region, or "Great American Desert," was parceled out in plots. After paying a fee, farming, and living on the land for five years, the homesteader became the land's owner.

This was not an easy task. Summers reached a heat of over 120 degrees Fahrenheit, and blizzards in the winter would bury livestock. While the grass could grow to over six feet tall, trees were scarce. For settlers in the second half of the 19th century, one of the most basic needs, building an adequate shelter, was a challenge. They turned to the earth for the solution, constructing sod houses, or "soddies," made from bricks of soil.

The key to the construction of a sod house? Grass roots. These fibrous networks grew thickly intertwined and sometimes over 10 feet deep. They could be removed in dense chunks that would withstand years of rain, weathering, and even fires.

First, large strips of soil were divided by ploughing long troughs into the ground—slicing through thick prairie grass roots. The resulting sections were then cut into smaller, rectangular bricks (around 3,000 bricks were required to build a 16 foot x 20 foot house). These bricks were laid into walls, forming the main structure of the house. Then, scarce timber could be used as poles for roof support, often with more strips of sod covering the top of the house.

The concept of using soil in building is far from new. The construction of earth-based structures has been traced back to many cultures: from Viking-age turf houses, to the adobe homes of Southwestern United States tribes, to the rammed-earth walls in the Great Wall of China. These techniques are so popular because dirt is easily accessible and has a high thermal mass. Thermal mass slows the passage of heat through the structure, so earthen homes stay cool in the summer and warm in the winter.

Though it has fallen out of use, the sod house remains. In Custer County, Nebraska, the "Sod House Capital of the World," a survey found 22 houses still standing, many containing original walls over 100 years old. This modest home remains a symbol of the West and the resilience of both the homesteaders and their grass roots.

The history of the mystery of Area 51

BY SOPHIA ANAIN, BEHAVIORAL NEUROSCIENCE, 2022

From numerous conspiracy theories to the organization of a raid, Area 51 has captured the public's curiosity for decades. A YouGov poll conducted in 2019 found that 54 percent of U.S. adults believe that the government knows more about unidentified flying objects (UFOs) than it admits. With more attention on the base this year than ever before, one must wonder—what sparked America's fascination with Area 51? Why do we think there are aliens there at all?

While suspicion surrounding Area 51 has been circulating since the 1980s, the government base has been around far longer. In 1955, CIA officer Richard Bissell traveled to Nevada and surveyed 38,400 acres of uninhabited land northwest of Las Vegas. Within three years, this territory was withdrawn from public use by the US Atomic Energy Commission. For the next fifteen years, the research conducted at Area 51 was done under strict confidentiality. In 1974, astronauts from the Skylab space station took photographs of the region. Suspiciously, the National Photographic Interpretation Center immediately removed the images and had them stored in a restrictive vault; no one except government officials have seen the actual images.

Area 51 owes most of its infamy to Bob Lazar. In 1989, Lazar claimed to have worked at the military base trying to "back-engineer a downed alien spacecraft." While Lazar's claims have never been verified, his allegations sparked America's fascination with Area 51 and many reports of UFO sightings soon after. Speculations only increased over the next decade, particularly in 1996 when President Clinton signed a Presidential Determination making the base exempt from "any federal, state, interstate, or local hazardous or solid waste laws that might require disclosure of classified information concerning that location to unauthorized persons." Though laws were previously made protecting Area 51, its existence was not officially acknowledged until 2013. At this time, the Freedom of Information Act required the release of Area 51 related documents from the national security archive. The released reports detailed the testing of a U-2 spy plane in the area. Rather than confirming rumors of extraterrestrial aircrafts, this explained the numerous UFO sightings in the area.

About six years later, 21-year-old college student Matty Roberts would spark a movement to storm the base when he was "bored at 2 a.m." While the mass media coverage and a warning from the air force resulted in a small turnout, the air of mystery surrounding Area 51 persists.

PHOTOS BY WIKIMEDIA COMMONS AND PICRYL

The evolutionary roots of anxiety

BY RACHEL GRIEP, BIOLOGY AND PSYCHOLOGY, 2022

DESIGN BY LILLIE HOFFART, ENVIRONMENTAL SCIENCE, 2022

Often characterized by rapid breathing and a pounding heart, anxiety is a familiar feeling that everyone has experienced at one point in life or another. Anxiety disorders are currently the most prevalent mental illness in the United States. According to the Anxiety and Depression Association of America, 18.1 percent of the adult population (or approximately 40 million people) suffer from an anxiety disorder each year. Although unpleasant, anxiety is useful and has been shaped over many generations through natural selection. But, anxiety, like all good things, is no longer good in excess and too little anxiety can be just as detrimental. In order to understand and effectively treat anxiety disorders, we must understand the evolutionary roots and benefits of anxiety as well.

Researchers view emotions such as anxiety as physiological and cognitive response patterns that evolve through natural selection to help humans achieve specific goals and avoid threats. Psychologists have long recognized the evolutionary benefits of anxiety: John Bowlby, Mary Ainsworth, and Melanie Klein discussed the benefits of separation anxiety in infants. In his book *Fears, Phobias, and Rituals*, psychologist Isaac Marks discusses stranger anxiety, which arises in infants around six months of age. Researching other species, specifically primates, has shed light on the evolutionary roots of stranger anxiety, as infanticide is a strong selective force in many animals; evidence shows that human infants are more likely to be abused or killed by strangers than by those who are familiar. Infants who develop stranger anxiety tend to be the ones who survive. Transcultural and universal fears such as separation and stranger anxiety are most likely adaptive. It is important to note that if infanticide were rare, this evolutionary hypothesis would not hold up.

> "Although unpleasant, anxiety is useful and has been shaped over many generations through natural selection."

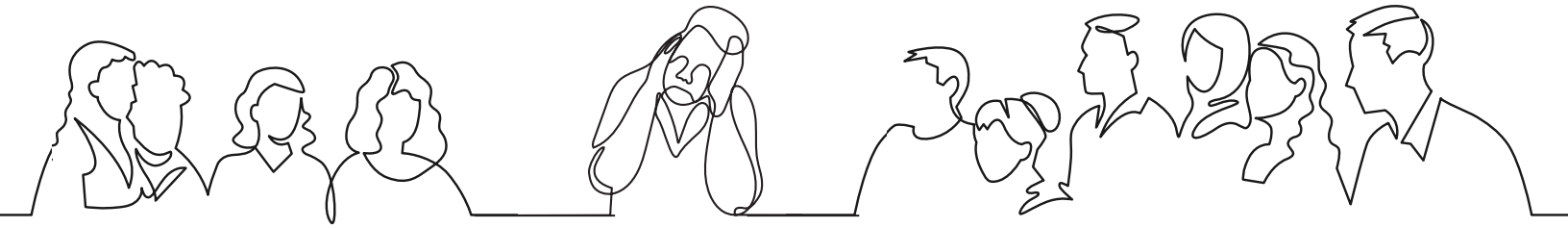
Some fear responses are primitive and involuntary, such as a response to a loud sound or crash, whereas other fears develop over time and are learned from example. Infants often first form separation anxiety after experiencing their mother's absence for the first time. Then with further exploration and a better understanding of death, children develop a fear of heights, monsters, lions, and tigers. Middle childhood is characterized by a fear of injury and accidents, and adolescence is characterized by the development of the more complex fear of social isolation. Children evolved to develop domain specific fears to evolutionarily recurrent danger. In the 2012 Childfund Alliance report "Small Voices, Big Dreams," child fears from over 5,000 people from 44 countries were recorded. The report found that a majority of children, including children growing up in urban environments, have a fear of "dangerous animals and insects." Evolutionary fears are not catching up with modern day threats—one is much more likely to die from a car crash now than a poisonous snake bite.

There is even an evolutionary explanation behind agoraphobia. Agoraphobia is defined as a type of anxiety disorder in which people avoid places or situations that cause them to feel panicked or embarrassed. Mild agoraphobia is comparable to animals in the wild not wanting to leave their home territorial range. Animals that travel beyond their familiar range often experience danger, and increased wariness helps them survive.

People can find joy in anxiety as well. People use fake anxiety-inducing stimulants such as horror movies as entertainment and as a way to train themselves to handle anxiety when it becomes real. Horror movies work because they play to the common fears that reside inside almost every human being, such as environmental stressors, predation, social isolation, contagion, and intraspecific violence. These fears are known as universal triggers. Domain specificity is an evolved sensitivity to these specific dangers. It is the hypersensitivity of domain specificity that leads to category expansion until harmless objects become included in a particular category, ultimately leading to anxiety disorders. For example, someone who has developed a phobia of moths may have experienced the category expansion of predation until it not only included harmful predators such as snakes, and spiders, but also a harmless species such as moths.

Anxiety is a defense shaped through natural selection. As treatment of anxiety disorders by prescription medication becomes more prominent, it is important to understand in which situations anxiety is necessary and to distinguish between which physiological aspects of anxiety reflect abnormalities and which reflect normal operations of the anxiety system. Through understanding the evolutionary roots of anxiety, the most effective treatments to anxiety disorders may be found.

Ethology and Social Biology (1994). DOI: 10.1016/0162-3095(94)90002-7
Current Biology (2013). DOI: 10.1016/j.cub.2012.11.055



GRAPHICS BY SHUTTERSTOCK

Debugging the gender gap in computer science:

Women were the original programmers, so why aren't they still doing it?

BY CLAIRE BOHLIG, MECHANICAL ENGINEERING, COMPUTER SCIENCE MINOR, 2023 DESIGN BY KYLA VIGDOR, DESIGN, 2021

Computer programming is stereotypically a male nerd field, much more than other scientific or engineering disciplines. When you picture a programmer, it is probably a geeky-looking man sitting at his computer typing away. This would be a funnier image if it wasn't partially true. Women only hold 20 percent of jobs in computer science, and the percent of computer science degrees given to women was cut in half from 1984 to 2013, from 37 percent to 18 percent. But this disparity, and these stereotypes, weren't always reality.

> "None of the girls were ever introduced [at conferences or to the press]; we were just programmers."

The very first programmer was a woman. Ada Lovelace, a British aristocrat and daughter of the famous poet Lord Byron, wrote programs for a machine named the "Analytical Engine" built for performing mathematical calculations. After studying just the schematics, Lovelace was able to write an algorithm for the engine to calculate Bernoulli numbers, a complex numerical series. Lovelace continued to write programs, papers, and notes about the Analytical Engine, and in one note she landed upon a fundamental of modern computer science. Note G explains that computers eventually should "act upon other things besides number." Lovelace developed the concept that through abstract machine numbers, we can express powerful ideas, just as your laptop uses bits and bytes to supply you with cat memes. Sadly, the project was never funded and the Analytical Engine was never fully built.

It wasn't until the early 1940s that computing again had a focus and women were once again pivotal. During the World Wars, women were hired as workers to calculate ballistic trajectories. When done by hand, this took hours or even days, so governments across the world scrambled to find any way to calculate them quicker. Two American engineers were hired to build the Electronic Numerical Integrator and Computer (ENIAC), and the female "computers" were hired to continue calculating trajectories, this time on a multi-room calculator.

These "computers" were the first modern programmers, punching holes into pieces of paper joined at the ends to create 'loops' that were fed into the ENIAC. "None of the girls were ever introduced [at conferences or to the press]; we were just programmers," ENIAC programmer Kay McNulty described in the book *Recoding Gender: Women's Changing Participation in Computing*. Men did not program the ENIAC, as they were the ones building and developing the computer, the ones doing the hard, flashy, and impressive labor.

So if the first programmer was a woman, and the idea of programming was introduced by a woman, and the original programming teams were women, what happened between then and now to cause such a disparity in the field?

Since programming was brand new, no one knew what the requirements were for being a programmer. Post World War II, businesses who wanted to use the new technology would hire anyone with a college degree and recruit for programming jobs on college campuses. But in the 1950s, only 24 percent of college graduates were women, blocking most that were interested from recruitment. Adding to that, women weren't expected to continue in a career path. Of the programmers working on the ENIAC machine, the majority of women left the field voluntarily within two years to have children or to get married.

But the main reason for the conversion of female computers to the "bro-grammers" we see today is that programming underwent a major rebranding. A movement in the late 1960s began to market programming as "software engineering," and since engineering was a male dominated career path, it could safely absorb the programming field under a single male associated blanket. Men became the default hire based on stereotypes alone, which was enough in a booming field to ensure the cycle of men hiring men would continue as the decades went on.

Today we know that men aren't naturally better suited for engineering any more than women are naturally better suited for housework (on average the sexes perform the same on US standardized tests). And yet the number of female programmers in modern society continues to shrink.

Women were the original programmers, and had no issue developing brand new ways of thinking that are fundamentals of computer science today. With computers gaining more and more prevalence in our lives and cultures, programmers are needed more than ever. If Ada Lovelace could program a theoretical idea of a computer, women should be able to program on real computers today.

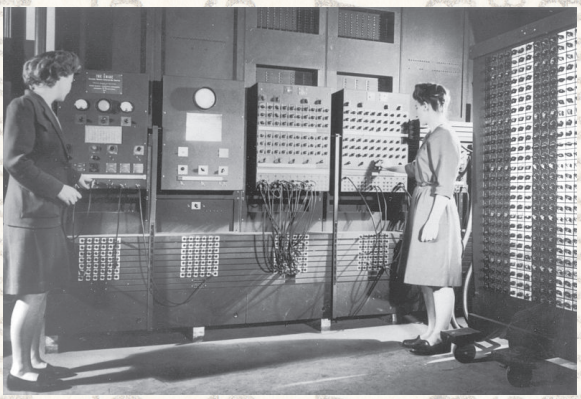


PHOTO BY WIKIMEDIA COMMONS

Booting up:

The curious origin stories in the language of computing

BY WILLIAM BONAVENTURA, APPLIED PHYSICS, 2021

The field of computer science is riddled with technical jargon. Just think of common movie scenes in which a coder spews a mouthful of incomprehensible phrases, leaving the other characters completely lost. Although much of the language describing how data is stored and transferred in our society sounds foreign to many, occasionally a word or two will leak out into the public domain due to its simplicity and eccentricity. It's worth taking a look at the illuminating and often amusing backstories behind a few of these words.

Labeling a discovered computer issue an insect may not be the first idea that comes to mind. Nevertheless, the term "bug" is largely considered to have gained popularity one fateful night in 1947 at Harvard University. Former Navy Rear Admiral Grace Hopper was working with an electromechanical computer called the Mark II when she discovered an error in the system. The culprit was a moth stuck in one of the relays, an electrical switch. The moth was removed and taped to the team's log book for preservation—the first named instance of "debugging" a computer. From then on, hunting for "bugs," or minor problems in software, had cemented its place in the computational lexicon.

GRAPHIC BY SHUTTERSTOCK

Another peculiar, yet ubiquitous, phrase in internet communication is "spam." Spam refers to bulk, untargeted junk mail that is commonly distributed for commercial purposes. The origin story behind the phrase is one rooted in an altogether different domain from computer science: comedy. Specifically, it stems from a 1970 Monty Python sketch in which the popular canned meat spam was chanted repeatedly, much to the annoyance of the angry shop owner. In turn, the notion of spam became synonymous with flooding a system with large amounts of data. Remarkably, this is not the only Monty Python reference in the programming world. One of the most popular programming languages, Python, was also named after the comedy troupe, according to the official Python documentation; the language's developer, Guido van Rossum, turned to the BBC series "Monty Python's Flying Circus" for inspiration for the clever name.

These phrases provide a small glimpse into the curious naming of technological concepts. Using familiar terminology may make these ideas more accessible to the general public, helping promote computer science literacy and enthusiasm. Creative naming may be the best way to debug subconscious fears towards coding as a whole.

Expand your mind (and heal it, too!):

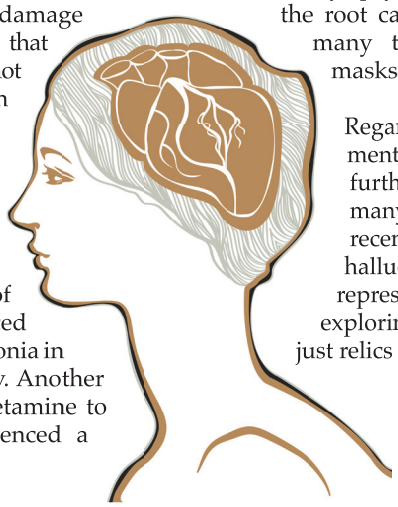
The use of psychedelics to treat mental health issues

BY LILY WEBER, BIOLOGY AND ENGLISH, 2023

When you think of the term "psychedelics," there are many things that probably come to mind: hippies, music festivals, or even certain types of music. What probably doesn't come to mind is treatment of mental illness. Yet, despite stigma and bureaucratic barriers, scientific interest in the therapeutic potential for psychedelics is only growing. According to Schenberg et al. published in 2018, the primary interest of current studies is to investigate whether psychedelic drugs may have a place in psychiatric care.

Importantly, as highlighted by Krebs et al. in 2013, many psychedelics, including LSD, psilocybin, and mescaline, are not associated with risk of brain damage or addiction. The study also concluded that psychedelic use by its participants was not associated with worsened mental health outcomes and was even seen to be correlated with decreased mental health issues.

One doesn't have to look very far to find a plethora of studies providing scientific backing for the use of psychedelics to treat mental health issues. One group of researchers found that psilocybin reduced depressive symptoms, anxiety, and anhedonia in patients even months following the study. Another group conducted a clinical trial using ketamine to treat chronic PTSD; participants experienced a rapid and pronounced reduction in their symptoms. A third group conducted a meta-analysis on clinical trials using LSD to treat alcoholism and determined LSD had a significantly positive impact on alcohol misuse.



So how are these "illicit" and taboo drugs beneficial to so many? There are many theories, though the one most commonly cited relates to the spiritual or even religious experiences offered by psychedelics. These experiences may help foster a feeling of connectedness with life and greater mindfulness overall. One clinical psychologist, Dr. Rosalind Watts, says psychedelics may have the capability to confront the root causes of mental health issues as opposed to many traditional medications, which often only masks symptoms.

Regardless of how exactly they function to treat mental health, it's clear that psychedelics warrant further research and consideration. Fortunately, many are working to help make this a reality. Denver recently became the first city to decriminalize hallucinogenic mushrooms. This does seem to represent the beginnings of public receptiveness to exploring these drugs in greater depth as more than just relics from the 60s.

DESIGN BY LILLIE HOFFART, ENVIRONMENTAL SCIENCE, 2022
GRAPHIC BY SHUTTERSTOCK

TALKING TO YOUR MOTHER WITH THAT MOUTH:

The development of language in infants

BY EMMA TUSUZIAN, PSYCHOLOGY, 2023
DESIGN BY ANANYA DHANDAPANI, UNDECIDED, 2023

At four months old, we begin our linguistic journeys with receptive language, or the ability to comprehend speech. This means we can already distinguish phonemes, the most basic units of sound. Around the same time, we develop productive language, the ability to produce words and speech. At ten months, we start babbling, playing with different sounds until they become language-specific. *"Mama."* The meaningful one-word stage comes in at around one year old, and by eighteen months, we are armed with two-word speech. *"More food."*

Countless parenting books and online guides indulge new mothers with information about their baby's growth, teaching them when to root for their child to say "mama." The stages of language development are easy to observe and commonly known, but the "how" and "why" behind childhood language acquisition remain a mystery. From B. F. Skinner's idea of nurture to Noam Chomsky's idea of nature, renowned 20th century psychologists have attempted to explain development, learning, and thinking.

Skinner's Operant Learning Theory suggests we learn language by associating words with their meanings, imitating the language patterns observed in others, and revising our own use of language based on reinforcement from authority figures. Being "nurtured" by external and environmental influences allows us to develop language. Chomsky's Theory of Inborn Universal Grammar, however, claims that children's language use is too complex to be explained by operant learning. Children instead come pre-wired with a language acquisition device, a theoretical innate mental capacity allowing infants to acquire and produce language. This language skill is therefore a "natural" capacity hard-wired into the brain at birth.

In addition to theories of different language acquisition sources at infancy, there is a popular concept surrounding the significance of age in language development. Some psychologists believe that childhood is a limited window of time when we are especially apt to learn and master skills; it is a critical period for language development. After age seven, children who have never had exposure to language struggle to master it and do not develop the fluency of a native speaker. Speed of development is one of many other differences between language learning in children and adults, which may give insight into what makes this age vital for communication.

> "The stages of language development are easy to observe and commonly known, but the "how" and "why" behind childhood language acquisition remain a mystery."

Though many hypotheses surrounding acquisition are difficult to prove, 21st century research has made leaps and bounds in understanding the importance of a child's early relationship with language. A child's learning environment is never without the slow, exaggerated speech of adults fawning over an endearing babbling baby. While "baby talk," also known as Parentese or Motherese, often seems instinctual, it has been observed to support language development. In a study on the effectiveness of Parentese, a slow rate of speech and an emphasis on vowels led to large improvements in infants' ability to recognize words. Infants were then better able to differentiate these clearer sounds when given enough time to process them.

Repetition of words also seems to support a strong mental representation, or a symbolic connection to words, and eventually a more accurate production, or articulation of those words. A University of Pennsylvania study investigated the ability of newborns to learn simple repetition-based structures through brain imaging. Scientists had newborns listen to basic syllable sequences with immediate repetition (e.g. "mubaba") mixed with random control sequences (e.g. "mubage"). They found repetition sequences triggered *greater* brain activation than the random sequences. The brains of newborns responded the same way to repeated patterns of stimuli *automatically*, suggesting this was most likely a natural mechanism. As trials continued, activation only increased in response to the repetition sequences, showing that repeated exposure improved recognition of the pattern. Ultimately, the study suggests words that contain repeated sounds, which are typical of baby talk, have an advantage for early language learning.

While many studies point to the benefits of Parentese, some encourage parents to learn strategies for optimal language learning. Knowledge and feedback on language practices meant immediate and longer-term positive impacts on language skills, as babies showed improvements at 14 months compared to those of parents without coaching.

Recent research has suggested exaggerated speech offers the *best* input for language learning. Infants tested were capable of segmentation, identifying boundaries between words or syllables in spoken languages, only when they heard "baby talk." This is just the start of understanding language development in its prime efficiency, which could lead into discussions of other forms of communication. Do these discoveries have further implications about mannerisms or instincts that unknowingly influence the development of our children?

Proceedings of the National Academy of Sciences (2008). DOI: 10.1073/pnas.0806530105
Developmental Science (2019). DOI: 10.1111/desc.12762
The Journal of the Acoustical Society of America (2010). DOI: 10.1121/1.3419786
Cognition (2016). DOI: 10.1016/j.cognition.2015.12.004

PHOTO BY UNSPLASH

CRIMINAL MINDS:

THE BEGINNINGS OF BEHAVIORAL ANALYSIS

BY YASMINE MYFTIJA, BIOLOGY, 2021

DESIGN BY MARISSA KEESEY, ELECTRICAL ENGINEERING, 2022

Touting a legacy of 15 entertaining seasons on television, "Criminal Minds" centered around the FBI's Behavioral Analysis Unit (BAU) and the agents that use behavioral science-based methods to track down heinous killers. You've probably watched it, or know someone who watches each episode with popcorn in hand. But how much do you really know about the Behavioral Analysis Unit?

The BAU was created in the early 1970s as an effort to curb the increased prevalence of homicides and sexual assaults occurring in the United States. It was founded by two trailblazing agents: Robert Ressler, a veteran who solved robberies, arsons, and homicides within his post in the Army, and John Douglas, a hostage negotiator for the FBI. The program's main goal was to study incarcerated criminals in an effort to gain insights that would hopefully help prevent or solve future crimes. While the study of criminal behavior wasn't new, the use of psychology to create profiles of a criminal was rarely used, if ever, and law enforcement relied primarily on hard evidence. In fact, the term "serial killer" didn't exist until Ressler coined it to describe the pattern of multiple instances of murder in different locations over time, allowing for periods in which they would cool off and return to their lives.

A psychological profile is, by definition, a tool that helps law enforcement narrow a suspect pool; it provides a description of the type of suspected perpetrator based off of the evidence at a crime scene and the many clues left behind that reveal one's behavioral patterns and personality. To build a basis for this system, Ressler and Douglas set out to meet with and study incarcerated killers such as Ed Kemper, the infamous "Co-Ed Killer" who inspired the character of Buffalo Bill in the film "Silence of the Lambs." Kemper was eager to talk to the agents and provided insights into the minds of serial killers, including his proclivity to harm animals as a child, which paralleled that of others, and a deep-rooted childhood trauma traced back to his mother, which influenced his choice of victims. The two agents gathered information from serial killers and predators about their motives, how they planned crimes, the details of their crimes, and the disposal of evidence, amongst other topics such as childhood and family life.

It was through these interviews that Ressler and Douglas managed to begin the field of forensic psychology and create a basis of the three main types of perpetrators: organized offenders, disorganized offenders, and mixed offenders. The distinctions lay in the level of intelligence; for example, organized killers were described to be smarter, with a stable lifestyle, and a tendency to dispose of evidence. Disorganized killers had a lower intelligence, carried out their crimes with less forethought, often had a history of mental illness, and were more violent than their organized counterparts. The body of knowledge built through Ressler and Douglas's interviews provided substantial evidence supporting Macdonald's Triad, a theory from 1963 which linked pyromania, bedwetting past the usual age, and extreme cruelty to animals to particularly violent homicidal behavior.

Furthermore, Ressler and Douglas's work in the field revealed that the crime scene held more than physical evidence and could be helpful in determining the killer's psychology. They may leave behind a signature, such as using a certain knot or harming the victim in a specific way, that may even indicate to the profiler a mental disturbance or personality type. In the end, they had interviewed 36 incarcerated criminals and, with the help of Ann Wolbert Burgess's studies with sexual assault victims, compiled and created a working database.

Since Ressler and Douglas began their groundbreaking work, the Behavioral Analysis Unit has expanded immensely, including branches into violent extremism, terrorism, violent prison and street gangs, and hostage negotiations. It's even been immortalized in another television show, Netflix's "Mindhunter," a fictionalized but mostly true account of Ressler and Douglas's work.

Getting to the root of how humans understand music

BY ERICA YEE, INFORMATION SCIENCE & JOURNALISM, 2020
DESIGN BY LILLIE HOFFART, ENVIRONMENTAL SCIENCE, 2022

There is something about music that can hit the spot or make us feel a certain emotion. Those with untrained ears can pick up on slight variations in chords and melodies, even if they cannot always articulate the differences. It also seems that humans often share similar emotions and associations evoked by listening to the same music. Decades of research in the area of music acquisition and understanding back up these gut feelings.

To introduce this topic, it helps to first understand a bit of music theory. There are 12 notes in Western music, and they can most clearly be seen on a piano, where they are arranged in a repeated pattern. Out of these 12 notes, every major and minor scale is comprised of a seven-note subset. Each of those scales revolves the tonic, or the first note in the scale. The tonic note feels like home to a listener. That is, we instinctively want music to resolve, or land back at home, by ending on the tonic.

Music is made by using notes from a scale to create melodies — notes strung together horizontally over time, like a line that you can sing — and harmonies — notes stacked vertically and played at the same time to create a chord. In a chord, the root is structurally the most significant pitch and sounds the most prominent. Because the root is the basis of a chord, it also gives the chord its name. The root at any point in a song can change to make the music sound more interesting while the tonic remains the same.

The tonic is so important that musical compositions based on the tonic's scale are labeled based on the key of the tonic. It follows that compositions typically begin and end with a note in the tonic chord.

An influential study published in *Perception & Psychophysics* in 1994 found that implicit knowledge of varying aspects of musical structure developed at different ages in children. The researchers demonstrated that by the age of 5, children exhibit understanding of key membership — essentially, which notes sound like they belong with a given tonic. While children at this age did not not perform as well on recognizing implied harmony — a prototypical accompaniment to a melody, 7-year-olds and adult participants showed implicit knowledge of both.

A 2005 study in *Developmental Science* with slightly older participants, 6- to 11-years old, affirmed that children in Western-influenced countries had implicit understanding of common musical properties even without training. Each child heard a series of chords followed by a final chord. The final chord was either the tonic, the chord best suited to resolve a musical phrase, or a less stable chord. In one experiment, French children guessed if the target was sung with one of two vowel sounds. In another, Australian children guessed if the target was played on a piano or trumpet. In a third experiment, Canadian children guessed whether the target sounded harmonious or discordant. In all groups, performance was faster when the target was the tonic chord. Performance was also more accurate for the Canadian children with the tonic as the target.

One theory for how humans acquire such knowledge about music structure is based on the statistical properties of music. For instance, notes in a tonic chord may be more recognizable because they occur more frequently in a given composition than other notes in a scale. However, this theory of relative frequency of occurrence may be limited to explaining only some aspects of musical structure due to conflicting research findings. The *Perception & Psychophysics* study, for example, found that children seem to develop knowledge of key membership before implied harmony. But harmonic accompaniment is already present in music that young children are exposed to, such as TV show theme songs.

Much work has been done studying implicit understanding of Western musical concepts, especially in children. But there are still many more potential areas of further research on how the human brain understands and is affected by music. For the majority of music lovers, though, it's enough that a song just feels right. As American poet Henry Wadsworth Longfellow put it, "Music is the universal language of all mankind.

Perception & Psychophysics (1994) DOI: 10.3758/BF03213891
Developmental Science (2005) DOI: 10.1111/j.1467-7687.2005.00447.x

PHOTO BY SHUTTERSTOCK

BEFORE THE BEAKERS:
A HISTORY OF SCIENCE

BY AMANDA ZAVALA, CELL & MOLECULAR BIOLOGY, 2020

This summer, for the first time in a long time, I left the lab. I cleaned up my bench, closed all my data files, and went the way of the medieval scientist: I went to England, and I listened to lectures about what Greek philosophers thought makes up the world. Until about the 17th century, this was science—natural philosophy, to be more precise. A natural philosopher theorized about the building blocks of our world, and a theory only had credibility if it was supported by ancient thought. The work of Plato, Aristotle, and other well-known Greek philosophers made up the entirety of the coursework at the University of Oxford when it was founded. Oxford was a major hub of knowledge in the Middle Ages, one of the few not controlled by the church. Students came from around the world to become educated in the arts of rhetoric, grammar, arithmetic, geometry, astronomy, and music in small groups with a resident master.

Over eight hundred years later, Oxford hasn't forgotten its past. Colleges boast centuries-old traditions, and the student-master relationship has evolved into mandatory personal tutoring. They still have many of their original 13th century buildings, with yellowed limestone arches looming high and Latin mottos carved on every surface. Walking along the cobblestones in Oxfordshire feels like stepping back in time—then you spot an Oxfam thrift store, and maybe stop for ice cream and a bit of shopping. I personally had a wonderful time drinking a smoothie at Europe's oldest coffeehouse in between visiting the botanical garden and the History of Science Museum.

The History of Science Museum is one of the many gems that brought the England and the Scientific Revolutions Dialogue of Civilizations into being. The Dialogue started as an honors seminar by the College of Engineering professor Dr. Waleed Meleis, but he felt that a lecture on the state of scientific and engineering knowledge in the 20th century was incomplete without the context of how we've gotten to where we are. "We live in an era of what's hot, what's novel," Meleis said when I asked about what sparked his interest in the history of science. "Our education is focused on what's been learned in the last 50 years, but modern science and engineering is based on thousands of years of thought." The history of science is an orphaned subject, not history, not science, and not appreciated in a modern education. Without the context of how our scientific facts developed, we lose an appreciation for the art of discovery and the work of all the scientists before us. This love of the roots of scientific thought led Meleis to bring students to Italy to learn about how the Renaissance and Scientific Revolution influenced what he dubs the Computational Revolution of the 20th century, and then later to London to emphasize the work of key 17th century scientists.

No one better exemplifies why the Dialogue has moved to London or the evolution of scientific practice than Francis Bacon. Born in London and educated at the University of Cambridge in the early 17th century, he was initially a scholar of the medieval curriculum. He had a deep reverence for the philosophy of Aristotle, but was the first to publish in criticism of his work. Whereas the typical natural philosopher believed that the ancients had a sacred knowledge that could be rediscovered through study, Bacon and other prominent scholars of the Scientific Revolution believed in knowledge coming from the observation of nature and experimentation. The change in philosophical beliefs, brought on by disillusionment of the medieval university structure and the influx of information from the New World, led to a willingness to accept ideas outside the realm of what was suggested by the ancient Greeks. For the first time, humanity began to manipulate nature to understand it, and the natural philosopher became the scientist.

From the laboratory, it's hard to imagine a time when experimentation was controversial. There was a time when we believed that stars revolved around the earth in spherical shells, because the fifth element aether had a natural circular motion. There was a time we thought disease was spread by bad smells and the evil eye. We still know so little, and there may be things we can never learn, but science has come such a long way from lectures about Aristotle. I never realized until I heard the lectures myself.

DESIGN BY YECHAN YANG, BIOLOGY AND PSYCHOLOGY, 2021
PHOTO BY GUS MUELLER, BIOENGINEERING, 2022

British Journal of Educational Studies (1971). DOI:10.2307/3120440.

“Mitochondria are more than just the powerhouse of the cell”

BY ROXANNE LEE, ENVIRONMENTAL SCIENCE AND POLICY, 2019
DESIGN BY KRISTI BUI, COMPUTER SCIENCE, 2021
PHOTOS BY GUS MUELLER, BIOENGINEERING, 2022

The importance of mitochondria cannot be overstated. These organelles, found in large numbers within the cells of most eukaryotic organisms, are responsible for the energy production that keeps cells and the beings they make up functioning. But this isn't all that they do. As Northeastern University biology professor and researcher Dori Woods succinctly put it, "Mitochondria are more than just the powerhouse of the cell."

Mitochondria also play key roles in vital functions like apoptosis (cell death) and steroid hormone biosynthesis. Beyond that, researchers suspect that they may also play roles in other cell behaviors and intracellular interactions. For all of their importance, however, there's much we still don't know about them.

Technical hurdles have made these ubiquitous organelles traditionally difficult to study, with many techniques for isolation masking the properties of any given individual mitochondrion. At present, most methods employed for the study of mitochondria require that cells are broken up, and mitochondria are scooped up as a result. This method can be rather inexact, as non-mitochondria materials can be incorporated in the sample, like proteins or other intracellular organelles. In addition, even though mitochondria have a variety of shapes and external and internal traits, they are studied in undifferentiated masses numbering in the millions, further increasing the difficulty of studying individual mitochondria and their functions. So, if you want to study pure mitochondria populations in order to determine their effects on cell behavior as Woods and her team wanted to, what can you do?

In order to better study mitochondria, Woods and her colleagues invented a modified version of fluorescence-activated cell sorting (FACS). FACS is a subset of flow cytometry, a technique that examines the physical and chemical properties of individual cells by flowing them past laser beams and sorting the cells based on the resulting frequencies. As size is one of the greatest barriers to the observation of mitochondria—normal cells range in size from 10 to 25 microns, and mitochondria are usually in the 0.4 to 0.5 micron range—the technique can't be used on mitochondria as it typically exists. To circumvent this, Woods, in association with BD Biosciences, a global medical technology company, patented a modified version of FACS that downsizes the technology to the nanoscale level so that it is capable of examining mitochondria, refining it to the point of examining these as single organelles. The "cell" in FACS was replaced by mitochondria, thus designating the new technology as "FAMS."

The team confirmed the technology performed as intended by using fluorescent dyes to label mitochondria and seeing if the technology could sort intended mitochondria from the rest, which it did. They showed that FAMS could sort mitochondria without damaging them by looking for and finding DNA in the sorted mitochondria, since intact and undamaged mitochondria contain DNA. The team proved the sorted mitochondria were still functional by confirming they could still generate ATP after being given ADP. ADP is a molecule in the body that supplies cells with energy among other functions. One of mitochondria's key functions is converting ADP into ATP, a complex organic molecule that fuels many processes in the cell.

FAMS sorts and isolates mitochondria without cross-contaminating or fusing them with each other. It not only sorts mitochondria, but sorts it based on characteristics like size, activity, protein make-up, and dynamics. The technology can also separate based on combinations of traits as well as individual ones. Because of FAMS, researchers can evaluate mitochondria subpopulation dynamics within the context of a single cell for the first time. The technology can examine any cell pieces individually, not just mitochondria, opening up the potential for cross-disciplinary utilization.

With this new technology, Woods next hopes to further study the nuances of mitochondria behavior, such as its communication with the nucleus, especially within the context of human fertility and reproduction.

More iron in a biofilm's diet

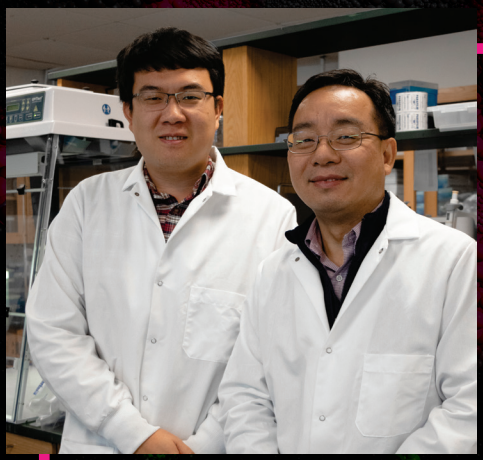
BY HUGH SHIRLEY, BIOCHEMISTRY, 2019

DESIGN BY KYLA VIGDOR, DESIGN, 2021

Biofilms are the name of the game in the Chai Lab at Northeastern University, and iron is shaking up the rules. Dr. Yunrong Chai and his team recently published an article in *Nature Communications* on their novel discoveries surrounding biofilm formation. Biofilms are communities of bacteria. They are tougher to kill with antibiotics than free bacterial colonies because of the protective coating that makes up the spaces between cells. The way that a biofilm forms and operates is still a question —one that Chai hopes to answer.

The team noticed that their model bacteria, Bacillus subtilis, requires hundreds of times more iron when growing as part of a biofilm than it needs to grow outside of a biofilm. This observation sparked the questions that started Chai and his team on their two-and-a-half-year-long project. Where is all that iron going, and what is it for? "Iron is very important, there's lots of biological processes that need iron," Chai said. "Bacteria will need iron to grow, and they will also need iron to build these biofilms." Without all that extra iron, a robust biofilm will never form. Through a collaboration with the Larese-Casanova Research Group at Northeastern University, the team found that 99 percent of the iron needed for biofilm formation wasn't used by the cells to grow and replicate.

High iron concentrations induce transcription of genes that code for the precursor of a siderophore protein, called bacillobactin. Siderophores are a group of proteins that bacteria use to scavenge iron from their environments. The precursor, 2,3-Dihydroxybenzoate (DHB), solves a key problem with iron, its insolubility. DHB binds to iron and helps it dissolve in the aqueous environment of a biofilm. The theory is that iron then acts as an extracellular electron acceptor. The implications of that discovery are powerful, as it means that bacteria might be communicating in ways that we hadn't previously realized.



Communication is key for biofilm formation; that's because biofilms are complex, genetically identical bacteria that can differentiate into specialized, phenotypically diverse forms that carry out unique functions. If that sounds familiar, its because a biofilm is eerily similar to a multicellular organism. It was thought that chemical messengers were responsible for cell to cell communication. "Chemicals are the language of bacteria," Chai said, but DHB changes things. Iron could act as part of a bacterial circuit that allows cells to communicate through electrical as well as chemical signals. That discovery isn't the only conclusion to the biofilm story, however. A second use for extracellular iron could change what we've been taught about cellular respiration.

The electron transport chain (ETC) is the essential final step for aerobic respiration. Electrons are passed down a chain of membrane-bound proteins until they are deposited on an oxygen molecule, forming water. Iron can also act as the final electron acceptor instead of oxygen for energy production. It might not be as efficient as oxygen, but in the anaerobic depths of a biofilm, iron can be a valuable alternative. "The textbook always tells you that this always happens on the membrane," Chai said. "They will never tell you that these electrons could leak and get into an extracellular space." That is still electron transfer, according to Chai, even if it isn't happening in a conventional way.

> "Iron can also act as the final electron acceptor instead of oxygen for energy production."

Extracellular electrical signaling and electron transfer for respiration aren't two competing theories. According to Chai, these two processes are likely happening simultaneously. The Chai Lab found that disrupting these processes by preventing cells from producing DHB disrupted the whole biofilm.

Biofilms are found everywhere, from the bottom of the ocean to the driest deserts and even inside of our bodies. It's theorized that biofilms in human and other eukaryotic microbiota might communicate directly with their hosts, potentially through Chai's electronic mechanism. The Chai Lab's paper represents a huge step towards a deeper understanding of how and why biofilms form, how they interact with their environments, and how they interact with us.

Nature Communications (2019). DOI: 10.1038/s41467-019-11681-0

PHOTOS BY ANUSHKA DESHMUKH, BEHAVIORAL NEUROSCIENCE, 2023 AND SHUTTERSTOCK

CAN'T SEE THE FOREST FOR THE TREE?

Largest quaking aspen forest is one cloned tree

BY LAUREN MACDONALD, ENVIRONMENTAL SCIENCE & CHEMISTRY, 2022

DESIGN BY KYLA VIGDOR, DESIGN, 2021

Approximately 80,000 years ago, a tiny seed belonging to *Populus tremuloides* took root in Central Utah in what is now Fishlake National Forest. That seed is now the world's heaviest organism, spanning 43 hectares and weighing more than 13 million pounds. The giant quaking aspen clone was first described in 1970 by researchers who named it Pando (Latin for *I spread*), but ecologists have known about the existence of quaking aspen clones for much longer.

Most trees reproduce sexually—pollen grains interact with ovules to create genetically unique offspring—but quaking aspens typically reproduce asexually. Once an individual tree has taken hold, it sends out horizontal root structures under the soil that are capable of growing brand-new sprouts (called ramets) that are genetically identical to the parent and remain connected until an individual dies. Asexual reproduction is what enables Pando to exist: one enormous root mass supporting an estimated 47,000 ramets. Each quaking aspen clone, including Pando, consists of generations of stems from young sprouts to 200 year old mature stems. As each generation matures and dies, younger generations are produced to take its place, and this makes it possible for quaking aspen clone stands to be thousands of years old.

> "Asexual reproduction is what enables Pando: one enormous root mass supporting an estimated 47,000 ramets."

The root system of Pando is fascinatingly useful. It performs all the same functions as a typical root system (water and nutrient collection and structural support), but it is also capable of evenly distributing these services across the entire area of the clone. This is especially important when clones reach the size of Pando because not all soil is created equal across the 43 hectares that Pando spans. Some areas are water or nutrient rich while some are too dry to support growth or may not have enough nutrients. Pando's vast interconnected root system helps ramets in healthy soils support other ramets, allowing them to take hold in areas where an individual tree could never survive because of insufficient water or nutrients. This also means that quaking aspens are more resilient to droughts and other environmental disturbances that might easily wipe out another species and are usually the first to populate an area after an avalanche or other disturbance.

Pando's roots are capable of more than just nutrient transfer; they also communicate with each other. Growth regulating hormones are passed from ramet to ramet through the root system and tell the entire clone when to flower, sprout, or become dormant. One example of this is auxin. Each ramet produces and stores this hormone, which dampens growth to prevent an excess of new stems in the immediate area. When a generation of ramets dies (from old age, fire, or other factors), those stems stop producing auxin. The resulting decrease in auxin levels signal to the rest of the clone that a generation has died and that it must begin creating new sprouts to replace the lost trees, leading to a surge of new growth.

Pando has possibly been alive since the last ice age, an impressive feat, but it's starting to die. A study by Dr. Paul Rogers and Darren McAvoy of Utah State University found that, for the last several decades, Pando hasn't been producing new sprouts, leaving only older trees that will soon die of aging. Aerial photography reveals that the area of foliage cover has been steadily decreasing over the past 70 years. Human involvement in the area (including campgrounds, vacation homes, and roads in Pando) has increased, and with increased human activity comes forest fire suppression. Fire is an important mechanism for triggering reduction in auxin and promoting new growth in Pando, so new trees haven't been as quick to replace old ones as in the recent past. Humans have also been artificially increasing the population of ungulates in Utah and across the Western United States for hunting purposes. More browsing deer and elk means that new shoots are being eaten before they can mature enough to withstand grazing by animals, and the overall effect is an aging clone that's unable to produce younger generations.

Luckily, researchers are becoming aware of the problem and have taken steps to try and protect this wonderful forest. Fencing against browsing ungulates and clear cutting sections to reduce auxin levels have both helped. This one clone is home to dozens of other species, from birds to mammals to other plants, and it would have catastrophic effects on the ecosystem if it were to die. Pando is extraordinary, unique, and vitally important; something we should prioritize protecting.

PLOS ONE (2018), DOI: 0203619

PHOTO BY FLICKR

PALEOBOTANISTS: THE HEROES OF CLIMATE CHANGE SCIENCE

BY PAULA HORNSTEIN, BIOCHEMISTRY, 2020
DESIGN BY NICHOLAS BERRY, ENGINEERING, 2023

"Love to have the opinion of a paleobotanist," says John Hammond, the fictional founder of Jurassic Park, to Dr. Ellie Sattler in the 1993 film as he invited her to preview his dinosaur park. Little did he know how relevant that statement would be more than 25 years later.

Paleobotanists, like Dr. Sattler, study plant fossils. They use their findings to piece together the evolutionary past of plants and characterize environments of previous ages. Often collaborating with paleontologists and paleobiologists, paleobotanists provide vital insight into life before our era. Their studies can cover a wide range of plantlife, from marine algae to plant pollen.

These studies are used to reconstruct the past, but they can also be used to foretell the future. Many paleobotanists today focus their research on plant and vegetation responses to climate changes of the past in order to predict responses to the dramatic climate change in our near future. In particular, their analyses pertain to divisions of greenhouse states: icehouse, mild greenhouse, and super-greenhouse. Understanding of how plantlife reacts to these transitions may offer support to possible solutions to the climate change that threatens life as we know it.

At least recent four studies of fossil records, summarized in a 2018 *Plant Biology* review, agree that plantlife is remarkably resilient through extreme climate transitions. Plants can migrate, acclimate, and adapt to changing weather conditions. Because DNA is not conserved in fossils from millions of years ago, paleobotanists must have keen eyes for morphological and anatomical traits that can be used to map evolutionary changes over time. Identifying these changes in behavior is complicated. However, if given enough fossil evidence and adequate characterization of the environment, it is possible to map a species' evolution with respect to the changing climate. This is a meticulous process, as a single geographical site must have an abundance of identifiable fossil records from thousands to millions of years past. When this type of site can be located, such as one in Astartekløft, East Greenland, it is of great value to paleobotanists, as well as their colleagues in mapping environmental resilience.

Paleobotanists also look to an event called the End-Triassic Extinction (ETE)—estimated to have occurred 200 million years ago. There have been five mass extinctions on Earth that humans can trace. The most recognized to people outside the field is the mass extinction that killed the dinosaurs, the End-Cretaceous Extinction. The ETE preceded this event by 150 million years. During the ETE, 75 percent of all known species on the planet became extinct—both terrestrial and aquatic. Although the exact cause of the ETE is unknown, it is known that the Triassic era experienced extremely high carbon dioxide levels. Today, scientists predict that by the year 2250, carbon dioxide levels will have reached ETE levels. Although the pace of global warming is about 280 times faster than that of the Triassic era, the pattern is analogous enough that it provides a window into our possible future.

> "How much can you know about an extinct ecosystem, and therefore, how could you assume you can control it?"

In their predictions, scientists combine the data from fossil records to contemporary tests of the effects of carbon dioxide on vegetation. These tests often subject different plantlife subjects to conditions of increasing carbon dioxide, allowing close monitoring of reactions of plants. These studies are, of course, limited by both space and time. But they offer a contemporary, verifiable understanding of plant life that can be integrated with longitudinal plant fossil data.

One of the largest obstacles in applying these studies is the inability of all humans to conceptualize deep evolutionary history. We can do our best to put the puzzle pieces together, but can never really get the full picture. The work of paleobotanists, however, is critical to even beginning to assemble the pieces. Plants demonstrate a resiliency unmatched by any living creature, surviving mass extinctions and often resurfacing stronger than before—granting scientists a foundation for further comprehension of past environments.

In *Jurassic Park*, Dr. Sattler asks John, "How much can you know about an extinct ecosystem, and therefore, how could you assume you can control it?" As a paleobotanist, albeit fictional, Dr. Sattler is certainly asking the right questions. For scientists in real life, however, understanding our Earth's history through its fossilized plant life does provide at least some insight into the mechanisms of climate change, and hopefully, how to counter this global dilemma.

Annual Review of Plant Biology (2018). DOI: 10.1146/annurev-arplant-042817-040405.

PHOTO BY SHUTTERSTOCK

Seemingly dead tree stump kept alive by neighboring trees

BY KATIE MCCREEDY, HEALTH SCIENCE, 2021

DESIGN BY KYLA VIGDOR, DESIGN, 2021

Newly published research from New Zealand takes the meaning of a "family tree" to a new level— a team based out of the Auckland University of Technology discovered a leafless tree stump kept alive through physiological coupling with neighboring trees.

The living, leafless stump was that of a Kauri tree, a species endemic to New Zealand. Normally, tree sap flows upward from the roots, through the tree, and toward the leaves when the sun shines. Intriguingly, this leafless stump moved sap upward through it's xylem, which is the vascular tissue that conducts nutrients and water from the root, during rainfall and at night. Much like the human vascular system, water and sap flow throughout the tree as blood flows throughout humans. This hydraulic flow is usually driven by the photosynthetic process: When it's sunny, plant leaves transpire, and water is pulled up the plant stem through capillary action toward the leaves in a continuous cycle to keep the plant nourished and growing.

Since this leafless tree stump had no leaves to facilitate the motion of sap upward, the team estimated that the sap must be emanating from somewhere else. They measured the water and sap flow of the Kauri tree's neighboring plants and discovered that these neighbors were sending the leafless stump sap through an underground network of roots. The neighboring trees supported the leafless stump despite it not contributing to the photosynthetic plant cycle. The researchers aptly dubbed this phenomenon of interconnected, community tree roots the "wood-wide web."

While the team witnessed this phenomenon in only the New Zealand Kauri species, this phenomenon was also observed in the United States in upstate New York, northern New Jersey, and New Hampshire. This New Zealand study is unique in that it went in depth into understanding how living stumps stay alive. This finding opens the door for a richer understanding of how deeply connected forests may be as the root web allows trees to share nutrients and water, which may be especially beneficial in sustaining forests in times of drought.

There is some concern that this interconnection may allow disease to spread more rapidly amongst trees, but the researchers have simply hypothesized this concern, and it is pending confirmation. Trees may not be the individual behemoths they appear to be on the surface; instead, this research highlights the value that community can have within species.

iScience (2019), DOI: 10.1016/j.isci.2019.05.009
PHOTO BY BRIANNA WATTS, BIOENGINEERING, 2023

One of the most terrifying predators you know used to be a vegetarian

BY KRISTINA KLOSOWSKI, BEHAVIORAL NEUROSCIENCE, 2021

The crocodile is one of the oldest creatures on the planet. For over 200 million years they have roamed the earth, surviving mass extinctions and outliving the dinosaurs. With their eerie ability to lay motionless in the water, eyes built uniquely for lurking, and a toothy grin to send chills down your spine, these animals do look a bit like they've lumbered out of an ancient horror film. Few other animals truly boast an appearance as downright terrifying as a crocodile.

However, despite their current status as fierce, meat-eating predators, certain periods in history knew a much different animal. As it turns out, throughout their evolutionary history, they have repeatedly evolved to favor a surprising diet: a plant-based one. While it seems quite contradictory to picture a vegetarian croc, science tells us that this happened not once or twice, but possibly up to six different times.

When scientists began studying the details of their terrifying toothy grins, they found that crocodile teeth were not always sharp, pointy, and designed for chomping prey as they are today. Some had flatter teeth with bumps and grooves, characteristic of teeth used for grinding and chewing plant material. In fact, it is inferred that ancient crocs had an incredibly varied diet, some being omnivorous and some preferring primarily plant-based diets. Fossil evidence indicates that these herbivorous creatures roamed the earth during the Jurassic period. Interestingly, this was the same period of time during which herbivorous dinosaurs thrived as well.

From this, an obvious question is posed: If crocodiles with a wide variety of diets were able to thrive millions of years ago, why not today? There are ongoing research efforts to further examine this. But for now it seems we will have to settle for living side-by-side with some of the fiercest hunters on earth, as we try to avoid the murky waters where the crocs roam.

Current Biology (2019) DOI: 10.1016/j.cub.2019.05.076
PHOTO BY SHUTTERSTOCK

STAFF PHOTO SPOTLIGHT

Towering overhead, evergreens shade the forest floor of Pacific Spirit Park in Vancouver, Canada. Species include Cedar, Hemlock, Douglas Fir, and Sitka Spruce. PHOTO BY GUS MUELLER, BIOENGINEERING, 2022

Follow us on Facebook, Instagram, and Twitter at @nuscimag
Read our work: nuscimag.com
Subscribe to our newsletter: bit.ly/nusci
Contact us: nusciencemag@gmail.com

Celebrating 10 YEARS NU SCI

Northeastern University
College of Science

Supported by the Student Activity Fee