CUSJ

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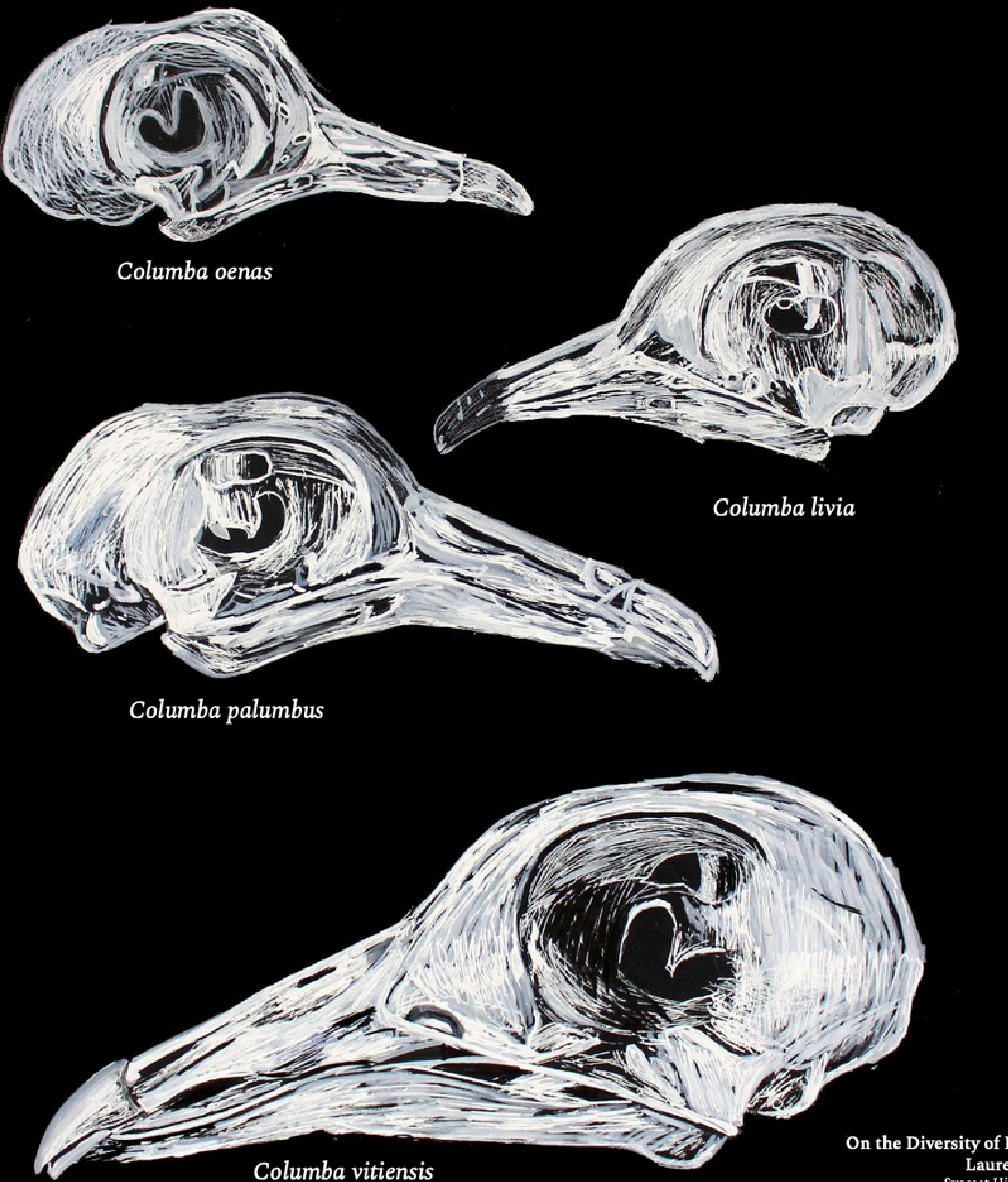

On the Diversity of Pigeons
Lauren Chen
Syosset High School
White gel pen

CUSJ
COLUMBIA UNDERGRADUATE SCIENCE JOURNAL

ABOUT THE JOURNAL

AIM AND SCOPE

The Columbia Undergraduate Science Journal (CUSJ) was founded in 2006 by students who were passionate about showcasing undergraduate excellence in scientific research. Since then, CUSJ has remained Columbia's premier publication for original scientific research and scholarly reviews and is managed by an editorial board of undergraduates with a vast scope of interests across all disciplines. The editorial board also manages the Columbia Junior Science Journal (CJSJ), a publication designed to introduce high school students to research, and **Columbia Scientist**, a publication aimed at increasing scientific engagement and thought at all academic levels. In addition to our publications, the CUSJ team is dedicated to nurturing the scientific community, both within Columbia and in the surrounding Morningside Heights and Harlem communities. To this end, the board frequently plans outreach and networking events relevant to young and early career scientists, including an annual Research Symposium poster session each spring.

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LETTER FROM EDITOR-IN-CHIEF

Dear Readers,

It is with great pleasure that we present the fourth edition, the Fall 2025 issue, of The Columbia Scientist. Originally established in 2022, The Columbia Scientist was created to highlight student research that defies the conventions of traditional scientific writing. It was meant to provide a platform for student writers to express their creativity, curiosity, and unique perspectives in science, while making scientific literature more accessible to its readers.

Since its founding, our publication has grown, receiving submissions from students around the world. These works showcase the many forms science can take, from cutting-edge medicines to the ethical implications of new technologies. Today, The Columbia Scientist continues to serve as a platform that highlights diverse perspectives and pushes the boundaries of what scientific literature can be.

The Fall 2025 edition represents the culmination of hard work put in by both the writers and editors this past year. It would not have been possible without the dedication of the entire Columbia Scientist team and editorial staff. Thank you to the previous Editor-in-Chief and current President Cindy Lu, who spent the previous year leading the editing process and putting together the pieces in this publication. Special thanks as well to Managing Editor Ahmed Hamdan, and previous presidents Kayla Pham and Priya Ray. Lastly, thank you to our dedicated editorial team and the students who submitted their work to Columbia Scientist.

This publication stands as a testament to the dedication of our student writers and editors. As you read through these articles, we hope you carry with you the passion and work that went into every piece.

Best,
Jenny Deng '27
Editor in Chief, Columbia Scientist

LETTER FROM CUSJ PRESIDENT

Dear Readers,

It is with great pleasure that I announce the release of the fourth edition of The Columbia Scientist. This issue, featuring talented young writers from around the world, reflects the Columbia Undergraduate Science Journal's mission to foster global dialogues in science. From evolutionary biology to quantum chips, each article demonstrates how curiosity and creativity continue to push the boundaries of discovery.

This edition also celebrates our Mentorship Program, through which underrepresented high school students in the New York City area work closely with Columbia undergraduates to explore science writing and research. Their voices and perspectives remind us that accessibility are central to the future of scientific communication.

As one of the Editors-in-Chief of The Columbia Scientist in 2024, I have had the privilege of witnessing the journal's remarkable growth and commitment to storytelling in science. This issue embodies that spirit of collaboration and inclusivity. I commend Editor-in-Chief Jenny Deng, Managing Editor Ahmed Hamden, and the entire editorial team for their dedication, creativity, and excellence in bringing this publication to life.

To our readers: thank you for your continued support of the Columbia Undergraduate Science Journal and The Columbia Scientist. We hope you enjoy engaging with the research, insights, and ideas shared in this issue.

Cordially,
Cindy Lu '27
President, Columbia Undergraduate Science Journal

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MASTHEAD

The Second Race for Space: Colonialism Déjà Vu on the Anthropocene Frontier

Grace Wu
Columbia University

We crave more. More clothes, more gadgets, more possessions to fill our lives. We browse TikTok Shop, load up our carts on Amazon, and venture to SoHo or the Upper East Side for shopping sprees. This endless desire fuels production, job creation, and economic expansion—a promise heralded by politicians and economists alike. Yet, we rarely pause to consider the limits of this pursuit. How far can we push an economy that relies on the Earth's dwindling resources? Can it continue indefinitely when the very foundation it depends on is finite?

1. The Promise and Peril of Astromining

Some elements are already slipping out of reach, either depleting rapidly or existing in concentrations too little to mine sustainably. Platinum group metals, vital for catalytic converters, are costly and difficult to recycle. Indium, a key component of touch screens, semiconductors, and solar panels, is found only in trace amounts within other mined ores (Kapilevich & Skumanich, 2009). There's also lithium—the backbone of modern batteries. Demand for lithium has more than tripled since 2017 and is expected to increase tenfold by mid-century, largely due to the push for electric vehicles.

Yet extracting a single ton of lithium from bedrock releases roughly 15 tons of greenhouse gases, trapping heat in the atmosphere and accelerating climate change (Tedesco, 2023).
Faced with this mounting scarcity, some have turned their gaze upward. The cosmos, vast and brimming with untapped potential, presents an alluring alternative. Instead of scarring Earth's landscapes and exhausting its resources, why not harvest what we need from the asteroids that drift through space? Unlike terrestrial mines, which have long been associated with dangerous working conditions and exploitation, space extraction could rely on robotics and artificial intelligence, minimizing human risk. The promise is seductive—mining without the suffering, progress without destruction. The logic seems sound, the opportunity boundless.

2. Global Inequities and Exclusion

But beneath the optimism lurks a familiar story. The rush to claim extraterrestrial wealth bears an unsettling resemblance to imperialist countries' past ventures into foreign territories to exploit material advantages. During the 19th-century Scramble for Africa, European powers seized vast territories, stripping them of their resources while leaving devastation in their wake. In Latin America, Spanish and Portuguese conquerors extracted gold and silver, fueling their own prosperity at the cost of local economies and environments. Today, the race for asteroid riches risks replicating these legacies. Wealthy nations and private corporations are leading the development of space mining technology, laying the groundwork for new legal frameworks that could allow them to extract resources from celestial bodies with little international oversight. Now, the race for asteroid riches threatens to unfold in much the same way—again this time with the wealthiest nations and corporations at the helm (Koch, 2008).

The cost of space mining is astronomical, limiting participation to the most powerful players. Among the leading asteroid mining companies, most are based in the United States and the United Kingdom. Astro Forge, a California startup founded in 2022, has raised over $55 million in funding. In February 2025, it partnered with another American company, SpaceX, to launch its first spacecraft, Odin, to image asteroid 2022 OB5, a near-Earth asteroid they hope to mine on their first extraction mission. Though communication failures limited the success of this launch, Astro Forge has planned test missions throughout the next decade to begin harvesting metal samples. Another California startup, TransAstra, is building a prototype that uses inflatable struts to open a soft-fabric bag around non-cooperative space matter and seals them inside for safe transport (Sims, 2025).

Other nations investing in similar astromining technology include Russia, China, India, and Japan —all ranked among the world's largest economies. Meanwhile, countries that once bore the brunt of colonial extraction are again at risk of being excluded. Ironically, many of the countries with the richest deposits of lithium, platinum-group metals, and indium have seen those very resources siphoned off by foreign firms. Bolivia, home to nearly a quarter of global lithium reserves, exports raw brine to China and Russia and lacks the refining plants or capital to build its own astromining infrastructure (Jamasmie, 2025). South Africa supplies over 80% of the world's platinum-group metals yet has seen little reinvestment in local automation or robotics, leaving it without the high-precision tools needed for off-Earth extraction (Frazzoli et al., 2024). Without substantial public and private investment, technology transfer, and access to affordable capital, they cannot develop the spacecraft, robotics, and processing facilities needed for asteroid mining. Just as wealth was funneled into several oligarchic empires, the resources of space could become the property of a privileged few (Mallick & Rajagopalan, 2019).

3. Ethics, Law, and the Way Forward

From an engineering perspective, space mining poses significant dilemmas regarding sustainability, responsibility, and the equitable distribution of resources. The American Society of Mechanical Engineers (ASME) Code of Ethics emphasizes that engineers must "consider environmental impact and sustainable use of resources" (ASME). The principle of sustainability must be central to space mining, yet without international oversight, corporations may prioritize short-term profitability over responsible resource extraction. Space mining, if pursued recklessly, could exacerbate inequalities rather than provide solutions.

Complicating matters further, the legal framework surrounding space mining remains murky. The 1967 Outer Space Treaty forbids national claims over celestial bodies, yet it does not explicitly ban the extraction of resources. Article II states that "outer space, including the Moon and other celestial bodies, is not subject to national appropriation," but private companies have found loopholes, arguing that while no one can own an asteroid itself, they can own whatever they take from it (Listner, 2011). This echoes legal maneuvers used during the colonial era, when European powers justified their conquests through doctrines like terra nullius, which conveniently declared Indigenous lands as empty and open for the taking. Now, corporations may use the same logic to stake their claim in space, arguing that what is unclaimed belongs to those bold enough to seize it.

The concentration of power in the hands of a few could have consequences beyond mere wealth accumulation. If a handful of corporations control the flow of asteroid-sourced platinum, rare earth elements, and other essential materials, they could dictate prices, destabilizing economies that rely on Earth-sourced counterparts. Countries without spacefaring capabilities may find themselves dependent on foreign suppliers, much as colonial economies were structured to serve European markets. The parallels are striking: a new frontier, a race for resources, and a system that ensures the benefits flow in one direction.

Furthermore, the ASME Code of Ethics calls for engineers to "act in a manner that enhances the honor, integrity, and dignity of the engineering profession" (ASME). Extracting resources from space solely for private profit, without international agreements ensuring fair distribution, contradicts this fundamental duty. A technology designed to serve all of humanity should not be monopolized by a few.

As history has shown, resource competition can breed conflict. During the colonial era, rival empires fought for control over resource-rich lands, leading to territorial disputes and wars. The same tensions could play out beyond Earth's atmosphere. Nations might position themselves to secure the most lucrative asteroids, and as space infrastructure advances, competition could escalate into military posturing—or worse (Bourbonnière & Lee, 2007). In a realm where the rules are still unwritten, power struggles could determine who gets what, and at what cost.

Yet for all its promise and peril, space mining is not the root of the problem—it is a symptom. The deeper question is not whether we should extract resources from asteroids, but why we feel compelled to keep extracting in the first place. Our reach beyond this planet reflects an unwillingness to accept limits, a belief that growth must continue indefinitely. But the truth is, no amount of expansion will change the fundamental problem of overconsumption.

Rather than looking outward for the next source of exploitation, we should focus on what can be done here on Earth. Advancing recycling technologies, reducing waste, and shifting toward circular economies would allow us to preserve the resources we already have. Investing in sustainable energy solutions and materials science could reduce reliance on finite elements. The future of human progress should not rest on how far we can go in pursuit of more, but on how wisely we can manage what we have.

If space mining is to proceed, it must be under a strict international framework—one that prioritizes the collective good over corporate interests. Resources beyond Earth should be seen not as commodities for the highest bidder, but as a shared opportunity for humanity as a whole. The question is not just about the fate of asteroids; it is about the lessons we choose to learn from history. Will we repeat the patterns of the past, or will we chart a new course—one defined not by conquest, but by responsibility?

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Google's Willow: Pioneering the Future of Quantum Chips

Emily Rosenthal
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In an era marked by the unprecedented speed of technological advancements, quantum chips, like Google's Willow, are reshaping the frontiers of computing. This article introduces the principle of quantum computing, highlights Willow's achievements, and explores its potential application across multiple fields.

Willow is a quantum chip, also known as a central processing unit (CPU), that serves as the "brain" of a quantum computer—a highly advanced computing machine that leverages quantum mechanics to process information (Schneider, 2024).

Quantum Computers versus Classical Computers

To begin, what sets quantum chips apart from traditional ones? Quantum computers leverage the unique properties of quantum bits—which, like classical bits, serve as the smallest units of information in a computer. While a bit represents a binary digit existing only in a mutually exclusive state of 0 or 1, a qubit can represent the two states simultaneously, a phenomenon called superposition (Usman, 2025).

Another transformative element of quantum computing is entanglement, where qubits become intrinsically linked. As posited by the Einstein-Podolsky-Rosen (EPR) paradox, measuring one entangled qubit instantly determines its partner's state, regardless of the distance between them. This phenomenon enables strong correlations between qubits, allowing them to share information and notice patterns efficiently (Adhikari et al., 2021).

The properties of superposition and entanglement further enable quantum parallelism—when multiple solutions are evaluated simultaneously. To illustrate, n classical bits can only store and process n bits of information. In contrast, n entangled qubits can store and process $2n$ units of information—thus dramatically reducing computation rates (Adhikari et al., 2021).

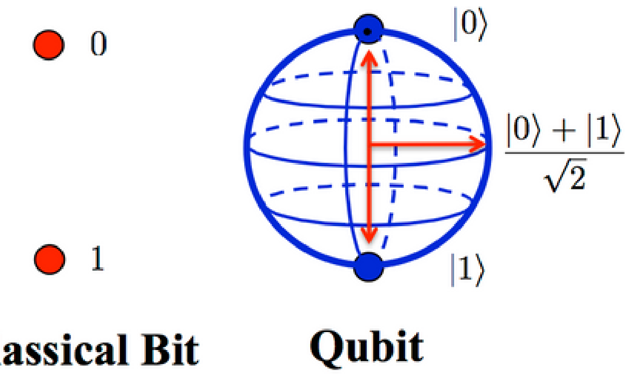

Figure 1: Visual representation of a classical bit and qubit (Usman, 2025).

Quantum Circuits

So, how do quantum computers solve problems? Computations are performed by manipulating qubits through a sequence of operations known as quantum gates, which can be demonstrated through quantum circuit models. These models consist of wires representing qubits, and gates that manipulate qubits into a new quantum state (Watrous, 2023).

Figure 2: This quantum circuit shows the single qubit X undergoing a sequence of operations: Hadamard (H), S, Hadamard (H), and T, forming the operation THSH (Watrous, 2023).

Quantum gates use constructive and destructive interference to either reinforce or cancel out certain states. When gates are applied to reinforce certain states, the probabilities of those states increase upon measurement. Conversely, when gates cancel out certain states, those probabilities become less likely. This principle allows quantum computers to amplify the probabilities of correct solutions while minimizing those of incorrect solutions, allowing faster detection of the solution (Watrous, 2023).

Quantum Error Correction

Despite the remarkable properties of quantum computing, its practical development has long been hindered by qubits' sensitivity to environmental disturbances—e.g., temperature fluctuations, noise, electromagnetic interference, cosmic radiation—which cause decoherence, a process in which qubits lose their quantum information (Wootton, 2018). In this way, decoherence is a severe limiting factor, whereby increasing the number of qubits increases error rates and severely limits scalability (Ahmed, 2024).

Willow's Achievement

Willow, Google's latest quantum processor and the successor to Sycamore, has tackled the problem of decoherence using "below threshold" error correction—a technique where adding more qubits actually suppresses errors rather than amplifying them (Moss, 2024).

Willow was evaluated using Random Circuit Sampling (RCS), a benchmarking technique developed by Google that evaluates a quantum chip's ability to generate and verify highly complex quantum circuits. Using this method, Willow completed a computation in five minutes that would take the world's fastest classical supercomputer, Frontier, 10 septillion years—a span that far exceeds the age of the universe (Neven, 2024).

This breakthrough was achieved via surface codes and logical qubits, concepts pioneered by Peter Shor in 1995. Surface codes organize qubits in a two-dimensional grid, allowing the system to detect and fix errors without inefficiently measuring individual qubits. Logical qubits distribute data redundantly across multiple physical qubits, so if some of them experience errors, the original data can be accurately retrieved. This synergy enables scalable, fault-tolerant quantum computing (Newman & Satzinger, 2024).

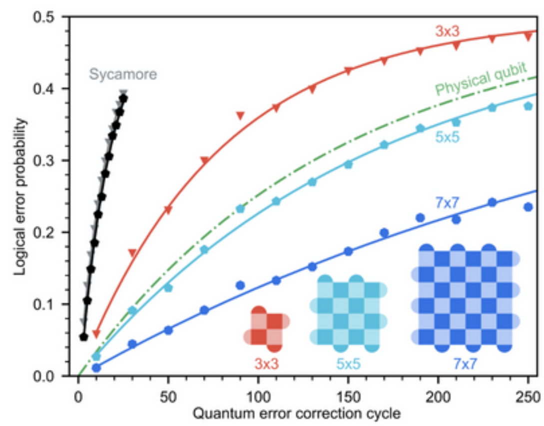

Figure 4: Increasing the lattice size from 3x3 to 5x5 to 7x7 reduces the encoded error rate by a factor of 2.14 with each expansion (Newman & Satzinger, 2024).

Applications Across Industries

Willow's success marks the dawn of a new technological era. For example, it can enhance molecular modeling by simulating atomic and subatomic interactions with exceptional accuracy—something traditional computers struggle with due to the complexity of electron behavior. This capability could accelerate breakthroughs in drug discovery, protein folding, and material design (Abelson, 2024). Beyond the sciences, quantum algorithms can help detect fraud patterns and model complex market dynamics (Koffman and Maclellan, 2024). Willow transforms quantum computing from a theoretical concept into a practical technology that paves the way for innovation and complex problem-solving. However, despite this progress, further development is still needed before quantum technologies can overcome other current limitations and reach their full potential in real-world applications.

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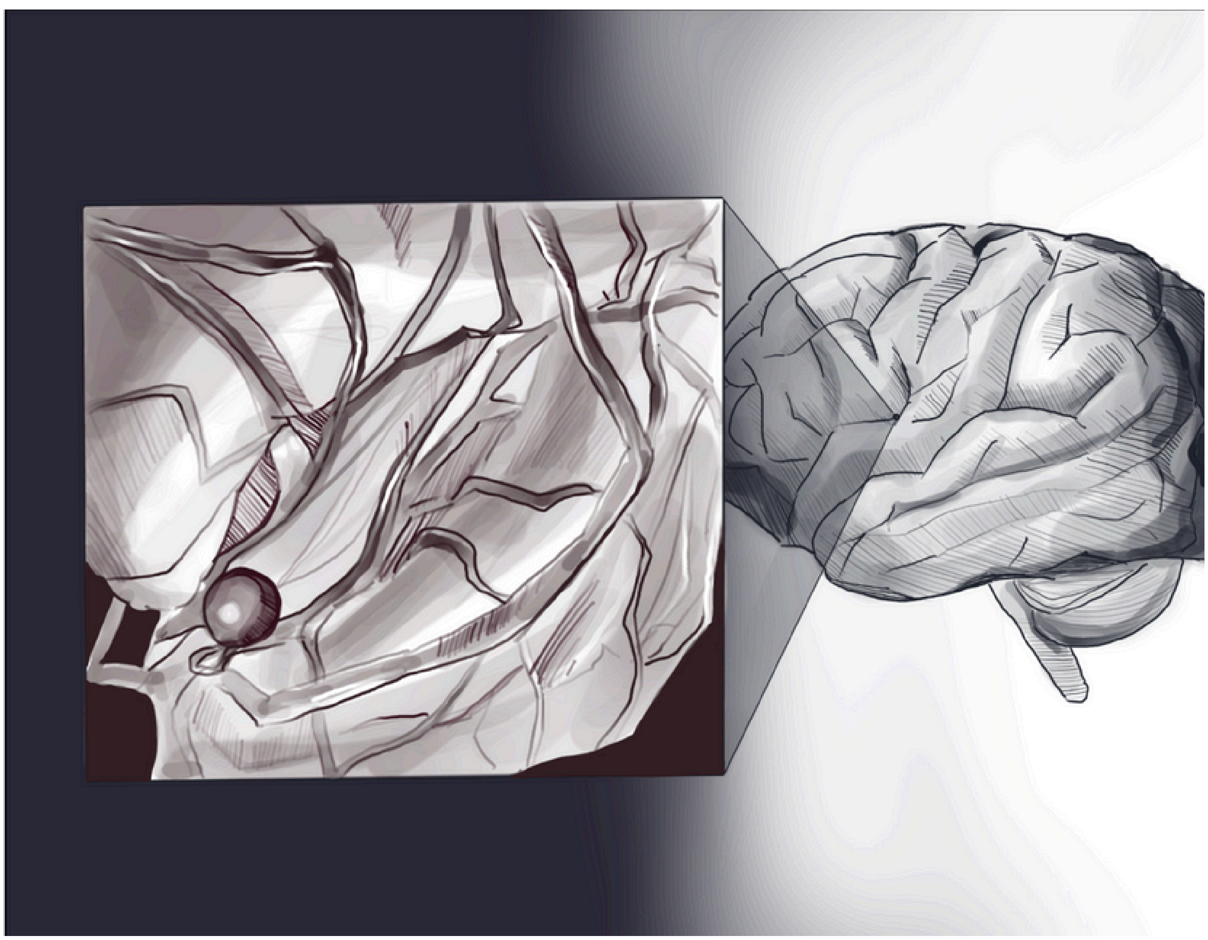
Brain Aneurysm

Kimberly Wang
Jericho High School

The illustration below depicts a brain aneurysm, a weakened spot in the wall of a blood vessel in the brain that bulges outward. The drawing displays a closeup of the aneurysm from the brain, where the bulge (the circular figure in the closeup) puts pressure on brain tissue and nerves. If the bulge ruptures, it can cause a hemorrhage, which is bleeding into the brain. A ruptured brain aneurysm can lead to severe complications like a hemorrhagic stroke, potentially causing significant brain damage. Understanding the cause of these aneurysms and developing efficient treatments can be extremely beneficial for future patients.



The Elephant in the Room is Female: Sex Bias in Behavioral Science

Lauren Subramaniam
Columbia University

“You run like a girl!” is a (misogynistic) insult.

But what about “You strangle your male mate, beat yourself against rocks, and starve yourself to death like a girl!” – a female octopus, to be exact? (Wood, 2018)

Many female animals showcase behaviors that are violent, gruesome, or sexually promiscuous: decidedly un-“ladylike” behaviors (Cooke 2022). However, 20th century science (especially ethology, the study of animal behavior) was unfortunately steeped in sexism, coloring the achievements and findings of Western scientists. Some of these bizarre female behaviors therefore went undetected and unstudied. In response, a new generation of feminist scientists, including zoologist Dr. Lucy Cooke and biologist Dr. Zuleyma Tang-Martinez, are challenging the narratives proposed for centuries (Cooke 2025, Hunt 2022, Tang-Martinez 2017). They are starting with the father of evolution: Darwin himself.

Many may know Darwin as the ‘finch guy,’ or the man who coined “survival of the fittest,” also known as Darwin’s theory of natural selection. In fact, his doctrine was so widely accepted by the early 20th century that natural selection was deemed the basic mechanism of evolution, and the “unifying theory of the life sciences” (“Charles Darwin,” 2024).

But, as Cooke highlights in her research, Darwin’s theories, specifically surrounding sexual selection, are also highly biased (Cooke 2022). He believed that male organisms play the only active role in pursuing mates, writing: “With almost all animals… there is a constantly recurrent struggle between the males for the possession of the females” (Darwin 2009). He went even further to say, in regard to the female of the species, that “she generally requires to be courted;” “she is coy, and may often be seen endeavouring for a long time to escape from the male” (Cooke 2022, Darwin 2009). Darwin was also the first to characterize “secondary sexual characteristics,” or traits like color that may help organisms attract a mate. These characteristics, he believed, were only present in male organisms. Darwin even went as far as to say that if such traits were present in females, they would “be of no service to her” (Darwin 2009).

> *Now, scientists are questioning why females lost song, rather than why males evolved it.*

Thus, Darwin paints a very clear picture: male animals aggressively vie for a passive female, who is then seduced and mated by the dominant male. However, this characterization isn’t the most complete. Darwin omits many nuances in the world of animal behavior, which is far from black-and-white.

One example of such nuance is bird song. Singing is traditionally thought of as a male bird trait: males sing to attract females, defend territories, and identify themselves to other birds (Thompson 2014). While generations of ornithologists noticed that female bird song did exist, male bird scientists were unwilling to study it. For example, out of 1,000 publications on the barn swallow, not a single paper studied female song until a group of female researchers released the very first study in 2020 (Wilkins et al. 2020). They found that female birds sing for many of the same reasons as males, and that it was actually easier to tell males and females apart by their songs rather than their colors, which indicates that song in female birds is distinct (Wilkins et al. 2020, Benedict and Wilkins 2021). They also found that song and plumage characteristics can better predict reproductive success in females, suggesting that a female's song and feathers play an important role in finding a mate (Wilkins et al. 2020, Benedict and Wilkins 2021). If female bird song and color are important for reproduction, they must have an evolutionary purpose for these secondary sex characteristics—a finding that, according to Darwin, would have been impossible. New research also shows that female ancestors of modern-day birds probably also sang, indicating that song evolved commonly across birds of all genders, not just males (Omland et al. 2021, Wilkins et al. 2020). Now, scientists are questioning why females lost song, rather than why males evolved it. Thanks to the women who led these groundbreaking projects, scientists are reframing their studies of birds from new perspectives.

Another instance of black-and-white assumptions in animal behavior is the long-perpetuated stereotype of male promiscuity and female monogamy: the idea that males evolved to mate with as many females as possible, while females evolved to mate with only one male. Darwin noted that promiscuity in animals exists, but only mentioned male behaviors (Cooke 2022). Angus Bateman, a botanist, would ultimately support the theory of male promiscuity with data. Bateman found in reproductive experiments using Drosophila fruit flies that males have more offspring when they mate with multiple females, while the "peak of female reproductive success" is after mating with only one male (Bateman 1948, Cooke 2022, Tang-Martinez 2017). Bateman used these results to argue that "males will be expected to show polygamous tendencies, whereas in females there would be selection in favour of obtaining only one mate, after which they would become relatively indifferent" (Bateman 1948, Cooke 2022, Tang-Martinez 2017). The problem is that this is only half of Bateman's data. The other half, revealed by Cooke and Tang-Martinez, shows that the more times a female fly mates with a male, the more offspring she has: in other words, promiscuity also benefits the female (Cooke 2022, Tang-Martinez 2017). But Bateman's second graph was largely ignored, and the promiscuity myth spread throughout the field of animal behavior.

Though there are certainly many animal species with promiscuous males and monogamous females, we now also know of cases where female animals are just as promiscuous as males. Female lionesses will mate with a male 20-40 times per day while in heat, with the female initiating these copulations and often mating with multiple male partners (Thornberry 2021, Cooke 2022). Many "monogamous" male and female birds will "cheat" on their partners; up to 40% of young in many North American birds are from other fathers (Stutchbury 2010). Patricia Gowaty, the first scientist to use paternity testing on bird eggs, found that birds of both sexes, not just males, are cheaters. She recalled in an interview with Cooke that her findings "...offended so many people that it was unbelievable. They couldn't imagine that females were anything but benign" (Cooke 2022, Incorvaia 2023).

Gowaty's experience highlights that even when data calls stereotypes and assumptions into question, scientists will ignore or even deny observations that go against the status quo. Darwin himself saw "exceptions" to the rules in his work, noting that calico coloring in cats is exclusive to the females, and that certain hen species are more aggressive and brighter-colored than roosters, but ultimately chalked these up to outliers and never investigated further (Darwin 2009). On birds specifically, a 1992 study on aggression expected to find aggressiveness in males. When they found instead that females engage in significantly more fights than males, the all-male team was perplexed. However, rather than investigating further, they completely dismissed the behaviors (Lawton et al. 1997, Tang-Martinez 2017). Thus, bias in science has actively prevented scientists from investigating interesting observations in the field.

Luckily, the rise of women in science is introducing all-new perspectives in animal behavior and other related fields. The new wave of feminism in science could be the key to understanding science in a whole new way, bringing justice for centuries of unexplored, yet important, female behaviors. Were it not for the female scientists who dared to challenge the norms of behavioral science, we likely would have never known that female birds sing and are promiscuous, too. Intersectionality between female scientists and queer researchers has even led to new studies on homosexuality in animals, disputing the idea that heterosexual behaviors evolved first (Lawton et al. 1997). The rise of new voices in science in the 21st century has highlighted the importance of bias removal in science. Being a good researcher means seeking the truth, even when the truth is uncomfortable or leads to more questions. As Darwin himself says, "The love for all living creatures is the most noble attribute of man" (Darwin 1871). That includes female creatures, too.

Those interested in learning more should read Bitch: On the Female of the Species by Lucy Cooke, and take Dr. Alison Pischedda's Animal Behavior course at Barnard!

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How AI is Helping Scientists Make Discoveries in Battery Science

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The demand for safer and more efficient battery technologies has never been more urgent, given the rapid expansion of renewable energy sources and the proliferation of electric vehicles. However, the traditional approach to material discovery for batteries involves extensive laboratory experimentation with trial and error, which can take years. Scientists from the Pacific Northwest National Laboratory (PNNL) and Microsoft were faced with this problem while trying to create a new battery material. To tackle this, they turned to artificial intelligence (AI). With the help of AI, researchers were able to screen 32 million materials and single out 18 candidates in only 80 hours(Pessarlay, 2024). A task of this magnitude would have taken a team of humans decades to complete before AI.

How Batteries Work

Before we dive into how the experiment worked, we need to learn more about how batteries work. On the left is a diagram showing the inner workings of a cell phone battery. As seen in the diagram, electrons move from one end of the wire to the other. Once they cross a load(component that pulls electron current away from the battery) such as a light, the negatively charged electrons power the load and simultaneously turn into a positively charged electron. The positively charged electron then moves through the positive electrode (cathode) and travels through the electrolyte where it turns negative. After that, the electron moves through the negative electrode (anode) and goes back through the wire to power the load. The problem with most batteries today is that they use a liquid electrolyte, which leaks toxic substances if broken. As a result, scientists are working towards a solid electrolyte battery to minimize safety concerns (Millholland, 2023). Solid electrolytes, however, are hard to make because they require a steady charge flow between the electrolytes and the positive and negative electrodes. This issue is what the scientists from PNNL and Microsoft were trying to solve in creating a solid electrolyte battery.

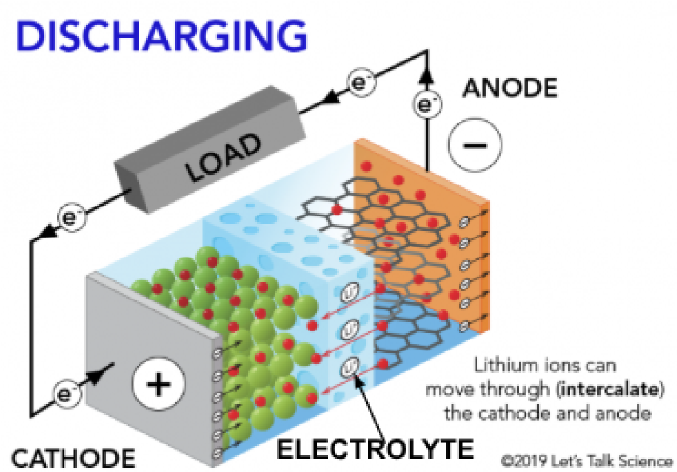

Figure 1: Diagram of how a battery works and how electrons move through a battery (Chapman, 2019)

Why Do We Need New Batteries?

As discussed above, liquid electrolyte batteries are used in most electronics today. These batteries are good because they have a long lifespan and are compact. However, they also have many problems such as overheating, leakage, and limited lithium supply. In addition, Lithium-ion batteries(the most common type of liquid electrolyte batteries) contain cobalt, which is mostly mined through child labor. Children working in the mines are paid around six cents (USD) daily, which brings up glaring ethical concerns (Purewal, 2022).

Of course, there are solid-state alternatives to Lithium-ion batteries that do not use cobalt. These batteries, however, have limitations as well. For example, Nickel-cadmium is a solid electrolyte battery that does not use cobalt. This type of battery is hard to damage and has a high energy density, allowing it to hold and release a lot of energy in a short amount of time. On the downside, nickel-cadmium batteries harm the environment when thrown away, and their long charge time limits their use. Overall, the limitations of the most commonly used batteries are why researchers from Microsoft and the Pacific Northwest National Laboratory wanted to find a new material for solid-state batteries.

The Experiment

The researchers utilized Microsoft's Azure Quantum Elements platform, which uses a collection of AI tools and HPC(high-performance computing) to conduct a screening of potential battery materials(Lardinois, 2024). The diagram on the right shows the steps researchers took to get down to their final electrolyte. The researchers started by entering a dataset with over 32 million materials into the platform. The materials were then filtered through various AI algorithms that processed the materials according to predefined criteria, such as stability, conductivity, and cost-effectiveness. The AI algorithms first checked to see how well the materials moved ions; if the material moved the ions efficiently, it would move on to the next stage. 150 materials made it past the first stage, and with the help of AI and the scientists, the top 18 materials were picked based on how easily their ingredients could be obtained. These 18 promising materials were then subjected to additional screening processes, directed by the scientists until the best material was identified. But what was this material?

Results

With help from AI, researchers were able to identify a new solid-state electrolyte material that is a combination of sodium, lithium, yttrium, and chloride ions(Conover, 2024). With these elements, scientists can create a solid-state electrolyte with 70% less lithium, no cobalt, and still has all the same benefits as a normal Lithium-Ion battery. According to Victoria Atkinson, an author from Chemistry World who has a PhD in chemistry, this new battery material could drastically reduce the price and environmental impact of these batteries in the future.(Atkinson, 2024) While further testing is required, the successful application of this AI in battery research shows AI's potential to speed up scientific discoveries. Ultimately, this application of AI could transform fields like chemistry, material science, drug discovery, and environmental science. This is because AI can allow researchers to explore many more combinations, and it allows them to predict useful materials much faster than researchers can. In the future, we can see AI involved in every research project, which will allow for new materials, proteins, and even species to be discovered.

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Griefbots, a New Ethical Dilemma

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'Griefbots' are one of many products that have emerged as a result of our new digital age. Continuing in the tradition of eliminating discomfort via the use of technological advances, griefbots are chatbots specifically designed to diminish, if not fully eliminate, our experience of grief. At their core, they are a specialized software that can 'simulate [a] conversation with someone who has died' (Lemma, 2024) by collecting personal data, either through the existing digital footprint left behind by the deceased or by information supplied from close friends and relatives. Large language models (LLMs) use this data to imitate the personality of the deceased, predicting their answers and mannerisms through the data they were trained on. They exist as 'dynamic digital entities' that can 'continuously learn and adapt based on the input they receive.' (Lemma, 2024) . In the past few years, applications claiming to have these capabilities have been increasingly popular, with programs like 'You, Only Virtual' being an example. Their website advertises that their griefbots, called "Versonas," are 'redefining the way we grieve' and are able to 'profoundly improve the lives of those who have lost loved ones, helping them feel connected and understood even in their absence.' ("You, Only Virtual")

When first hearing of so-called griefbots, most people are considerably disturbed by the notion and consider the software used in its implementation unethical. Many have found something unintelligibly perverse about the whole idea, even outside the limits of privacy concerns that are usually associated with AI ethics.

Studies have consistently concluded that grief varies in form between people, but its defining trait– the large emotional toll it has– remains constant. Neurobiology explains grief's origin through the reorganization of the brain's understanding of space, time, and attachment bonds (Davis, 2023). These three aspects are intertwined in an elaborate linkage of neurological pathways in order to establish a relationship between two people. As a result, your brain can maintain an internal map of how close you are to a specific person, as well as where and when you can find them relative to your location and time. As it is kept within your subconscious, you can shift the emotional attachment out of your immediate consciousness and focus on other things while still being aware of this information. Developmental psychologist Deborah L. Davis describes this 'neural map' as being able to make sense of what is happening and what can be expected from a special someone at a given moment without requiring considerable mental power, making the person get used to their presence and little quirks (Davis, 2023). In this sense, that relationship is a part of a person, something that makes them them as it quite literally alters their neurophysical makeup.

What would happen then, if this special someone suddenly disappeared from your life? While your conscious brain can rationally discern the new situation, memories of that person continue to make up the entangled web of emotional and physical relations. Your subconscious brain will continue to expect the information stored inside the bond due to the out-of-date information of the deceased's presence in space and time. Each time this expectation for specific results is unfulfilled, you experience the feeling known as grief. With time and a healthy psychological awareness, the subconscious brain can adjust to the new reality by creating new neural connections, but this process of 'rewiring' is among the toughest psychological challenges a person has to go through in their lifetime (Huberman Lab, 2022).

While most people lose symptoms gradually over time, those who experience prolonged grief may develop a condition known as 'complicated grief' (CG) as opposed to 'normal' or 'acute' grief (Mayo Clinic, 2022). Symptoms include obsessive thought patterns surrounding the deceased person, hyperfixation on reminders of the deceased, denial, an overall inability to enjoy life to the point where basic tasks cannot be carried out, and even suicidal ideation (Mayo Clinic, 2022).

Hence, it may be fairly obvious why someone may choose to use griefbots to ease the cognitive strain they are experiencing, but at what point does this artificial replica stop being a useful resource and become a source of denial and avoidance? Considering the neurophysical changes a grieving person must undertake to "heal" from the passing of a loved one, the griefbot may disrupt the natural rewiring that is required to truly recover. It is not difficult to imagine that the digital presence of the deceased would confuse the subconscious part of the brain that is trying to adjust to present conditions in space and time. It may prolong the process of creating new neural connections that allow the grieving individual to come to terms with the death and subsequently draw out the psychological and health-related symptoms that accompany grief. Even though some developers who create the griefbot software may argue that it is a new tool that can be used to help those dealing with grief, there is no evidence or long-term study to confirm or deny this (Reiboth, 2024). Further, there is a correlation between CG and increased activity in the pleasure-seeking part of the brain when they witness reminders of the deceased (O'Connor et al., 2008). This part of the brain also functions in emotional affirmation with the loved one when they were alive. Therefore, if communicating with the griefbots could potentially trigger the same response in the brain as in a real interaction, it would be worth examining if the software itself is capable of inducing CG. This potential for causing more harm than good suggests that more scientific investigation should be conducted before people are given access to these platforms.

Thus, the potential consequences go against the IEEE's policy 'to hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, to protect the privacy of others, and to disclose promptly factors that might endanger the public or the environment'(IEEE I.1).

Another problem is the subject of monetization. A report by Insight Ace Analytics approximated that the market for chatbots for mental health and therapy was valued at a staggering 1.15 billion USD in 2023 and predicts this value to increase to 1.71 billion USD by 2031 (InsightAce Analytic, 2024). This growing profitability is likely to attract corporations and software developers whose interest in financial return greatly exceeds that of their good intentions. Research has shown that people who experience high amounts of grief can be associated with poorer emotional decision-making capabilities (Fernández-Alcántara et al. 261, 2016), potentially making them easy and desirable targets to companies who promise to "bring back" their loved ones. At a vulnerable, grieving state that is privy to manipulation, it may create an incentive for businesses to use griefbots for monetary gain, such as charging a monthly subscription or making the griefbot a promoter for an ad. Laws regarding AI are infamous for their scarcity (PYMNTS, 2023) and griefbots are no exception. This oversight may easily lure in a privatized market that will have control over an individual's access to what is essentially a replica of their loved one. When taken with the possible psychological implications, this sort of emotional exploitation can undoubtedly cross the line into financial abuse. I suggest that the use of griefbots should be kept out of the private market until stricter laws surrounding the interaction between customers and the software company are established. In particular, the griefbot should be bought using a one-time payment rather than through a monthly subscription, while avoiding all paid promotions. Whether the griefbots are better maintained under public healthcare remains to be seen.

The issue of financial abuse can be considered a going against IEEE's vow 'to avoid injuring others, their property, reputation, or employment by false or malicious actions, rumors or any other verbal or physical abuses' (IEEE II.9).

Likewise, another issue is the question of consent. Who is able to provide consent for the deceased person to be imitated by the software? The legislation regarding the privacy rights of the deceased is unclear in most countries, and in some cases, it is outright denied. Of course, most laws did not consider artificially reanimated deceased people while they were being drafted, and so can seldom be taken as ethical guides in these scenarios. Some researchers, like Kwan Yiu Cheng, are attempting to use existing national jurisdictions to answer the following issue. In the case of the Chinese legal system (where most of the emerging chatbot software is based): 'The deceased's wishes should be respected if they explicitly opposed [using private data to create a griefbot]' Cheng states among his final remarks before suggesting that 'if the deceased was silent, then close relatives should be able to consent to the use of personal information for this private purpose' (Cheng, 2025). Either way, the legal system must clearly be updated to address potential conflicts of interest that may arise due to the use of private information to create the griefbot (International Association of Privacy Professionals). In the current state, it is unclear how software developers will navigate potential legal implications regarding using the deceased's digital information for building an LLM model.

To conclude, I want to re-emphasize three fundamental suggestions:

1. People with acute or complicated grief should not be given access to digital avatars of deceased loved ones unless:
   a. A person with complicated grief has shown no sufficient improvement with all alternative methods and has expressed a clear interest in the software
   b. There is explicit scientific evidence for the advantages of such an approach
2. Griefbots should not be sold or regulated within the private sector
3. Stricter inheritance laws must be implemented so that they encompass the person's 'image' after their death in such a way as to make sure that the griefbots don't infringe on the consent of the deceased whilst they were alive

Being a relatively new technology, it is difficult to say today whether griefbots can be labelled as unethical. While there is no definitive universal standard for judging ethics, the IEEE's Code distinguishes between finding a concept to be unethical based on personal sentiments and based on facts and established regulations we already adhere to.

Many know from experience the danger of impulsive access to innovative technology before laws and proper scientific assessment have a chance to catch up. Let's not let this be an example. Griefbots are–at best–highly questionable, and we cannot let that be the standard for their free access.

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A Human Creation or a Cosmic Constant?

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Introduction: Is Time an Illusion?

We experience time as a constant force: the steady march of seconds, minutes, and hours. We wake up to alarms, follow daily routines, and mark milestones by this seemingly absolute flow. But what if time isn't what we think it is?

Modern physics tells a far stranger story. According to Einstein's Theory of Relativity, time stretches and contracts depending on how fast you move or how close you are to a massive object. This phenomenon, known as time dilation, has been confirmed through atomic clocks, particle accelerators, and even GPS satellites (Encyclopædia Britannica, 2025).

If time can slow down, or even stop, what does that mean for how we perceive reality? If time isn't absolute, could our entire experience of past, present, and future be an illusion? This editorial explores why time may be more fluid than we ever imagined and how that challenges everything we know about the universe.

I. The Science of Time Dilation: Why Time Is Not Fixed

Before Einstein, most people believed in universal time, a single, constant clock ticking identically for everyone. But in the early 20th century, Einstein shattered that belief. He showed that time behaves differently under two specific conditions.

First, time slows when moving at speeds near the speed of light. For instance, if an astronaut travels at 99% the speed of light for ten years (from Earth's perspective), they would only age about 1.41 years. When they return, centuries may have passed on Earth, a one-way trip to the future (Encyclopædia Britannica, 2025).

Second, time slows in strong gravitational fields. Gravity distorts time near massive objects like black holes. An astronaut orbiting a black hole for just one hour could return to their spaceship to find that decades have passed for their crew. These are not just theories; scientists have verified such effects using highly sensitive atomic clocks aboard airplanes (Hafele & Keating, 1972).

So if time can stretch and shrink, does it even exist as a real, fixed "thing"? Or is it something far stranger, something dependent on perspective?

If time isn't absolute, could our entire experience of past, present, and future be an illusion?

II. Time Perception: How Our Brains Trick Us

Even as physics shows that time is relative, neuroscience suggests that our perception of time may be an illusion too. The human brain doesn't passively receive time; it actively constructs it.

Time feels slower when we're in danger. It speeds up when we're focused or having fun. People under stress or in deep meditation often report the sensation that time "stops." These effects reveal that we don't experience time directly; we interpret it through shifting brain states (Miyawaki, 2023).

Some researchers believe the brain simply processes events in order, not because time is real, but because sequence is how we understand change. If our minds construct time, and physics proves it can bend, what exactly is time? A dimension? A sensation? A shared illusion?

III. Time and the Future: What If We Could Control It?

If time is not fixed, what could this mean for the future of humanity?

Could we slow aging? In theory, astronauts traveling at near-light speeds could experience only a few years while centuries pass on Earth. Time dilation could one day let us "leap" through time, arriving in the future without aging significantly (Encyclopædia Britannica, 2025).

Could we manipulate time with gravity? Structures built near massive sources of gravity might one day slow time for the people living there. This could become essential for deep-space travel or even human life extension.

Is the future already written? Einstein once suggested that past, present, and future all exist simultaneously. Time, he argued, is simply a dimension, like width, height, and depth. If this is true, then perhaps the future isn't something that "happens." It's already there. We're just moving through it (Encyclopædia Britannica, 2025).

Conclusion: What If We Have Time All Wrong?

Time dilation shows that time is not absolute. It bends with speed. It slows with gravity. It essentially influences everything from satellites in orbit to the ticking of a human mind. If time can be bent, stretched, or halted, perhaps it's not a fundamental part of the universe at all.

What if the past, present, and future are all the same? What if we are simply locked into experiencing one direction of something far more complex?

We live our lives assuming time flows forward. But if time dilation is real, if our brains are constructing time, then maybe time is not something that passes. Maybe it's something we create.

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Microbial Medicine: Treating Inflammatory Skin Diseases

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The skin is home to a diverse ecosystem consisting of trillions of bacterial, fungal, and viral species. These microorganisms collectively make up the skin microbiome, which plays key roles in maintaining homeostasis and defending against pathogens on the skin. Maintaining a diverse and balanced skin microbiome is essential for a healthy skin barrier, as disruptions in this balance, known as dysbiosis, can lead to loss of beneficial microbes, proliferation of pathogenic microbes, and ultimately, the development of chronic skin diseases.

Various beneficial microbes residing on the skin are crucial to protecting against disease by competing with harmful microbes for the limited nutrients on the skin and by producing antimicrobial peptides, which are bioactive compounds that disrupt the cell membranes of pathogens. For example, *Staphylococcus epidermidis* and *Staphylococcus hominis* secrete antimicrobial peptides that inhibit the growth of *Staphylococcus aureus*, a common skin pathogen associated with inflammation in the skin (Glatthardt et al., 2024). Microbial dysbiosis, often induced by aging processes, environmental influences, cosmetic products, and the application of topical medications that alter the microbiome composition, can lead to a loss of beneficial microbes, allowing harmful species to thrive (Boxberger et al., 2021). These species are often opportunistic pathogens, meaning they are normally harmless but are capable of causing disease when the microbiome is disrupted. They may produce toxins and trigger immune responses, contributing to the development of chronic inflammatory skin conditions such as atopic dermatitis (commonly known as eczema), acne, and psoriasis.

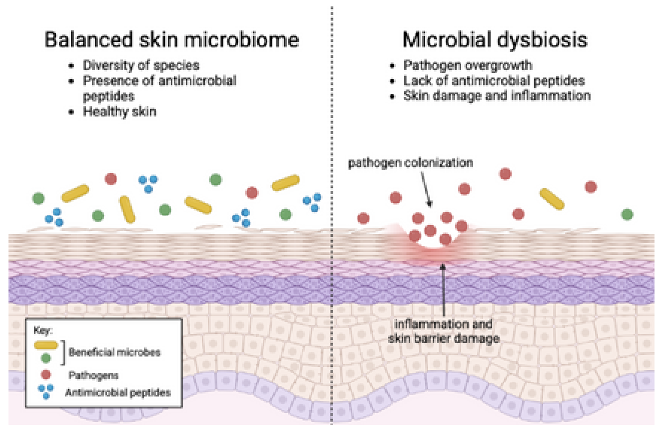

Figure 1: Comparison between balanced and dysbiotic skin microbiome.

Therapeutic Strategies for Microbiome Modulation

Microbiome modulation through bacteriotherapy is currently being explored for its potential in the treatment of common skin diseases. Bacteriotherapy can be administered through various methods: microbiome transplantation, probiotics, prebiotics, and postbiotics. In skin microbiome transplantations, an entire microbial community from a healthy individual is collected and transferred directly to the disinfected skin of a patient with a skin disease, introducing a diverse and well-balanced microbiome to potentially restore skin barrier function. Probiotics are live beneficial microbes, such as *S. epidermidis* or *Lactobacilli*, that provide health benefits. Postbiotics are the bioactive products produced by probiotics, which can help improve skin barrier function and immune regulation. Both probiotics and postbiotics can be administered either topically or orally. Prebiotics are contained in food and serve as nutrients for probiotics (Nezhadi et al., 2024).

These methods for manipulating the skin microbiome have proven to be promising alternatives to conventional purified chemical compounds, such as corticosteroids or topical creams, in management of skin disease. Once successfully colonized, live microbes can persist for a lifetime, providing lasting effects while reducing the need for repeated application (Ito & Amagai, 2022). Although research is still in its early stages, bacteriotherapy has demonstrated successful applications in human health interventions in recent studies. Bacterial transplants of commensal *Staphylococcus* species have shown therapeutic activity against atopic dermatitis through the inhibition of *S. aureus* growth (Nakatsuji et al., 2021). Additionally, the application of live *Lactobacilli*, which are known to have anti-inflammatory effects and promote restoration of the skin barrier, resulted in reduced abundance of pathogenic *Staphylococcus* and *Cutibacterium acnes* strains on the skin. This contributed to a reduction of inflammatory acne lesions (Lebeer et al., 2022). In a study involving psoriasis patients, treatments with certain probiotic species of *Bacillus* improved psoriasis conditions and reduced skin inflammation (Buhaș et al., 2023).

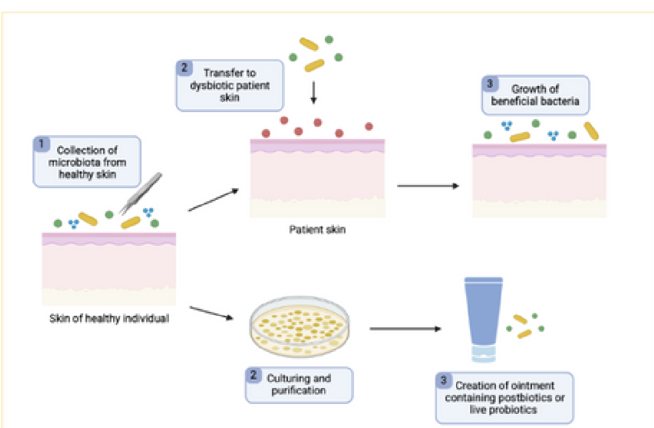

Figure 2: Skin microbiome modulation strategies through transplantations and bacteriotherapy.

Limitations and Implications

However, these therapies also come with limitations. During microbiome transplantation, it is difficult to identify which specific microbes are being transferred, creating the possibility of pathogenic taxa being transplanted. Although these opportunistic pathogens may not have been the source for initial disease in the donor, the recipient individual's skin may react poorly due to a weakened skin barrier (Callewaert et al., 2021). Additionally, with the microbial transplants and probiotic application, it may be difficult for newly transplanted microbes to persist and colonize on the skin at first due to potential differences in skin microenvironments between the donor and recipient, as well as immune responses in the recipient (Ito & Amagai, 2022). In the case of prebiotics and postbiotics, the effects of these compounds can be unpredictable. Prebiotics may unintentionally feed and stimulate the growth of non-targeted bacteria, leading to further imbalances in the microbiome, and postbiotics may trigger immune reactions or irritation in sensitive skin (Nezhadi et al., 2024).

Despite these limitations, microbiome manipulation therapies still represent a novel approach in restoring skin health. Research is still in its infancy, and further experiments are being conducted to refine these therapies and improve their safety and efficacy. With over one-third of the global population affected by skin diseases, it is important to explore alternatives like microbiome modulation that can support long-term skin barrier health while reducing reliance on conventional treatments that are often associated with systemic side effects and high withdrawal rates (Li et al., 2024). As the scientific understanding of the skin microbiome continues to grow, bacteriotherapy may become a widespread option for patients struggling with chronic inflammatory skin diseases.

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The Brain's Quantum Code: Why Neuroscience Needs to Embrace the Physics of Consciousness

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There is a moment in our childhood when we first ask the question that will stay with us for the rest of our lives: How does my brain suddenly wake up and realize, "I'm me"? Maybe it happens when we catch our own reflection in the mirror and, for a split second, feel like a stranger. Or when we stare up at the night sky, overwhelmed by the vastness of the universe, and wonder why we are aware of our own existence. Scientists have spent decades trying to answer this question by mapping neural circuits, measuring electrical signals, and analyzing brain activity. However, after all that, the greatest mystery remains unsolved. Why are we conscious?

Neuroscience has decoded memory pathways, restored movement to patients with paralysis, and saved countless lives. However, it still cannot explain why a melody raises goosebumps or why heartbreak can throb like a shattered bone. Artificial intelligence systems now generate art and outplay chess grandmasters, but nothing inside their circuitry feels a thing. This stubborn gap between information processing and lived experience has pushed a growing number of researchers to look beyond classical biology—to the strange realm of quantum physics—for answers.

For decades, scientists believed quantum mechanics—the strange rules that govern reality at its tiniest scales—applied only to atoms and subatomic particles, never to a warm, noisy organ like the human brain. Quantum effects such as superposition (when particles exist in multiple conditions at once) and entanglement (when particles stay connected even across long distances) looked far too fragile to survive in living tissue. However, a growing body of biological evidence is now overturning that assumption.

> *True scientific revolutions happen only when we confront the questions that unsettle us most—none greater than whether the mind itself is written in quantum code.*

Take plants, for instance; during photosynthesis, they seem to channel sunlight through "energy shortcuts" using quantum coherence, a process in which particles, such as electrons, move in a coordinated, wave-like manner, allowing plants to transfer energy more efficiently than classical physics would predict. (Engel et al., 2007). Equally astonishing, certain migratory birds may "see" the Earth's magnetic field via entangled electron pairs—the very "spooky action at a distance" that once baffled Einstein (Cai et al., 2020). Even enzymes, the biological molecules that help expedite chemical reactions in our bodies, appear to rely on quantum tunneling, a process where particles pass through barriers they should not be able to cross (Brookes, 2017). If quantum mechanics can shape photosynthesis, animal navigation, and biochemistry, why should the brain, one of the most complex structures in the known universe, be any different?

Physicist Roger Penrose and anesthesiologist Stuart Hameroff offer one possible explanation with their orchestrated objective reduction (Orch OR) theory, which proposes that consciousness arises from quantum activity within neuronal microtubules (Hameroff & Penrose, 2014). Imagine each subatomic particle in a microtubule as a coin delicately balanced between heads and tails; eventually, gravity tips the scale, causing the particle to drop into a single, definite state. This drop—where many quantum possibilities converge into one—marks the moment when uncertainty resolves into a concrete outcome. Penrose argues that such gravity-triggered events occur spontaneously, while Hameroff suggests that trillions of these synchronized drops fuse into a unified stream of awareness, much like movie frames blend into a continuous scene. Though microtubules are known to support basic cellular functions, in this view, they also act as quantum processors. Supporting evidence comes from anesthesia research, which shows that agents capable of erasing consciousness also disrupt microtubule dynamics (Craddock et al., 2017). If Orch OR is correct, then thoughts and feelings arise not merely from neurons firing, but from quantum events embedded in the brain's deepest architecture. And while we have mapped neurons and charted brain chemistry in great detail, the spark of conscious experience remains elusive. If quantum processes are indeed the hidden engine of the mind, dismissing them would be like nineteenth-century scientists insisting that light followed only classical rules—until quantum mechanics rewrote the story.

Quantum mechanics may influence consciousness in ways that could help explain brain disorders like schizophrenia, depression, and Alzheimer's; not just through chemical imbalances but also through quantum-level disruptions in brain function. This would mean that current treatments, which only adjust neurotransmitters like serotonin and dopamine, may treat symptoms rather than address the root cause.

Imagine mental health therapies that operate at the quantum scale, repairing cognition lost to dementia or reversing the neural scars of depression and PTSD. Rather than merely boosting serotonin, treatments grounded in quantum biology could recalibrate the brain at its most fundamental level—making quantum medicine the next frontier of neuroscience. The implications reach far beyond healthcare. If human thought depends on quantum processes, any artificial intelligence architecture that ignores those principles will remain fundamentally limited. Embedding quantum mechanics into AI design could be essential for machines to approach the flexibility—and perhaps even the awareness—of the human mind.

Tech companies are racing to create AI that thinks like humans, but what if they are pursuing this goal with the wrong method? No matter how advanced AI becomes, it still follows fixed rules and patterns, making predictable decisions. The human brain, however, is flexible, adaptable, and full of surprises, making it fundamentally unpredictable. If consciousness depends on quantum mechanics, AI built on classical computing may never achieve true awareness. Traditional computers process data step by step, while the brain might use quantum superpositions to consider multiple possibilities simultaneously before choosing an action. This could explain human creativity, intuition, and unpredictable thinking. A truly aware machine may not come from artificial neural networks but from quantum computing. Unlike classical computers, quantum computers process multiple possibilities simultaneously, making them more flexible and less predictable. If human thought is rooted in quantum mechanics, only quantum-based AI could replicate the human mind.

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Mainstream neuroscience often resists quantum theories of consciousness because they challenge[2] traditional models of the brain, which are based on classical physics and chemical interactions. However, fully dismissing quantum mechanics may mean ignoring a crucial piece of the puzzle. A common argument against quantum effects is that they[2] require extreme conditions, such as temperatures near absolute zero, to function—conditions that seem impossible in the warm, biological environment of the human brain. However, this assumption is already being challenged. Scientists once believed quantum mechanics had no role in biology, only to later find it in plants, birds, and enzymes. We once thought superconductivity could only occur at absolute zero until materials were discovered that achieved it at much higher temperatures (Bednorz & Müller, 1986). If these long-held beliefs are wrong, what else might we be overlooking?

True scientific revolutions happen only when we confront the questions that unsettle us most—none greater than whether the mind itself is written in quantum code. The task now is collective: neuroscientists could begin probing microtubules for elusive quantum states; physicists might design tools to investigate quantum activity in the living brain; clinicians may need to explore whether schizophrenia, depression, and dementia involve glitches in quantum coherence, not just chemical imbalances; and AI engineers should consider reimagining machines that think in qubits, not bits. Crack this enigma, and we unlock quantum medicine, reinvent psychiatry, and push artificial intelligence to the brink of sentience. Fail, and we leave the defining spark of our humanity—a sense of "I am"—shrouded in permanent mystery.

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A Flightless Future: How Will Avian Flu Impact the US?

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On January 6, 2025, the CDC reported the US's first human death from avian flu (Public Health On Call, 2025). As the first human fatality, this announcement demonstrates the need for a clear, cohesive response to minimize large-scale effects on public health.

Scientists first discovered avian flu in wild birds during the 1990s. However, animal populations were not commonly affected until February 2022 (CDC, 2025). Since then, the virus rapidly evolved to affect poultry, cattle, and many more species. As of March 5, 2025, avian flu has spread to 17 states and infected over 950 dairy herds (CDC, 2025).

Many scientists and researchers believe that, if mishandled, the avian flu could turn into a pandemic-level threat for humans and animals alike. Its current rate of evolution, along with multiple mutations, paint a grim picture. At this point, farm workers are currently the most at-risk population. Many refuse to test their livestock due to financial concerns, such as loss of profit due to shutdowns, worsening the issue (Awan, 2025). The United States Department of Agriculture (USDA) repeatedly struggles to limit the spread of avian flu across farms, with most measures, such as testing raw milk for avian flu and increased access to personal protective equipment, failing to quickly address the virus at its starting point (News Medical, 2024). As a result of these factors, avian flu has the potential to cause a pandemic if proactive measures are not taken.

Transmission and Cases

Avian flu, specifically the H5N1 strand, is highly transmissible across species. The H5N1 avian flu strain originated in wild birds but was later detected and known to infect humans, domestic poultry, cows, dogs, and more (CDC, 2025). Smaller infected animals, such as field mice, aided the spread of infections from farm to farm; as a result, the outbreak expanded to eight more states by April 2024.

> *Contact with influenza during flu seasons could lead to the sharing of genetic information between the two viruses, also known as recombination.*

Avian flu can also circulate without direct animal contact. Contaminated surfaces, such as milking equipment, can transmit avian flu, allowing it to become more widespread (News Medical, 2024). Current transmission of the avian flu to humans requires contact with the virus and then with the eyes, mouth, or nose. There are no known instances of it spreading directly from person to person. Moreover, there are many concerns regarding the transmission of the avian flu through raw milk, as tests have repeatedly detected it. However, there are no proven cases yet (Johns Hopkins Bloomberg School of Public Health, 2025). Current knowledge is subject to change as more and more information comes out regarding avian flu's evolution.

Interspecies transmission of H5N1 creates major concerns within agriculture and healthcare sectors. Sustained animal-to-animal transmissions in mammals other than cows, such as ferrets, are an ominous sign of the infectious potential of avian flu (News Medical, 2024). According to Andy Pekosz, a professor in microbiology at Johns Hopkins University, researchers learned that the virus began to mutate in ways that would allow it to spread more efficiently in humans (Johns Hopkins Bloomberg School of Public Health, 2025).

These mutations open up new pathways for large-scale infections, similar to the COVID-19 pandemic. Additionally, while there is no evidence of avian flu being airborne, contact with influenza during flu seasons could lead to the sharing of genetic information between the two viruses, also known as recombination (Johns Hopkins Bloomberg School of Public Health, 2025). Recombination occurs during the coinfection of a host cell, and is known to produce new or more virulent strains (Fleischmann, 2025). Recombinants of viruses can also infect previously immune individuals, leading to viruses causing multiple pandemics (Fleischmann, 2025). One such case of this is the H1N1 influenza virus that caused multiple pandemics in 1918-191, 1934, and 1947(Fleischmann, 2025). As a result of recombination, the risk of multiple pandemics across a multi-year span increases, expanding the impact of the virus.

Future

Concerning public health, the rapid evolution of the avian flu creates serious concerns. In 2020, gene swapping between avian flu strains in poultry and wild birds led to the creation of H5N1, the main culprit in most cases. First identified in Europe, H5N1 then rapidly spread to Africa, the Middle East, Asia, and the Americas (CDC, 2024). In 2021, there were 36 cases of avian flu, with 18 deaths in China, and spread to foxes by the end of the year (CDC, 2024).

Despite concerns of the spread of avian flu through raw milk, the CDC has marked its health risk as low in December 20, 2024 (HPAI in Livestock | Animal and Plant Health Inspection Service, 2024).

Currently, farm workers and the agriculture industry as a whole are the most vulnerable. Out of 77 human cases, most are those in direct contact with infected animals. As a result, the majority of protective measures target farms. Farmers have already killed over 166 million to slow down the disease, with little effect (Rust & Kaplan, 2025). One major flaw in this approach is that infected birds can be asymptomatic and spread the disease through their feces before it is detected. This requires each bird to be tested individually, which is expensive and time-consuming (Rust & Kaplan, 2025). Even worse, laying hens are the most susceptible to avian flu, which can wipe out whole flocks at once (On the Frontline against Bird Flu, 2025). The USDA offers financial incentives and reimbursements, however, it is not enough to encourage and support farmers in the fight against the disease (Reals, 2024).

Are We Doing Enough?

The USDA announced the outbreak on March 25, 2024, shifting control from localized scientists and farmers to government officials (News Medical, 2024). Due to a lack of studies and early testing, the avian flu spread quickly through multiple states with little stopping. In December 2024, a federal order to test all raw milk nationwide was enacted (Awan, 2025). While helpful now, avian flu was found in raw milk supplies months before and could have been tracked down and isolated earlier. Since 2022, the USDA has already funneled $1.7 billion into containing the spread of avian flu on poultry farms, including running multiple outreach programs to gain farmers' participation (News Medical, 2024).

While the government has taken some steps to mitigate the effects of the avian flu, its effects are negligible. As of 2025, the CDC recommends many biosecurity measures, including enhanced personal protective equipment, more testing, and increased outreach (CDC, 2025). However, even with millions of dollars worth of biosecurity, the spread of avian flu has not slowed down (On the Frontline against Bird Flu, 2025). Slow government response at the start could be the culprit.

Moreover, President Trump's intent to have the US exit the World Health Organization has created many worries about global cooperation in containing avian flu (Kozlov, 2025). Still, the current actions taken by the US government to limit avian flu have had an overall minimal impact, leading researchers, veterinarians, and farmers alike to call for a new approach.

Next Steps

Proactive measures must be taken to prevent an avian flu pandemic. Containment of infected animals should have already been organized, which could have prevented mass cullings and limited human cases. It is of utmost importance to have widespread animal surveillance to monitor outbreaks. Early-on testing can allow for the severity and reach of each outbreak to be understood and the spread to be limited (Awan, 2025). One way this can be achieved is by simultaneously testing milk from multiple farms; if avian flu is detected, it can be traced back to and isolated at its origin (Johns Hopkins Bloomberg School of Public Health, 2025). Moreover, farms should have easier access to testing equipment, more financial funding, and be updated on the current situation regionally (News Medical, 2024).

Farms should also have better access to testing equipment, more financial funding, and be regularly updated (News Medical, 2024). Vaccines for farm workers are also another important step. As they are currently the most at-risk, stronger protections, including vaccinations, could prevent widespread avian flu and ensure their health and safety (News Medical, 2024). Additionally, tackling the issue before it transmits widely can prevent a public health crisis. Addressing the avian flu by involving local scientists and workers is ultimately the best way to combat its spread.

Conclusion

Avian flu is a rapidly evolving threat to public health, animals, and the poultry industry as a whole. Already, the ramifications are seen through increased consumer prices, farms' financial struggles, human infections, and the deaths of thousands of birds and cattle. Undoubtedly, as avian flu continues to evolve through recombination, infection rates will sharply rise among both livestock and humans. Slow government reaction and the lack of proactive measures certainly intensified the severity and extent of the virus. However, collaborations between local officials and the federal government can halt the spread of the virus, and consistent monitoring of its evolutions can ensure the proper treatment of new strains.

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ENVIRONMENT

Nurdles

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Nurdles are tiny (3-5 mm) plastic pellets that serve as the building blocks of plastic products, posing a significant threat to ocean life and animals.

They are made from fossil fuels and contain harmful chemicals, including phthalates, Bisphenol A, Flame retardants, Organotins, Heavy metals, and perfluoroalkyl and polyfluoroalkyl substances. The chemical makeup of nurdles produces bacterial hosting capabilities, creating a plastisphere' camp that can act as a reservoir for fecal and pathogenic bacteria.

Nurdles go through a global plastic supply chain during the transportation of supplies, and nurdles often get leaked into the ocean due to their small size. Plastic pellets can be released at any stage of the plastic pellet supply chain including during production or transportation. The nurdles can spread via wind, currents, and tides, ultimately ending up in nearby habitats and ecosystems, both on land and in the sea. These spills are disastrous and hard to clean up, oftentimes diverting to different places. Once spilled, these nurdles can trickle through sewers, storm drains, and the ocean, leading to detrimental and disastrous problems.

Nurdles can be found in communities, protected areas, fisheries, and even in remote regions. Nurdles' impact is not just limited to communities, it poses one of the most serious threats to marine life, harming everything from seals, seabirds, fish, and many more. Furthermore, over 220 marine species have ingested plastic debris including puffins, turtles, urchins, fish, and more. Once digested, these nurdles remain in the stomachs of wildlife, leading to malnutrition and oftentimes starvation.

One of the largest nurdle spills in history took place on Sri Lanka's coast in 2021. During the incident, the X-Press Pearl unleashed a record 1,680 metric tons and 70 billion 5 mm plastic pellets. The plastic engulfed the beach to the point that the sand could not be seen. Images of nurdles stuck in fish mouths and gills raised public concerns about the safety of eating seafood while also affecting the fisheries, which are a major source of income for Sri Lanka. Fishermen who were already having difficulty making ends meet because of COVID-19 containment measures saw a significant decline in their income as a result of the ship catastrophe.

It is not feasible to remove every pellet from the marine and coastal environment once it has been spilled. To ensure that nurdles are packaged, stored, and transported with utmost care, steps must be taken both domestically and internationally to prevent plastic pellet pollution at its source through effective laws and regulations. Currently, due to a lack of industry transparency and reporting, nurdle spills are unrecorded because they are not classified as "hazardous" materials. There are no IMO rules regulating plastic pellets and spills across the ocean, despite their detrimental impact on the ocean and environment. As a result, there is little to no research on nurdles or its prevention. The gap between scientific evidence and social awareness of this issue remains inadequately addressed.

Research must be conducted on this topic, as well as on plastic pollution and its impacts on the ocean. Individuals can prevent nurdles spills by spreading awareness, supporting policy legislation, or identifying nurdles on local beaches. There are a couple of policy legislation citizens can support including the UN Global Plastics Treaty and the Plastic Pellet Free Waters Act. Simple mandates to regulate and enforce stricter precautions can help remove the 11.5 trillion plastic pellets that end up in the ocean every year. It's this vital, yet overlooked, scientific evidence that must be brought up in topics of current interest and government policies.

Inflammation: The Hidden Culprit Behind Memory Loss

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What if the immune system is the key to preserving memory, rather than memory functioning solely in the brain? The reality for millions suffering from Alzheimer's disease consists of struggling to recall aspects of loved ones and feeling lost. Traditionally, neuroscientists have understood Alzheimer's as a neurodegenerative disease marked by the accumulation of amyloid beta proteins and tangled neurons. The accumulation of amyloid beta proteins and tangled neurons disturbs communication between brain cells while triggering inflammation and cell death. The damage that follows reduces the ability of an individual's memory, thinking, and behavior, leading to cognitive decline. However, research is evolving and suggests that the root causes extend beyond the brain and instead rely on the body's immune system.

Recent studies highlight the critical role of the immune system in maintaining cognitive function, especially through the regulation of the brain-resident immune cells known as microglia. These immune cells clear waste and harmful substances but become less efficient as time goes on. This decline contributes to and results in neurodegeneration (Bullut et al., 2021).

Long-lasting and overactive responses known as chronic systemic inflammation can be found in an individual's immune system and are currently being viewed as a hidden but evident cause of brain cell damage over time (Wu et al., 2021, p.1). This occurs often due to the brain's immune cells, called microglia, becoming less effective as we age. The microglia may start producing too many inflammatory signals called cytokines (Bullut et al., 2021). However, these signals are able to block the brain's ability to produce new neurons- a process known as neurogenesis. This emerging research suggests that Alzheimer's disease is not only a neurological disorder but also an inflammatory one. Recognizing this nature may offer a new path to prevention by being able to manage inflammation early in life.

> *If systemic inflammation is the hidden fire behind memory loss, then we hold the match, and the power to extinguish it before it spreads.*

Inflammation is scientifically recognized as the body's natural defense mechanism against destructive infections and injuries (Cekici et al., 2013, p. 2). Scraping a knee or catching a cold helps your immune system's ability to trigger an inflammatory response and heal any damage that occurred. Additionally, when inflammation becomes chronic due to persistent stressors, such as pollution, unhealthy life choices, or aging, there is a shift from a protective to a harmful state. Think of inflammation like a fire: when controlled, it protects, but when unchecked, it destroys healthy tissue.

Chronic systemic inflammation damages the brain and harms the heart and joints. Recent scientific studies have linked systemic inflammation to Alzheimer's disease. One key connection that links systemic inflammation to Alzheimer's is that chronic inflammation can damage blood vessels, reducing oxygen and nutrient flow to the brain. This disruption sets the stage for cognitive decline. For example, researchers found that individuals who exhibited better memory function had increased levels of monocytes, a type of white blood cell involved in immune response (Patel et al., 2024, p. 67). While this may seem counterintuitive given that monocytes are usually associated with inflammation, their role in Alzheimer's Disease is more complex. In healthy conditions, monocytes help clear harmful proteins from the brain. However, when systemic inflammation becomes chronic, these immune cells can contribute to neural damage rather than protection (Munawara et al., 2021, p. 3). The delicate balance between brain health and immune activity is highlighted as inflammation plays a crucial role in Alzheimer's progression.

Although aging is a significant risk factor in Alzheimer's disease, many people unknowingly live[2] in a state of chronic inflammation due to modern diets high in processed foods and stress. This further supports the idea that inflammation is a silent but powerful driver of memory loss, one that we can potentially mitigate through lifestyle modifications[2] and medical interventions.

If systemic inflammation continues to be a key factor in Alzheimer's disease, addressing it early on could be a tool for prevention. Unlike genetics, which we can't change, inflammation is largely influenced by modifiable factors such as diet, stress management, and exercise. A holistic approach, incorporating regular physical activity, socialization, and adequate rest, can reduce inflammation and promote cognitive health (Scheiber & Mank, 2023). Despite these promising insights, the healthcare system still classifies Alzheimer's disease as an untreatable condition rather than a preventable, whole-body condition. Shifting the medical focus toward inflammation could transform the way we diagnose, treat, and prevent memory loss.

Alzheimer's is also not an inevitable part of aging. The growing evidence linking cognitive decline to systemic inflammation suggests that individuals have more control over brain health than previously believed. By promoting habits that can prevent inflammatory responses, there is a stronger pathway for the medical community to explore new pathways for treatment. It's time to rethink Alzheimer's. If systemic inflammation is the hidden fire behind memory loss, then we hold the match, and the power to extinguish it before it spreads.

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Societal Pressures and Gendered Aging: How Expectations Around Pregnancy Contribute to Women's Increased Development of Alzheimer's Disease

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Alzheimer's disease (AD) is a neurodegenerative disease that slowly deteriorates memory and cognition, eventually leading to the inability to carry out day-to-day tasks ("Alzheimer's Disease Fact Sheet," 2023). AD is more prevalent in women, but why? Harvard studies have shown that it is due to women aging at a higher rate than men (Budson, 2022). Due to cultural and societal expectations, women have been pressured to establish families and become mothers (Güner and Öztürk, 2023b). Giving birth accelerates aging, which increases the probability of women developing AD ("Does Pregnancy Accelerate Aging? Yale Findings Suggest It Does – at First," 2024). The social and cultural pressure on women to have more children can in fact cause long-term detrimental effects on women as it increases their rate of aging.

Unwanted pregnancies can create a mental toll for women, inducing stress and causing accelerated aging. With the recent overturning of Roe v. Wade, 40% of women have been forced to carry out unintended pregnancies, which has increased the rate of postpartum aging significantly (Berg and Woods, 2023). Aging increases amongst women after childbirth due to the increased release of hormones, leading to mental deterioration (Faisal-Cury et al., 2021). This increased rate of aging amongst women leads to memory loss and the development of AD.

Women also hit puberty earlier than men, increasing estrogen, a group of steroid hormones which promote the development and maintenance of female characteristics of the body, production (Biro et al., 2012). This increased estrogen is beneficial for aging as it improves cognitive function. However, estrogen production significantly decreases after menopause, causing a cognitive decline and amplifying aging (Thornton, 2013). Decreased estrogen production after hitting menopause also leads to diabetes, a dysfunction in glucose metabolism. Improper metabolization of glucose then leads to a high risk of developing AD because it causes lack of sleep (Pacheco & Pacheco, 2023). This enhances amyloid plaques and Tau – excess proteins in the brain that contribute to the development of AD – accumulation on the neurons. Due to diabetes causing a decreased functionality in metabolizing glucose, sleep is disturbed, disrupting the circadian rhythm. This pattern of spikes in glucose levels and lack of sleep becomes cyclic and results in a decreased flow of cerebrospinal fluid (CSF) – liquid found in the spine and brain that aids in cushioning, providing nutrients, and removing waste from the brain – to the brain which aids in the removal of amyloid plaques and Tau. As a result, the decrease in estrogen that women experience during menopause causes diabetes to form as a symptom.

Diabetes, which is the impairment of glucose metabolism, plays a vital role in developing AD because its reduced regulation causes neuronal death (Role of Glucose Metabolism in Alzheimer's Disease, 2024). This causes a reduced volume of the brain that further inhibits sleep and induces a cyclic pattern of glucose being unregulated.

With sleep fragmentation and reduced brain volume, Tau and amyloid plaques are not removed to the extent that they would be with regular CSF flow. Due to the decrease in brain volume, the hippocampus loses neurons, causing memory decline. Reduced brain volume also causes ventricles to lack CSF flowing within them, ultimately leading to impaired regulation of nutrients for brain repair and removal of excess proteins.

Stressors associated with pregnancy can lead to diabetes, reducing sleep, which is directly correlated with reduced CSF flow (JackW, n.d.). All these factors are attributed to the decrease in estrogen after menopause, which accelerates aging (Levine et al., 2016). Aging is already caused in women after giving birth; with menopause, the conditions for aging heighten. However, due to these effects being predominantly shown in menopause, we can conclude that the factors for AD are more severe in women because of the many factors and developments that decreased estrogen may cause (Ali et al., 2023). Due to pregnancies and menopause leading to a decreased level of estrogen, women are more prone to developing AD and the associated health issues that come with it such as cardiovascular disease, diabetes, and sleep disorders (Batulan, Bhimla, and Higginbotham, 2024). A study at Johns Hopkins found that there had been a small but significant (3.03%) increase in self-reports of anxiety and depression amongst women in states where abortion bans have affected women more detrimentally ages 18-45 in the six months following the overturning of Roe v. Wade ("Analysis of U.S. Census Survey Data Reveals Uptick in Anxiety and Depression Among Women in States With Trigger Laws Post-Dobbs Abortion Decision," 2024). As pregnancy continues, the stress inflicted upon women's bodies causes them to age more. This disparity between men and women developing AD can be caused by the contributing factors of societal pressure on women to have children.

Women developing AD at a heightened level than men is not an uncontrollable biological issue. The stigma around women that do not have children can cause lasting detrimental effects on women as it increases their chances of developing AD. Bans on abortion and pressure for child rearing have extended effects on women's bodies that are not widely known. Policy makers need to recognize the biological research on gendered aging to fully understand the scope and consequences of their policies. Body autonomy should be a right for all women since pregnancies can adversely affect their health.

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