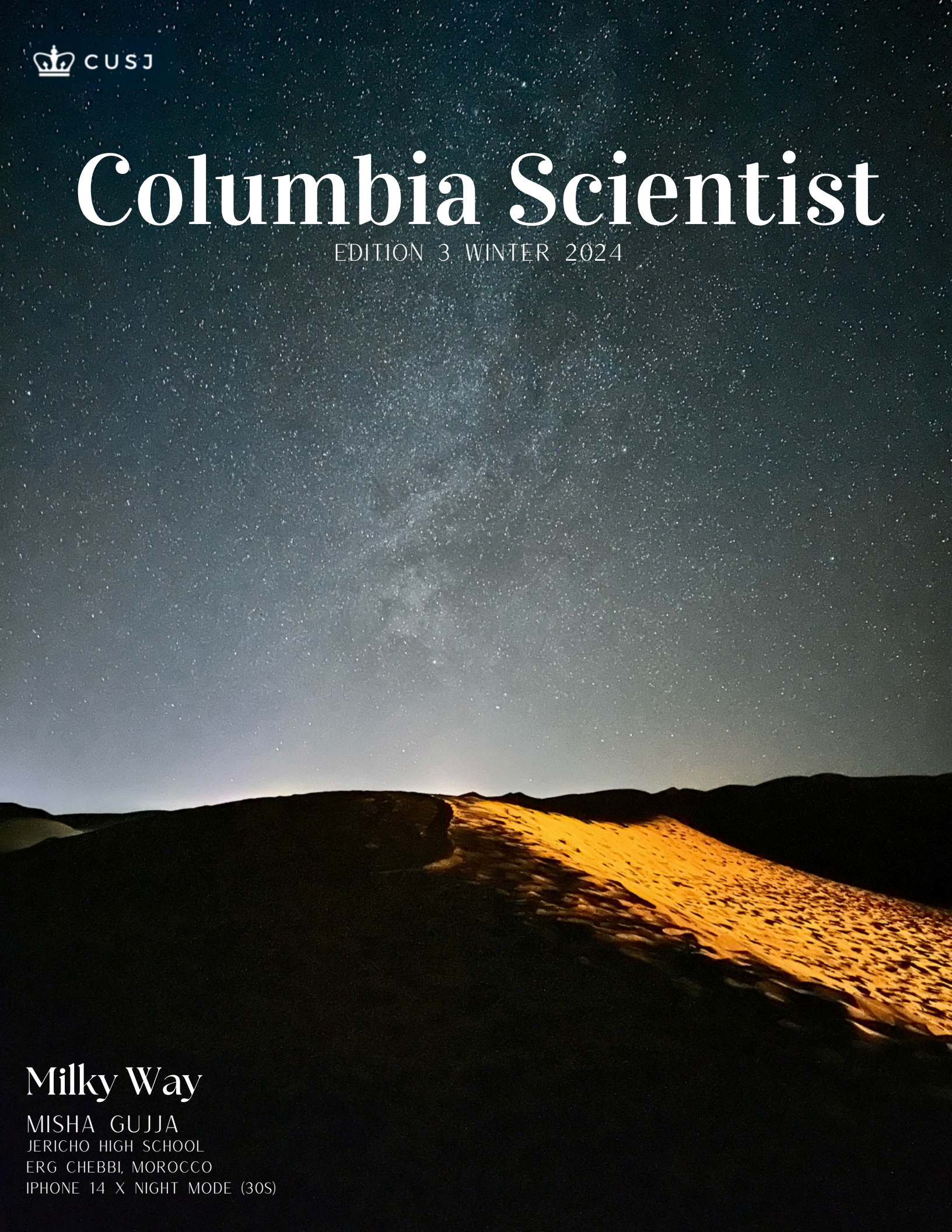
CUSJ

Columbia Scientist

EDITION 3 WINTER 2024



Milky Way

MISHA GUJJA
JERICHO HIGH SCHOOL

ERG CHEBBI, MOROCCO
IPHONE 14 X NIGHT MODE (30S)

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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TABLE OF CONTENTS

ADMINISTRATIVE

Letter from Co-Editors-In Chief....4
Letter from President....5
Letter from Masthead....6

SELECTED WORKS

Milky Way
Misha Gujja....1

Bloody Breakthrough: Menstrual Blood-Derived Stem Cell Therapy
Joanna Lin....7

Whispers of Tomorrow: Gene Therapy's Quest to Silence Neurodegeneration
Axel Perez....9

Ozempic and the "Miracle Drug" Craze
Megan Sargent....11

The Implications and Challenges of Nature-Inclusive Cities
Carolyn Eloy....14

Algorithmic Architecture and Computational Fluid Dynamics: Innovating Structural Design in the Spinning Desert Oasis Project
Crystal (Yirou) Su 17

Automatic Video Labeling and its Potential Uses
Jose Rubio 19

Nanocrystals
Samyra Mahiba....21

First-Ever Gene Therapy for High Cholesterol: The One-Time Solution to 4 Million Annual Deaths?
Lehansa Marambarage....22

Riding the Wave of Innovation: The Unspottable Surge of Lipid Nanoparticles in Modern Medicine
Angelina Mao....25

Advancements in Skin Cancer: Treatment Using Immunotherapy
Angelina Mathew....27

Cells, Cells, Cells: The Building Blocks of Life and Art?
Chidalu Emy-Munonye....29

The Birth of Action Potential
Avantika Palayekar....32

Orbital Ecology: Science's Frontier in Addressing the Space Debris Dilemma
Eva Cullen....33

Defective Detective: We Need *Explainable* Machine Learning in Patient Care
Maria Storch....35

Potential of Microrobots to Effectively Remove Blood Clots and Delivery Targeted Drugs
Emily Matthew....38

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LETTER FROM CO-EDITORS-IN-CHIEF

Dear Readers,

It is with great pleasure that we present the third edition, the Winter 2024 issue, of the Columbia Scientist. Originally started in 2022, the Columbia Scientist serves as a platform for all people to comment upon or highlight current ethical issues within any field of science. This year, we are happy to feature both essays and artwork from students across the nation. Additionally, seeing young scientists dive into conversations about what's right and what really matters isn't just uplifting—it's a reminder that progress isn't just about what we can do, but about what we should do. Their thoughtfulness shows a real commitment to making sure innovation stays grounded in humanity and purpose.

We want to acknowledge the delay in the publication of this issue and provide transparency about the factors that contributed to it. Originally, we planned to release this publication in Spring 2024. However, the campus environment during that time—marked by intense discourse, protests, and tension surrounding the conflict in Israel and Palestine—impacted our capacity to meet this timeline as we pivoted to healing as a community.

We focus on delivering high-quality content that fosters curiosity, innovation, and creativity. Yet, we recognize that the broader Columbia campus atmosphere influenced our capacity to finalize the selected works as planned. After careful reflection, we decided to take the necessary time to ensure this issue met our standards and aligned with the values of the Columbia Scientist community.

This paper would not be possible without the help of many fantastic students and faculty. We would like to thank Priya Ray '25 and Adriana Delagarza '25 for their extensive work on this publication and the exceptional leadership of the Columbia Scientist as Editors-in-Chief of the previous year. We would like to thank the many students who participated in Columbia Undergraduate Science Journal's annual Summer Publishing Program or in the Art of Engineering course who wrote many of the essays featured in this edition. We would also like to thank the wonderful team of editors behind the Columbia Scientist and the support of the Columbia Undergraduate Science Journal for their help in putting together this publication. Most importantly, we would like to thank all of those who submitted their work to the Columbia Scientist.

It has truly been a delight to curate the selected pieces and feature the talent of many young scientific minds. We sincerely hope you enjoy reading this edition as much as we did.

Best,
Stephanie Nnaji '26, Cindy Lu '27
Co-Editors-in-Chief, Columbia Scientist

COLUMBIA UNDERGRADUATE SCIENCE JOURNAL

LETTER FROM CUSJ PRESIDENT

Dear Readers,

It is with tremendous pride that I announce the release of the third annual edition of the Columbia Scientist. This issue — rooted in unwavering purpose and driven by transformative innovation — exemplifies the spirit and founding principles of the Columbia Undergraduate Science Journal (CUSJ). At its core, CUSJ exists to showcase exemplary scientific research and its profound implications for life and society. From breakthroughs in stem cell therapy to the revolutionary role of machine learning in patient care, this issue represents a profound manifestation of the utilization of science for humanity. Our selected works do not exist in a vacuum but, rather, are part of a global dialogue of progress driven by science.

As an associate editor in 2022, I had the privilege of witnessing Columbia Scientist's beginning. Two years later, I am filled with immense pride for the authors and the Columbia Scientist team that have brought this issue to fruition. Countless hours of invisible labor are concealed within each page. This work — and science in general — would not be possible without the contributions of many. I commend the Columbia Scientist Editors-in-Chief, Stephanie Nnaji and Cindy Lu, and their team for their tremendous work on this issue. From hundreds of submissions, they have thoughtfully and carefully curated a selection of impactful and original scholarship to bring to you — our readers.

To our readers: your curiosity and avid readership are the foundation of our work here at CUSJ. Thank you for your continued support and thoughtful engagement with our selected works. Without further ado, I invite you to enjoy the Winter 2024 edition of the Columbia Scientist!

Cordially,
Kayla Pham '26
President, Columbia Undergraduate Science Journal

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MASTHEAD

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Bloody Breakthrough: Menstrual Blood-Derived Stem Cell Therapy

Joanna Lin
Columbia University

What are periods? No, really. What is it that makes up the monthly bleeding that half of the population experiences?

It should come as no surprise that approximately 1.8 billion people menstruate every month worldwide (Rohatgi & Dash, 2023). However, less is widely known—and discussed—about the biological components of a period. Menstrual blood is composed of three distinct fluids: blood, vaginal fluid, and the shedding of the uterine lining during menstruation. For scientists, that same menstrual blood may also be the next cutting-edge tool in regenerative medicine. Researchers believe in its wide-ranging ability to treat degenerative conditions such as Alzheimer's disease and to repair damaged or deteriorated organs such as the heart and skin.

Pioneered in 2007 by Xiaolong Meng et al., the discovery of menstrual blood-derived stem cells rattled the field of regenerative medicine. Stem cell therapy aims to repair injured or diseased cells using lab-grown stem cells, which are manipulated to develop into specialized cells such as nerve and cardiac cells. For example, for a person with heart disease, stem cells could be injected into heart muscle to differentiate–become mature and specialized–into cardiac cells, subsequently repairing the injured tissue.

While stem-cell therapy holds promise in paving the way for groundbreaking treatments, there are a host of challenges and ethical considerations associated with conventional methods of cell acquisition.

> *Contrary to the stem cells obtained invasively, menstrual blood-derived stem cells can be harvested by simply collecting menstrual fluid, often through the use of sterile menstrual cups from healthy fertile women between the ages of 22-30.*

Menstrual blood-derived stem cells eliminate many associated ethical concerns and the need for invasive operations for acquiring stem cells. But most of all, menstrual-blood derived stem cells stand out in their accessibility. However, this begs the question: how viable are stem cells derived from menstrual blood?

Research indicates that menstrual blood-derived stem cells express a range of characteristics similar to those of both embryonic and adult stem cells, indicated by specific cell markers in certain conditions (Faramarzi et al., 2016). As opposed to adult stem cells derived from bone marrow, menstrual blood-derived stem cells have the capacity to undergo multi-lineage differentiation, allowing for a greater range in their treatment capabilities. Further research has also found that menstrual blood-derived stem cells are able to differentiate into cells in bone, fat, cartilage, liver, and cardiac muscle, to varying capacities (Sayeh Khanjani et al., 2014). Such versatility in treatment capabilities holds considerable promise for potential therapeutic applications in the future.

Expanding on this potential, a recent study conducted by Yanling Zhang et al. simulated the use of menstrual blood-derived stem cells to treat intrauterine adhesions, a condition resulting in scar-tissue buildup in the uterus, within mice (Zhang et al., 2016). Researchers treated the mice using menstrual blood derived-stem cells, taken from human menstrual blood, which were injected into the mice through their tails (Zhang et al., 2016). The injected cells were able to migrate to the injury site and transform into cells within the uterine lining (Zhang et al., 2016). Following the treatment, the mice made an incredible recovery, showing significant improvement in their uterine lining and fertility (Zhang et al., 2016). Zhang's finding suggests that menstrual blood-derived stem cell therapy could be used as a novel method of treatment for intrauterine adhesions in humans.

Menstrual blood-derived stem cells have also demonstrated effectiveness in treating an array of other diseases in mouse models. These diseases include acute and chronic liver diseases, acute lung injury, epithelial ovarian cancer, Alzheimer's disease, and neurodegenerative diseases, among others (Chen, Qu, Cheng, Chen, & Xiang, 2019). Beyond disease treatment, a simpler example of using menstrual blood for stem cell therapy is found in treating cutaneous wounds, which are injuries to the skin. The goal of cutaneous wound repair is to restore the damaged tissue to its original state, leaving no scars. Yanling Zhang et al. found that after mice were injected with menstrual blood-derived stem cells, they exhibited significantly improved wound healing and enhanced formation of new blood vessels at the injury site (2016). Beyond generating specific cells used in the rebuilding of damaged tissue, menstrual blood-derived stem cells also secreted several proteins used in cell signaling for wound repair post-injection, increasing their ability to heal wounds to their original state (Zhang et al., 2016).

While researchers are optimistic, there remains a degree of uncertainty in the efficacy of menstrual blood-derived stem cell therapy. Recent research has reported that menstrual blood-derived stem cells from donors over the age of 40 showed a diminished long-term proliferation capacity, raising concerns about the efficacy among different age groups of donors (Haining Lv, Hu, Cui, & Jia, 2018).

In the complex world of regenerative medicine, the potential of menstrual blood in stem-cell therapy remains yet to be fully discovered, but ongoing research offers hope in the next "bloody" breakthrough.

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Whispers of Tomorrow: Gene Therapy's Quest to Silence Neurodegeneration

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Limited treatment options are available for neurodegenerative diseases (NDs), leaving millions of patients and their families worldwide to endure these conditions while struggling to access essential medical care. The troubling predicament of these individuals has pushed scientists to explore new therapeutic avenues that may offer new hope to these patients.

Neurodegenerative diseases diminish patients' quality of life and are characterized by the loss of structure and function of neurons, the primary cells of the nervous system. The effects of this loss depend on the type of neuron and its location in the brain. For instance, patients with Parkinson's disease (PD) gradually lose their motor abilities, whereas patients with Alzheimer's disease face cognitive disruption.

Unfortunately, not only are treatments for these diseases limited, but existing options also tend to target symptom relief rather than the diseases' chemical and biological root causes. In addition, the blood-brain barrier (BBB), a highly selective membrane that filters molecules and ions from entering the brain, prevents some existing drugs from reaching their destination, blocking the effects of the treatment altogether (Sudhakar and Richardson). Therefore, there is a pressing need for new innovative procedures, and gene therapy offers a possible lasting solution to this problem.

Gene therapy refers to the introduction of a therapeutic gene–whether it be a synthetic DNA molecule made by researchers or an extracted gene naturally found in another organism– to replace a harmful one in an organism's DNA (Papanikolaou and Bosio). When this gene is introduced into a cell, it is expressed by cell machinery, leading to beneficial effects. In the case of NDs, genes could be introduced that help combat neuron degeneration, protecting the patient from further genetic mutations or chemical dysregulations by changing its core genetic makeup.

These therapies have already shown success in treating other conditions. As of 2024, five gene therapies for rare diseases have been approved by the U.S. Food and Drug Administration. These include treatments for a blood hemoglobin disorder (Beta-thalassemia), a brain condition that damages the protective myelin sheaths of neurons (adrenoleukodystrophy), and a disorder characterized by lack of blood clotting (hemophilia A) (Mullard 87). Although it may seem unfeasible, gene therapy is a very real technology that is already in use today.

But how are therapeutic genes actually transported to their targets? A common method to carry therapeutic genes are viruses. Viruses can first be modified so that they are no longer harmful to the health of the host organism. This virus is then loaded with the desired gene and introduced surgically or non-invasively to deliver the gene to target cells (Li et al.). Efficiently implementing this delivery technique ensures the gene therapy reaches the target cells, as opposed to other methods where the BBB or the cell membrane of neurons could block it.

To confirm the safety and efficacy of these gene therapies for the treatment of NDs, clinical trials are absolutely critical. Trials have been conducted on a range of NDs, but one disease of particular

interest has been Parkinson's disease, where neurons that produce the chemical dopamine, essential for movement control, decay in the brain. The majority of the trials, in animals and humans, focus on introducing a gene that codes for enzymes that control the production of dopamine. The goal is to combat the effects of losing neurons that produce the chemical (Muramatsu et al). The results from the study by Muramatsu et al. were promising, showing that participants' motor performance improved following the genetic treatment. Although the small number of participants —six individuals— was a limitation of the study, the results show that the potential of gene therapy should be taken seriously and tested further.

Gene therapy holds significant promise in becoming a solution for neurodegenerative diseases, considering the current absence of curative treatments. Similar to every novel procedure, gene therapy faces challenges that include its accuracy in introducing a gene into the patient's genome and potential disruption of other genes (Papanikolaou and Bosio). Nonetheless, this should not stop its development. With further advances in these procedures and genetic engineering techniques, gene therapy could become the gold-standard treatment and help millions of patients globally. There should be great effort placed into developing better techniques for the delivery of these systems to ensure their accuracy and efficiency. After all, gene therapy may hold life-saving and life-changing potential for those afflicted by neurodegenerative diseases.

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Ozempic and the "Miracle Drug" Craze

Megan Sargent
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On March 12th, 2023, Jimmy Kimmel opened the Oscars by jokingly announcing, "Everybody looks great. When I look around this room, I can't help but wonder: Is Ozempic right for me?" ("Jimmy Kimmel", 2023). His words came after numerous celebrities, including Elon Musk and Amy Schumer, announced that they were using the prescription drug to lose weight. But it's not just celebrities jumping on the Ozempic train; millions of individuals have been sharing their experiences with the drug, especially on TikTok, where the hashtag has since garnered over 350 million views (Awan, 2023). Such popularity has inspired the nickname of "the miracle drug," but many overlook how misleading this title can be.

Ozempic is one example of a medication that falls under the larger umbrella of glucagon-like peptide-1 (GLP-1) receptor agonists, delivered in weekly shots. These agonists (known as semaglutide) are synthetic hormones that mimic the function of GLP-1, a naturally occurring hormone that is released after we eat ("What is Semaglutide", n.d.). When GLP-1 is released, it stimulates the secretion of insulin and inhibits glucagon secretion to regulate blood sugar (Holst, 2007). Because of this, GLP-1 receptor agonists have been a staple for treatments for diabetes, a disease characterized by low blood sugar levels and little insulin production ("What Is Diabetes?", n.d.). GLP-1 has another function, though. It has been credited with delaying gut motility and gastric emptying, which slow down digestion and allow you to feel fuller for longer (Shah, 2014).

Ozempic's primary use has always been for the treatment of type 2 diabetes, and it was cleared by the FDA for this purpose in 2017 ("Novo Nordisk", 2017). While the medication has never been cleared for weight loss, this hasn't stopped individuals from using it "off-label," a practice by which patients are prescribed drugs for purposes other than those FDA-approved. Off-label use is especially prominent with Ozempic, as most doctors are comfortable giving a prescription for individuals who are overweight or obese and have seen little progress with other medications, even if they don't have type 2 diabetes. Because this process is so simple—often only requiring a conversation with a doctor—it has prompted huge demand for the drug. In 2021 a similar semaglutide drug, Wegovy, was approved for weight loss purposes, helping to relieve pressure on Ozempic and the diabetics who rely on it. However, the craze for the drugs never showed signs of slowing down, with prescriptions rising 300% from 2020 to 2023, and both Ozempic and Wegovy being put on the FDA's Drug Shortages list in 2023 (Raman, 2024).

Shortages aren't the only issue with Ozempic: misinformation surrounding its use and effects are also rampant. For one, a popular notion surrounding Ozempic is the idea that individuals who take it can eat as much as they want without gaining weight, which is far from the case. Instead, Ozempic works as an appetite suppressor, decreasing the amount of food individuals are likely to eat on the drug without actually changing the caloric value of the food itself. Another common misconception comes from its side effects, specifically "Ozempic face." "Ozempic face" is the phenomenon observed when rapid weight loss on Ozempic leads to the look of a hollowed-out face. While this trend has been credited as normal, the rapid weight loss it requires likely goes well beyond the maximum weight loss of 1-2 pounds per week that the CDC

recommends, promoting a dangerous standard (Kassel, 2023). The consequences this can have on one's body are significant—including irritability, fatigue, and even malnutrition (WebMD, 2023). Weight loss medications that seem to offer rapid results, like Wegovy, may also lead individuals to become obsessed with the numbers behind their progress each week, even if such progress is not sustainable in the long-term.

Perhaps the biggest issue with the drug has been people's dependency on it. Ozempic and Wegovy used for weight loss only serve as temporary solutions to issues that often stem from complex underlying lifestyle problems. Additionally, once individuals stop taking the drug, their appetites quickly return to normal, making it hard to sustain such weight loss. Because of this, many have experienced "Ozempic rebound," during which individuals gain back most, if not more, of the weight they had before taking the medication (Schimelpfening, 2023). One study funded by Novo Nordisk, the company that makes Ozempic and Wegovy, found that, a year after taking the drug, participants gained back, on average, two-thirds of the weight they lost (Wilding et al., 2023). If Ozempic was cheap and widely available, long-term use of the drug could be a viable method of sustainable weight loss; however, Ozempic is anything but. The drug's consistent shortages and high cost—sometimes exceeding $1,000 per month in the US without insurance—make it difficult to rely on for long-term use, forcing most people to also deal with the difficulties of withdrawal (Davis, n.d.).

Still, the drug has shown incredible promise. While most medications can offer weight loss at 5-10% of one's body weight, Ozempic has skyrocketed above these averages, leading to weight loss closer to 15-20% ("The Ozempic Effect", n.d.). However, there is an undeniable danger that comes with labeling Ozempic—or any drug for that matter—as a "miracle drug" and ignoring its downsides. As the craze for the drug builds, its drawbacks become less obvious, and incentives for proper individualized research also start to drain. This is especially dangerous, as the drug is not without long-term consequences.

While little is known about the long-term impact on metabolic and cardiovascular health, Ozempic is associated with an increased risk of thyroid cancer, hypoglycemia, and gallbladder disease, among a variety of other consequences (Korte, 2023).

In the end, Ozempic is not a "miracle," but, rather, a drug like any other—offering a long list of benefits and risks that must be weighed before choosing to take it. Taking the drug without being aware of the potential consequences can have serious ramifications, both short- and long-term. Until we stop treating medication as a trend, perhaps it is on us to remember that true "miracle drugs" are few and far between. After all, if it seems too good to be true, it probably is.

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The Implications and Challenges of Nature-Inclusive Cities

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Is isolation from nature harming city-dwellers? The lack of biodiversity in cities contributes to ecological, environmental, and psychological challenges.

Habitat loss and pollution are among the biggest threats posed by urbanization. In fact, a research study by Dr. Brooke Williams and colleagues found that between 2000 and 2013, 1.9 million km of untouched land became modified by humans, meaning that animals are losing places to live (Williams et al., 371). The Living Planet Index, managed by the Zoological Society of London and the World Wide Fund for Nature, finds that wildlife populations decreased by an average of 69% since 1970 (Almond et al., 4).

The detrimental effects of increasing industrialization extend to humans as well. The environment of a city itself can be unpleasant, as the "urban heat island effect" makes cities 5 to 11 degrees Celsius hotter than rural areas (Zipperer et al., 13-14). This happens due to a lack of vegetation, the prevalence of buildings that reflect light, and the geometry of buildings. The urban heat island effect increases temperatures and increases ozone production (Zipperer et al.). Additionally, cities often produce large amounts of CO_2, which "is associated with a myriad of health problems, lower life expectancy and increased infant mortality" (Castells-Quintana et al., 1).

The issue even goes beyond physical health; Ventriligo et al. found that there is a correlation between urbanization and mental health issues. Cities are often overpopulated to the point where people don't know their neighbors, leading to less socialization. High living costs in many cities can lead to socio-economic problems, and pollution from traffic and factories leads to climate challenges. All of these factors have been correlated with increased rates of suicide, schizophrenia, and depression (Ventriligo et al., 4-7).

Cities are often overpopulated to the point where people don't know their neighbors, leading to less socialization. High living costs in many cities can lead to socio-economic problems, and pollution from traffic and factories lead to climate challenges.

Inversely, living in areas that are in close proximity to nature has been shown to have positive effects on mental health. Jimenez et al. find that being exposed to nature has benefits like decreased stress levels, improved sleep quality, positive emotions, and reductions in depressive moods, among other benefits.

A straightforward solution to these challenges caused by a lack of nature would be to incorporate more nature into cities. Some cities have already attempted this, but it is not being realized at a large scale due to several factors. Firstly, the cost of maintaining green spaces in cities is high, particularly due to the cost of maintaining exotic plant species. Additionally, the fact that much of the land in cities is privately owned makes it challenging to acquire sufficient amounts of land to incorporate green spaces into cities (Murphy, 71-76).

Dr. Rob McDonald, Lead Scientist for the Global Cities Program at The Nature Conservancy, argues that there might also be safety considerations. Having large, open, natural spaces can allow illegal activity to happen "in the shadows," as crimes could be committed by night when these places are not guarded unless restrictions are put in place, which is why many parks in cities have to close earlier in the evening (Benepe, Adrian et al.).

Despite these challenges, some cities have been able to successfully implement nature and thrive. Cities like Kodiak, Alaska are teeming with nature, but Kodiak enjoys the advantage of a more natural geography, with large mountains and wildlife just beyond the city. It's more fair to compare modern cities to one like Portland, Oregon, which is more representative of the average northeastern American city: mostly flat and filled with tall buildings.

Portland is in Multnomah County, where CO_2 emissions were 21% below 1990 levels in 2021 according to the Summary of 2021 Multnomah County Carbon Emissions and Trends. Portland especially is taking clear steps to be more sustainable, which is reflected by its constant drop in CO_2 emissions since 2000. Their "Grey to Green" program significantly improved the city's health, energy use, and overall livability. For example, they implemented ecoroofs, where vegetation is grown on many roofs of the city. Unlike other local governments, much of the land they choose to purchase is kept as a natural landscape; this not only improves the aesthetics of the city but also decreases air pollution. By using Oregon's Grey to Green program as an example, many cities in the U.S. can take steps to be more environmentally sustainable.

For cities that are home to more disadvantaged groups of people, the resources to implement intricate systems like Portland's may not be available. Studies have even shown that there is a correlation between a city's income and the amount of green space it has (Gerrish & Watkins, 293-308). Lower-income cities therefore may suffer from pollution, increased temperatures, and flooding. However, hope is not lost for these cities to incorporate nature and thrive. As Kimberly M.S Cartier proposes in her article "Growing Equity in City Green Space," cities can make green spaces from places like vacant lots and unused parking lots. It is most important to ensure that the community is involved throughout the process of these green projects. Citizens should be involved during the planning process to ensure that the space will be useful and beneficial to the community.

Policymakers today can take action towards improving cities by deciding to incorporate more nature, whether that be through revamping abandoned places, implementing full programs to increase biodiversity, or simply planting more trees in the city. Every case will be different and complex, but what is most important is that local governments are aware of potential challenges and community concerns. America's nature has been deteriorating ever since the Industrial Revolution in the 1800s, and we can clearly see the effects of it in hindsight. However, it's not too late to undo mistakes and move towards a future where we can reconnect with nature for the health of ourselves, other life forms, and the environment around us.

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Algorithmic Architecture and Computational Fluid Dynamics: Innovating Structural Design in the Spinning Desert Oasis Project

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Under the guidance of Professor Gao, I worked as a research assistant in the National Natural Science Foundation of China program “Biological Induced Calcite Precipitation Technique aimed at combating desertification” from 2021 to 2022. This experience in geotechnical engineering, particularly using soybean urease-induced calcium carbonate deposition for windbreak and sand fixation, provided a foundational understanding of manipulating natural processes to enhance environmental stability. During our fieldwork in the desert, we faced such an environment's typical and harsh conditions. To effectively address these challenges, I devised a multifunctional complex known as the “ Spinning Desert Oasis,” utilizing advanced computational modeling and simulation techniques to maximize adaptability and minimize environmental impact.

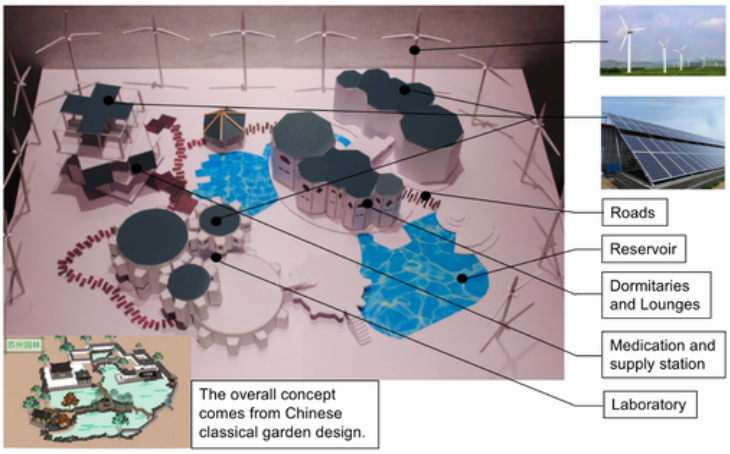


Figure 1: The Model of the “Spinning Desert Oasis” Design Project)

The Medical and Supply Station, a pivotal component of the Oasis, utilizes a design inspired by the Rubik’s Cube. This modular structure benefits from advanced computer-aided design (CAD) software, facilitating independent rotation of each segment. Michela Turrin, an expert in performance-oriented architecture and computational fluid dynamics (CFD), along with her colleagues, discusses in their critical review published in Renewable and Sustainable Energy Reviews that CFD "can significantly enhance the aerodynamic performance of buildings by simulating wind loading and sand erosion" (Turrin et al., 793). This capability is crucial in my design, as it helps mitigate damage from the severe desert winds commonly encountered in such environments.

The Laboratory unit, influenced by the interlocking gears of traditional movie projectors, consists of interconnected yet independent modules. This configuration employs algorithmic modeling to provide rotational flexibility, allowing adjustments in orientation based on real-time environmental data gathered through embedded sensors and integrated IoT systems. Turrin and her team further elaborate on the importance of CFD

integration in the early design stages to enhance the adaptability of structures to their environmental contexts (Turrin et al., 794).

The Dormitories and Lounges, drawing inspiration from the nest-like structures of desert-dwelling organisms and the Australian concrete pipe hotel, are modeled using advanced simulation software to assess thermal dynamics. Elena Lurie-Luke, whose work on biomimicry and innovation in technology is well-documented in Biotechnology Advances, highlights that "biomimicry can lead to significant advancements in energy efficiency by replicating natural thermal regulation mechanisms in buildings" (Lurie-Luke, 1499). This approach has shaped the environmental integration of my design, optimizing comfort while maintaining energy efficiency.

Lastly, M. Nejat Bahadori, renowned for his studies on traditional passive cooling systems in Iranian architecture as detailed in Scientific American, underscores the value of historical methods in modern design: "Historical approaches to desert architecture, using passive cooling, can inform contemporary sustainable building practices" (Bahadori 146). Inspired by Bahadori's insights, the Oasis incorporates passive cooling strategies such as shaded walkways and thermally insulated communal spaces that leverage natural ventilation to maintain comfort and reduce energy use, blending ancient wisdom with modern technological applications.

In conclusion, this design research showcases the integration of the Biological Induced Calcite Precipitation Technique with advanced architectural and computational methods to establish a sustainable habitat in deserts. The "Oasis" project leverages interdisciplinary approaches combining geotechnical engineering, biomimicry, and computational fluid dynamics to enhance adaptability and sustainability in extreme environments. This endeavor demonstrates the potential of merging traditional architectural insights with modern technology to address environmental challenges effectively, highlighting the crucial role of innovative scientific research in sustainable development.

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Automatic Video Labeling and it's Potential Uses

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Automatic video labeling is present today and can be accomplished through several sources. Examples of these are YoloV8, Dataloop AI, and teachable machines. These different video labeling software work by training a Large Language Model (LLM) to recognize specific photos and label objects or subjects as they see fit. When LLMs are trained through several hundreds or even thousands of images, the accuracy of their readings can become very close to, if not 100%, accurate at times. The question is how can we use video labeling to help everyday people, especially the elderly.

The main issue that disabled or elderly people face when they fall is not the impact itself but their inability to call for help. Today, devices made with physical buttons worn around the neck of people susceptible to falls by providers such as Medical Guardian, ADT, LifeStation, etc., can cause a problem when the person becomes incapacitated due to the fall they experienced.

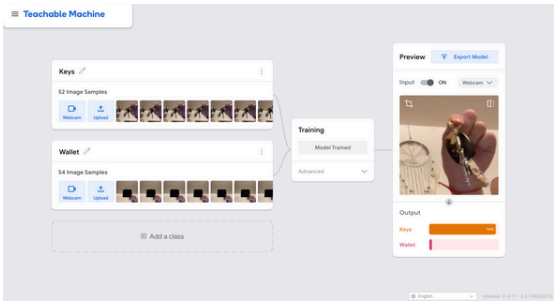


Figure 1: Example of a photo recognition software known as a "Teachable Machine" that can be trained with several hundreds or thousands of photos.

According to the CDC Injury and Prevention Control site, "About 36 million falls are reported among older adults each year—resulting in more than 32,000 deaths" (Moreland, 2020). As for non-fatal falls in adults at or above the age of 65, the amount of falls recorded in 2014 was 29 million, resulting in 7 million injuries. However, because of the development of technology in fall detection, such as the emergency button worn around the neck, the number of falls and fall-related injuries among adults at or above 65 decreased from 2016 to 2018. "Smart technologies are necessary for ambient assisted living (AAL) to help family members, caregivers, and health-care professionals in providing care for elderly people independently" (Zin, 2021). Older adults are at a higher risk of being injured when they fall. Because of this, there is a large number of elderly individuals who do not get to a hospital in time and inevitably pass away.

> *The traditional solution to helping elderly and or disabled people when they become incapacitated due to falling is still reliable, but the idea of using LLMs to more quickly and accurately provide support is becoming more prominent.*

"As has already been suggested, evaluating fall detection devices needs to become more standardized to properly evaluate the strengths and weaknesses of the currently available devices" (Chaudhuri, 2015). There is no set standard test for testing these models yet. The application of such a concept needs more time for development. With the ever-growing field of AI and LLM training, the future in which lives can be saved because of the technological advancements we have made possible.



Figure 2: visual representation of subject enacting scenario of being off balance and falling to the floor

With this idea of being able to label when an elderly person experiences a fall and gets injured, future applications of these models with higher accuracy in recognizing are limitless. Beyond such benefits for elderly individuals, these models can be placed in nursing homes or even in public settings like stairs. As an example, in the case of an incident, ambulances will respond to the scene faster than someone who can call 911.

An idea that could be brought to light is teaching a LLM to recognize signs of distress or fall/injury in elderly people. The model can be trained by reenacting scenarios where subjects are off balance or have fallen on the floor. This thought process is apparent in a paper by authors Aniqua Nusrat Zereen et al. 2023. Their system consisted of a cloud-based storage, which was responsible for analyzing the detection of falls in their scenarios. "It achieved an accuracy of 91.6% for ordinary actions and fell with a recall of 97.02% for unstable motion" (Zereen, 2023). Through several scenarios, they reenacted, some of which were having a test subject lose their balance, falling, bending over, etc. The model could recognize injury and falls with a 91.6% accuracy.

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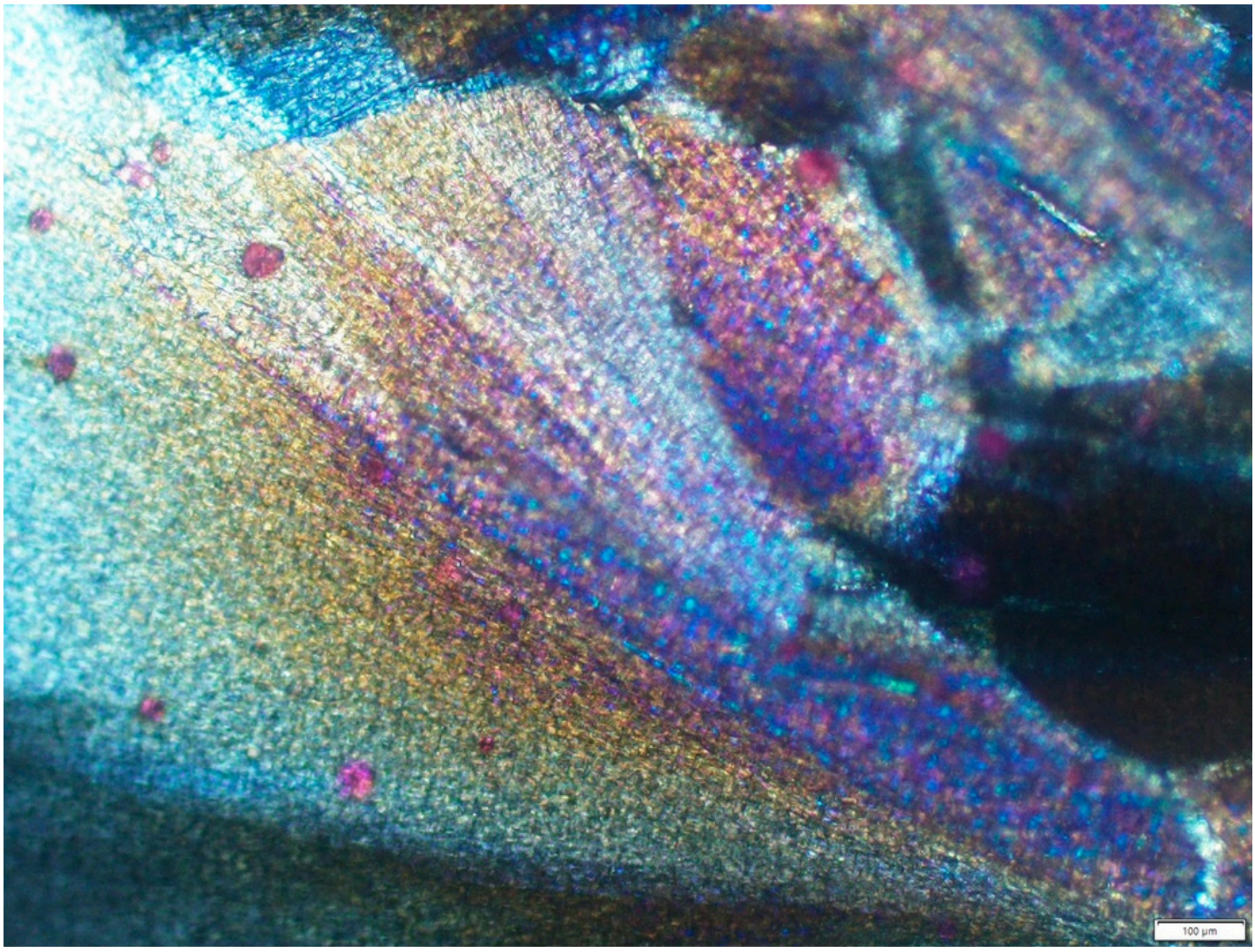
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Nanocrystals

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Below is an image of nanocrystals in a partially crystallized solution. The solution that these crystals are in is called MOPS buffer (morpholino-propanesulfonic acid), which is there to stabilize conditions at a constant pH. The purple circular objects are DNA nanocrystals, which are made up of DNA strands that self-assemble into triangular structures. These specific triangular DNA subunits, which can number in the hundreds, form 3D lattices, thus creating a nanocrystal. These specific nanocrystals are purple because they've been synthesized with ethidium bromide, a common DNA dye that is magenta in nature. In this image, the buffer has started to crystallize, forming a thin film that alters light wavelengths as they hit the crystal, resulting in a spectrum of colors. These nanocrystals are later going to be imaged using x-ray diffraction, a technique that will let us visualize exactly how the crystals are arranged on an atomic level. Having a comprehensive understanding of molecular arrangement can let scientists determine where certain molecules bind to DNA, which is important for studying the efficacy of chemotherapeutic DNA-binding drugs.



First-Ever Gene Therapy For High Cholesterol: The One-Time Solution to 4 Million Annual Deaths?

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In a recent presentation at the American Heart Association's November meeting, Boston-based Verve Therapeutics introduced a novel, single-infusion treatment for dangerously high levels of cholesterol: a gene-therapy treatment known as VERVE-101. The results of the Phase 1 trials, led by Dr. Sekar Kathiresan, chief executive of Verve, support the first-ever evidence that a single DNA nucleotide in the human body can be rewritten for a significant clinical effect. Dr. Kathiresan's study is the first human trial of VERVE-101 (Murphy).

Extremely high cholesterol levels result in early death due to cardiovascular disease, the leading cause of death in the world. 1 in every 5 deaths in the U.S. can be traced to heart disease caused by high levels of a form of cholesterol known as low-density lipoprotein (LDL) cholesterol (CDC). LDL cholesterol blocks blood to the heart and brain, narrowing arteries and thus setting optimal conditions for heart attacks and strokes.

Heterozygous familial hypercholesterolemia (HeFH) is a genetic disorder causing extremely high LDL. Altered genes can be passed down from one or both parents to be expressed in an individual. These genetic changes prevent the body from lowering the LDL cholesterol that builds up in the arteries and causes heart disease. Globally, 1 in every 250 people are affected by this disease (CDC).

While most cholesterol patients can usually take a safe and effective class of drugs known as statins, this method of reducing LDL requires patients to take medication every day, leaving them vulnerable on days they fail to take their treatment. Furthermore, these general drugs have no effect on some patients with extremely high LDL due to genetic disorders like HeFH (Stein); only 3% of patients with heterozygous familial hypercholesterolemia, globally, have reached target treatment goals (AHA).

Instead of taking daily pills or intermittent injections over decades, anyone at risk from high LDL cholesterol levels could potentially benefit from Verve Therapeutics's gene-editing treatment VERVE-101 after just one infusion. Blood LDL levels are regulated by the PCSK9 protein and the LDL-cholesterol receptors on cell membranes. LDL-cholesterol receptors on the surface of hepatocytes, or liver cells, normally decrease cholesterol levels by taking up and breaking down LDL particles from the bloodstream for intracellular use, thus decreasing cholesterol levels in the bloodstream. On the other hand, PCSK9 helps regulate LDL-cholesterol by increasing bloodstream levels; PCSK9 binds to and degrades LDL-cholesterol receptors. Hence, cholesterol intake into cells is inhibited, leading to a higher level of LDL-cholesterol left in the bloodstream. VERVE-101 is a lipid nanoparticle comprising a messenger RNA molecule and a guide RNA molecule that can recognize PCSK9 (Verve Therapeutics).

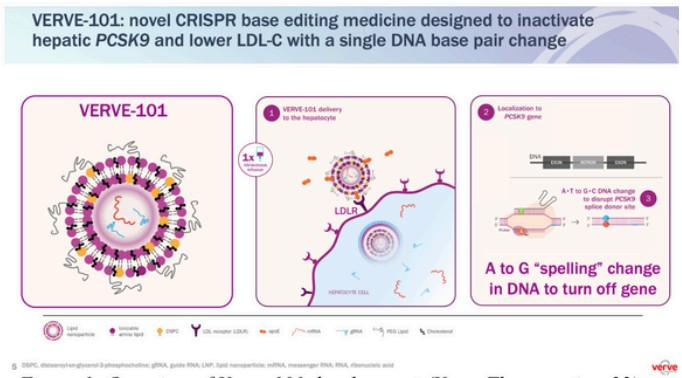


Figure 1: Overview of Verve-101 development (Verve Therapeutics, 22).

Together, this gene-editing complex can permanently turn off the PCSK9 gene in the liver through the Nobel Chemistry Prize-winning CRISPR/Cas9 genetic "scissors," invented by biochemist Jennifer Doudna and microbiologist Emmanuelle Charpentier in 2020 (see Figure 1). Furthermore, the researchers had the power to edit liver cell genes without having to extract, edit, and reinfuse the cells back into the patient's body, making VERVE-101 a minimally invasive treatment. In the ongoing trial, researchers are infusing different doses of CRISPR base-editing molecules that find their way to the liver to edit PCSK9.

Of the ten patients from the U.K. and New Zealand in this Phase 1 trial, 7 were men and two were women, with an average age of 54 years. Each participant was diagnosed with HeFH — they had inherited one gene for the disorder from one parent — and still had extremely high LDL cholesterol levels (average measure of 201 mg/dL) despite taking the maximum-tolerated LDL cholesterol-lowering medication. A majority of study participants also suffer from severe coronary artery disease and had experienced heart attacks, undergone coronary bypass surgery, or undergone stenting (removal of cholesterol-based plaque in blood vessels through a mesh tube), to have adequate blood flow to the heart. None had been taking PCSK9 inhibitors before the study (Stein). In April 2024, three additional patients were administered the second highest dosage of 0.45 mg/kg. Between the total of five participants in the 0.45 mg/kg cohort, VERVE-101 demonstrated up to 73% time-averaged LDL cholesterol reductions, with an overall average reduction of 46% (due to a data cut-off date on March 18, 2024). The patient with the highest-received dosage (0.6 mg/kg) experienced a 55% reduction in LDL cholesterol (ACC). In two patients from the 0.45 mg/kg and 0.6 mg/kg cohorts, LDL cholesterol lowering effects have been maintained up to 270 days in the ongoing follow-up. Participants are required to undergo a long-term follow-up study for 14 years, as required by the FDA for all participants in human genome editing trials, before VERVE-101 can attain FDA approval (Philippidis).

Amidst the celebration of having tapped into the human genome, many experts voice concern in editing the human genome without full awareness of the consequences of doing so. Albeit, further analysis indicated VERVE-101 does not induce chromosomal translocations or structural variants following treatment (Verve Therapeutics) (see Figure 2), clinical trial enrollment was put on pause on April 2, 2024, on the basis of "laboratory abnormalities," after a patient experienced a severe drug-related adverse event (Reuters).

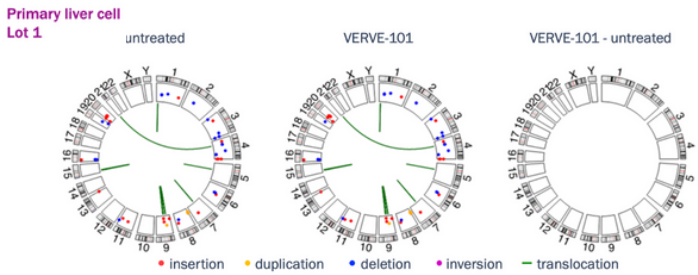


Figure 2: No chromosomal translocations or structural variants were observed after treatment of primary human liver cells with VERVE-101. (Verve Therapeutics, 33).

Researchers note that elusive and inadvertent genetic changes, known as "off-target effects", could result in major health complications later on (Stein). Ethical problems on who would be able to afford life-saving gene-editing treatments—which cost millions of dollars per patient—also come into the picture when introducing this treatment to the public. Additionally, the use of gene editing for therapeutic reasons could give way to the use of gene therapy for non-therapeutic or enhancement purposes, which, again, could develop deeper ethical divides.

Overall, VERVE-101 has great potential as a novel, single-course gene therapy drug that can replace daily pills or intermittent injections for decades on end, preventing the death of 4.4 million patients annually suffering from high LDL cholesterol globally (WHF). As Dr. Doudna once stated, "The world stands on the edge of an era when gene editing can address many serious [and hitherto 'incurable'] ills plaguing humankind." With the advances of pioneering minds and organizations, such as Verve Therapeutics, humanity is only getting closer to this ultimate objective.

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Riding the Wave of Innovation: The Unstoppable Surge of Lipid Nanoparticles in Modern Medicine

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In the surging tide of scientific advancement, lipid nanoparticles have risen like a wave, propelling the field of medicine to uncharted horizons. Captivating researchers and practitioners alike, these transformative carriers have surfed past conventional drug delivery barriers. This article embarks on a voyage into the world of lipid nanoparticles, exploring their ability to traverse biological barriers, encapsulate diverse therapeutic cargo, and unleash their curative potential with precision. Prepare to delve deep into the intricacies of these lipid spheres, poised to usher in a new era of healthcare, precision medicine, and enhanced patient care.

Lipid nanoparticles, nanoscale particles composed of lipids, are amphiphilic molecules, meaning these molecules have a hydrophilic (water-loving) component and a hydrophobic (water-repelling) component. These molecules' head groups are the former, and the tails are the latter (Ahmed, 2023). Liposomes, the most common type of lipid nanoparticles, adopt a core-shell structure, wherein the hydrophilic head groups form an aqueous core, and the hydrophobic tails create a protective lipid bilayer. This lipid bilayer acts as a protective shield, encapsulating a diverse range of therapeutic payloads that the nanoparticles carry. The hydrophilic shell, on the other hand, renders the nanoparticles biocompatible, facilitating their circulation in biological systems.

The inherent flexibility of these lipid nanoparticles enables them to encapsulate and transport various types of therapeutic agents like insulin for diabetes with unparalleled precision, presenting an array of promising medical applications.

"The inherent flexibility of these lipid nanoparticles enables them to encapsulate and transport various types of therapeutic agents like insulin for diabetes with unparalleled precision.

Offering a myriad of advantages over traditional drug delivery methods, lipid nanoparticles harness a unique structure with properties to revolutionize therapeutic interventions and open the door to more effective, targeted, and patient-friendly treatments. One of the most significant advantages lies in the remarkable ability of lipid nanoparticles to surmount biological barriers and selectively target specific tissues or cells; this facet leads to enhanced therapeutic efficacy and reduced side effects. The nanoparticles allow for targeted delivery to target certain tissues or cells in the body, and the enveloping of drugs in the lipid nanoparticle protects drugs from degradation, ensuring the drugs remain stable and effective until they reach their intended destination (Dhiman, 2021). This not only improves the drug's efficacy but also reduces side effects by minimizing exposure to healthy tissues (Dhiman, 2021). Due to their biocompatible nature, lipid nanoparticles are generally well-tolerated by the body, so there is a reduced risk of immune responses or adverse reactions to them.

In the field of medicine, lipid nanoparticles have demonstrated diverse and promising applications. Serving as efficient carriers in drug delivery, gene therapy, and in vaccine development, they enable targeted delivery, enhanced efficacy, and new therapeutic possibilities (Tenchov, 2021).

Most notably, when utilized in vaccine formulation, lipid nanoparticles have the potential to enhance immune responses and improve vaccine stability, holding promise for the development of more effective vaccines against various infectious diseases (Tenchov, 21). The SARS-COV-2 pandemic brought forth an urgent need for effective and scalable vaccines, and mRNA-based vaccines became a beacon of hope. Lipid nanoparticles played an integral role in the delivery of mRNA vaccines, such as the Pfizer-BioNTech and Moderna vaccines, enabling the safe and efficient transport of mRNA strands that encode the viral spike protein for human cells (Wilson, 2022). These lipid-based carriers protected the fragile mRNA from degradation, facilitated its entry into cells, and triggered an immune response against the coronavirus without integrating into the recipient's genetic material. By harnessing the potential of lipid nanoparticles, scientists achieved a momentous feat in vaccine development, paving the way for revolutionary vaccination strategies and offering a glimmer of hope in the battle against the pandemic.

In the ocean of scientific exploration, lipid nanoparticles, like any transformative force, also face formidable waves and currents on their journey toward revolutionizing medicine. Ensuring the stability of nanoparticles during storage and transportation, improving targeting efficiency, and understanding potential long-term effects are some of the key areas of research (Hallan, 2021). Additionally, navigating the uncharted waters of regulatory approvals and clinical trials adds further complexity to their voyage (Baumber, 2022). Despite the challenges, their potential for targeted drug delivery, personalized medicine, and multifaceted therapeutic applications continues to propel us toward a brighter and healthier future. With each challenge faced, these tiny marvels only grow more resilient, reminding us that the promise of lipid nanoparticles is both vast and unyielding, ready to embrace the untold possibilities that lie ahead.

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Advancements in Skin Cancer Treatment Using Immunotherapy

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One in five Americans will develop skin cancer in their lifetime. Skin cancer affects 5.4 million people each year, and that number continues to grow. In 2023, it was estimated to be about 97,610 new cases, 7,990 of which would result in death [1]. Skin cancer is one of the deadliest cancers, which generally develops in middle-aged adults and is most frequently diagnosed in those aged 65-74. There are four types of skin cancer: Basal cell Carcinoma (BCS), Squamous cell Carcinoma (SCC), Melanoma, and Merkel-Cell Carcinoma (MCC). Basal cell Carcinoma is the most common type of skin cancer and the least dangerous. Squamous cell Carcinoma is generally common and tends to spread. Melanoma is the most well-known skin cancer and can spread incredibly quickly. Lastly, Merkel-Cell Carcinoma is a less common yet highly aggressive type of skin cancer. Early stages of skin cancer, or unregulated cell division, much like various other types of cancers, are often treatable and reversible using surgeries and treatments. Radiation therapy and chemotherapy both take a heavy toll on individuals receiving those treatments. In many ways, immunotherapy is more effective and is the superior alternative to other therapies.

Immunotherapy is a treatment where doctors attempt to alter someone's immune system to fight a disease, most commonly cancer. It teaches the immune system to recognize cancer cells and kill them. Immunotherapy can kill cancer cells while leaving normal cells unharmed. It can also boost the immune system to find and kill even more cancer cells. Immunotherapy is mainly used to treat advanced cancers that have not responded to any other types of treatment or recurrent cancer. Immunotherapy has been widely used; however, its implications for skin cancer are more recent. First, immune checkpoint inhibitors target and inhibit checkpoints on the immune cells. By blocking the checkpoints, immunotherapy can teach the immune system to differentiate the cancerous cells from the normal immune ones.

> *This approach aims to increase the efficacy of cancer treatment by simultaneously targeting cancer cells through chemotherapy and boosting the immune system's ability to fight cancer through immunotherapy.*

Immunotherapy can also administer cytokines to induce the immune system's response. In addition to blocking immune checkpoints, PD-1 also needs to be stopped. Programmed Cell Death Protein 1 (PD-1) inhibits immune responses using white blood cells (T-cells) [5]. Immunotherapy can be administered intravenously (IV), orally in a pill or capsule, topically as a cream, or intravesically through the bladder. Lastly, it can be injected into tumors [3].

Immunotherapy seems to be the more commonly chosen alternative for therapies to treat cancer, including chemotherapy. Chemotherapy is more often used for cancer, as it is a very aggressive treatment method. It can weaken the patient and kill other types of cells besides cancer cells, such as hair and somatic cells. This occurs because chemotherapy attacks rapid cell growth, which is often cancerous; however, rapid cell proliferation is found in hair follicles.

Chemotherapy attacks cancerous cells and tumors; immunotherapy stimulates the immune system to work diligently to fight cancer independently. While both therapies have proven effective at killing cancerous cells, chemotherapy has

significantly more limitations. These limitations are more bodily, such as fatigue, nausea, and pain. One of immunotherapy's most prominent restrictions is its expense. Compared to chemotherapy, it has no severe side effects on individuals, leading to the exorbitant treatment cost [4].

However, recent research has concluded that a combination approach of using both chemotherapy and immunotherapy would be the most effective treatment for fighting cancer [2]. Both immunotherapy and chemotherapy have their benefits and limitations; however, combining them is the most effective solution since it can remedy them. Using a combination would boost the efficacy of cancer treatment by simultaneously targeting cancer cells through chemotherapy and strengthening the immune system's ability to fight cancer through immunotherapy [2]. A combination approach could also reduce the overall cost of both therapies as only certain aspects of each treatment are used, not the entire treatment plan. Therefore, a two-pronged therapy plan that combines immunotherapy and chemotherapy would not only be cost-effective but also be the superior option for the patient's overall well-being.

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Cells, Cells, Cells: The Building Blocks of Life and Art



Photo by University of Pennsylvania on the Gene Therapy Process

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We as humans seem to be enamored with the concept of life. People constantly think about what it means to be alive and how to best use our own lives. It shows up everywhere, in our conversations, our classes, but especially in our art. Artists are constantly using the living world as inspiration, from the sculptures of ancient Egypt to the paintings of Claude Monet. But what if we could paint with life itself? That's the reality of artists all over the world – developing innovative and peculiar works of art from cells, proteins, and living tissue. Pushing the boundaries of artistic expression, their works often explore the complexity of life. These people form a diverse bunch, making up a category commonly referred to as "BioArt".

What is "BioArt"?

At its core, "Bioart" is defined as the use of biological materials or processes to create a work of art. In this way, Bioart isn't a genre with a set theme like abstract or surreal, but instead a name for the countless works made with tools pioneered by science. One popular tool is cell or tissue engineering. Cells are the smallest unit of any organism while tissues are collections of similar cells that work together. The process of growing tissue involves cells being placed into an incubator, a heating device which maintains the best temperature for cell growth.

By growing their medium in a lab, artists can manipulate tiny living things to look or behave a certain way. An artist can introduce certain proteins to get a specific shape or color. They may try to alter the behavior of the cell, making an easily weakened cell more resilient. It's no different from when a painter mixes distinct shades to get that perfect hue. However, the nature of BioArt means no artist gets full control over the final outcome. Bacterium, or single-celled microorganisms, are another material often used. Different bacterial paints can communicate with each other, causing chemical reactions and influencing the final painting in a way that is complex and difficult to predict (Frankel et al., 2023). A consistent look is sacrificed for artistic expression. For artists, the goal is to have a creation whose very existence prompts deeper thought.

What are some examples of "BioArt"?

One such artist is Oron Catts, director of SymbioticA, a research lab at the University of Western Australia, and co-founder of the Tissue Culture and Art Project. The scientists here began by growing different tissues on glass and then transitioned over to more sophisticated biomaterials, in the words of Catts himself.

SymbioticA's Worry Dolls, developed in the year 2000, were the first sculptures built from live tissues from the lab. These "semi-living" dolls were inspired by Guatemalan dolls which are believed to absorb the worries of their owner. Each doll represents a different worry about the impact of biotechnology. Doll B represents worry about biotechnology and the forces that drive it, while Doll E represents worry about eugenics. Moreover, Doll H (seen below) represents worry about hope and unintended consequences that result from those who have it (Catts et al. 2001). Catts was surprised by the public's response to the work. Initially, he thought that the work would basically trigger people to think about humanity's relationship to life, about biotechnology, only to realize that many people use the dolls to express their most intimate concerns (Catts, 2023).



Photo by Tissue Culture & Art(ificial) Wombs Installation on Semi-Living Worry Doll H

The SymbioticA lab has given birth to many other bio artists, each with different contributions to this emerging genre. Paul Vanouse, a past student of SymbioticA, worked with gel electrophoresis. This is a procedure used to separate different strands of DNA by their sizes, like a stream with many nets placed across it. Smaller fish will pass through the nets easily, while larger fish will have a harder time getting through the nets and travel more slowly. This process ends up creating DNA rings of varying sizes inside the gel. Vanouse used that process to create a map of planet Earth. By developing a circular container for the materials and picking DNA strands of certain sizes, he was able to control how far the genetic material traveled through the gel, shaping his desired outcome.

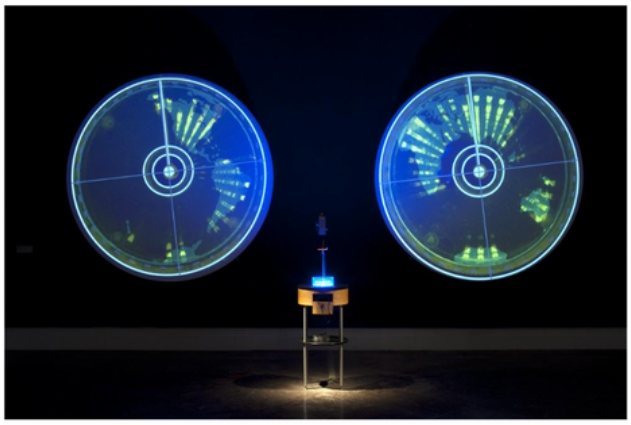


Photo by Paul Vanouse on Ocular Revision

What is the goal of BioArt?

A constant in BioArt is an artistic appreciation for the concept of life, how it can be manipulated by human forces. Synthetic biology, the wider field it falls under, works to combine the principles of engineering with biological systems. Redesigning organisms so that they produce a substance, such as medicine or fuel, or gain a new ability, are common goals of synthetic biology projects (National Human Genome Research Institute, 2019). The industry tends to focus on what exactly a group of altered cells can do. Artists, on the other hand, are more concerned with asking questions about what synthetic biology means, than engaging with the idea of "usefulness". In the words of Oron Catts, " ... the idea of growing fragments of bodies, without ever intending to reproduce them into bodies, was something that was of interest for me, it raised the right questions" (Catts, 2023). Artist Anna Dumitru, who works to combine microbiology with antique objects and crafting techniques, takes a more assertive stance. She declares that she is not interested in justifying the contribution of art as research in the present academic setting, which aims to monetize impact (Thomas, 2013). The contribution of art is art itself.

This stance is not necessarily shared by the wider scientific community. Lack of institutional support, lack of financial support from the federal and private sectors, and lack of access to equipment all prevent BioArt from expanding as an interdisciplinary field (Jagodzinski, 2020).

In the early years of SymbioticA, Catts developed the program without getting paid by the University of Western Australia. Catts recognized it was important to push the idea that this type of artistic research is as valid as scientific research, that everyone should have similar rights to have access to those resources (Catts, 2023).

Why should you care about BioArt?

Society needs artists. There need to be individuals that are critiquing the violent, even unethical nature of synthetic biology by exploring it. For Catts, it was never about the perfect piece, but about problematizing humanity's newfound powers over life. This sentiment seems to ring true for many. Next time you are in a lab or a museum, think about the value of science, art, and life. All three are inherently connected.

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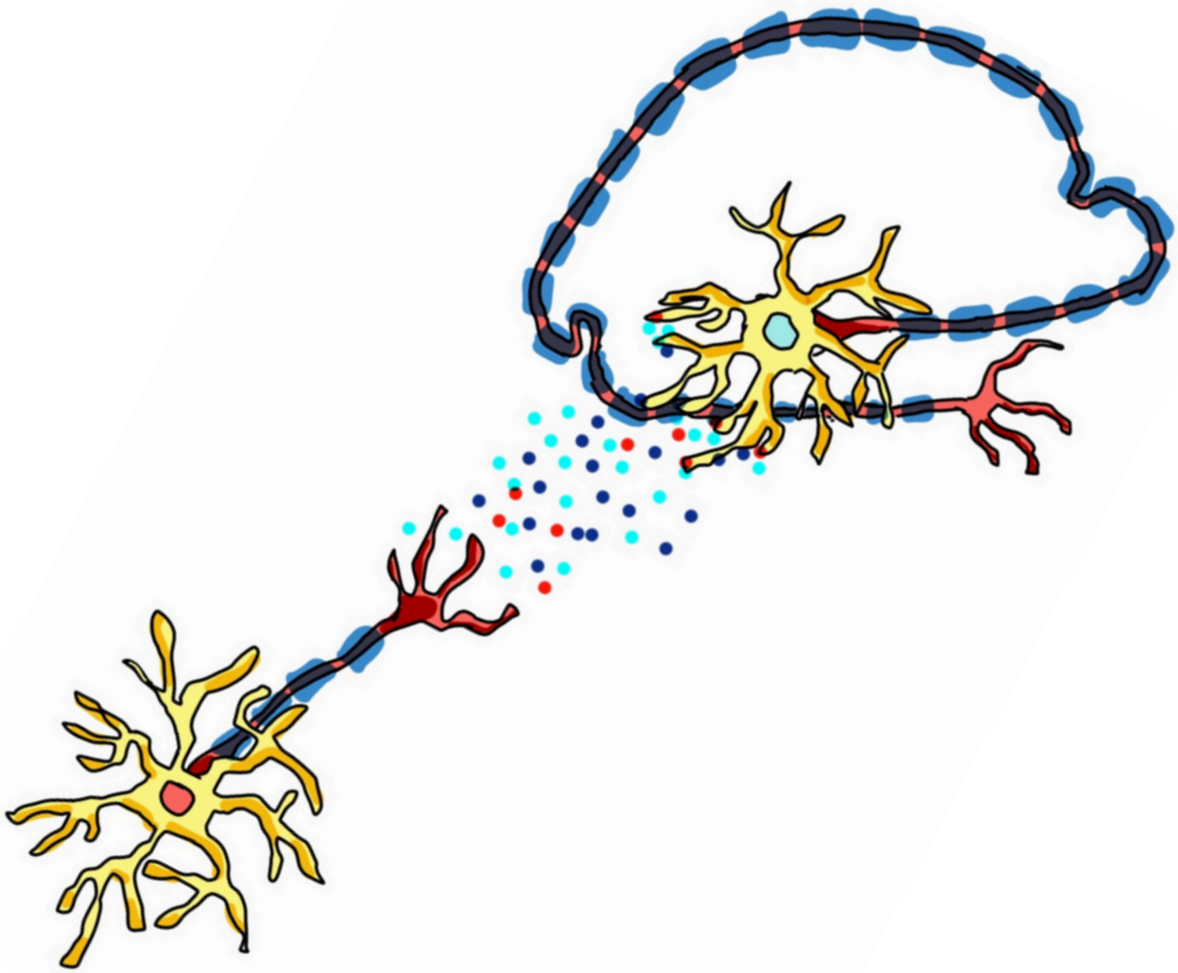
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The Birth of Action Potential

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The title of this submission is 'The Birth of Action Potential' as a reference to the famous painting by Michelangelo, 'The Creation of Adam'. Though not the most accurate description of how the process actually works, I believe that it is a simple way to showcase a complex process of a neuron transmitting its message via neurotransmitters from its axon terminal to the dendrite of a nearby neuron. This is a digital work that tries to represent the beauty of the complex structure that is the brain by zooming in on a simple action that drives people to be who they are.



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Orbital Ecology: Science's Frontier in Addressing the Space Debris Dilemma

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Amidst the vast expanse of space, an invisible threat looms closer to our planet than many might realize. Over 100 million pieces of space debris — which include defunct satellites, spent rocket stages, small meteoroids, and fragments from disintegration, erosion, and collisions — clutter the near-Earth space. Shockingly, only 27,000 of these fragments are actively monitored by the Department of Defense's global Space Surveillance Network (SSN) sensors (Dunbar, 2021).

Now, consider a piece of untracked debris hurtling through space at an average speed of 15,700 miles per hour, a common velocity for objects in low Earth orbit (Dunbar, 2021). Should it collide with a satellite or spacecraft, the results could be catastrophic. At these high velocities, even small fragments possess immense kinetic energy. A collision with an active satellite can disrupt communication networks, impact weather forecasting, hinder navigation systems, and interfere with Earth monitoring capabilities (Muelhaupt, 2015, p. 2).

Worse, these collisions can usher in the terrifying Kessler Syndrome.

Proposed by NASA scientist Donald J. Kessler in 1978, this theory describes a tipping point where space debris becomes so dense that one collision leads to a cascade of further collisions (Peralta, 2011). Such a chain reaction could shroud our planet in an almost impenetrable barrier of debris, making any further space missions and satellite operations exceedingly dangerous.

But there's hope on the horizon. Several ongoing efforts use collision monitoring and avoidance technologies to attempt to prevent this cascade. Global collaborative frameworks like the Space Data Association (SDA) are using collaborative, global surveillance efforts to provide real-time data on satellite movements and potential debris threats (Space Data Association, n.d.). This information is widely disseminated, promoting shared responsibility and a more proactive approach to debris management. Similarly, LeoLabs proactively deals with threats through "space traffic" management. They leverage state-of-the-art algorithms to devise collision prediction models (eoPortal Directory, 2021). With such tools in play, satellites can autonomously reroute their trajectories, dodging incoming debris and evading potential collisions — a crucial step in halting the accumulation of space debris.

Additionally, researchers are developing satellite materials that disintegrate efficiently upon atmospheric re-entry, which refers to the process where a spacecraft or satellite returns to Earth's atmosphere from space, in the process withstanding extreme heat and friction. Space agencies are prioritizing designs utilizing drag sails and space tethers while minimizing the use of external components, which could potentially become detached and add to the debris problem (NASA, 2007). Electrodynamic tethers or "space tethers" harness electromagnetic interactions with the Earth's magnetic field to generate thrust, facilitating controlled deorbiting (Gallagher, Johnson, Moore, & Bagenal, 1998, p.1).

Dragsails, on the other hand, increase a satellite's atmospheric drag, ensuring a methodical, fuel-free descent and burn-up, thus leaving no residual debris (Rhatigan & Lan, 2019). These innovative technologies present an ecologically friendly solution to debris mitigation.

In the meantime, pioneer projects like NASA's Restore-L and DARPA's Robotic Servicing of Geosynchronous Satellites (RSGS) program — an initiative by the U.S. Defense Department agency dedicated to advanced technological research for military applications — are aimed at increasing the longevity of technology through the engineering of longer lasting satellites. These initiatives offer in-situ satellite servicing, refueling, repairs, and upgrades (Saplan, n.d.; Alessandro, 2016). This can extend satellite operational life, reducing the frequency of replacements and, consequently, slowing the addition of debris to the orbital environment.

To combat the growing threat of space debris, humanity must transition from mere orbital exploration to responsible "orbital stewardship." Our response now determines our legacy: will we be celebrated as astral pioneers, or will we be remembered as no more than cosmic litterbugs?

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Defective Detective: We Need Explainable Machine Learning in Patient Care

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Discovering a medical diagnosis and formulating a treatment plan is like a detective solving a case. Imagine if Sherlock Holmes or your favorite Criminal Minds character claimed they identified the killer, but their explanation is, "I don't really know why, but I analyzed tons of databases and I saw this pattern. Just trust me – I tend to get these right." This explanation would never hold up in court, so why should we accept this kind of approach from AI in medicine? Patient care has long been a human task, but the artificial intelligence boom has sparked research into their intersection. From pharmaceutical development to patient history analysis, researchers are working to harness the power of AI to transform medicine.

Artificial intelligence (AI) is the development of computer systems that can perform tasks that traditionally require human intelligence. By analyzing vast amounts of data, including patient records, research papers, medical images, and genetic information, AI is well suited to recognize patterns and make informed decisions, providing valuable support to healthcare professionals in making accurate diagnoses and effective treatment plans.

When making a diagnosis, doctors must consider numerous clues. Dr. Jennifer Barker, a professor of pediatric endocrinology at the University of Colorado School of Medicine, explains that the process involves evaluating the patient's history, symptoms, physical exam, and laboratory tests, "What's really important is being able to collate all of the information and decide what fits, and if the information doesn't fit, does it matter?" Luckily, AI can examine thousands of variables in a fraction of the time a human could.

While finding disease indications is straightforward, crafting treatment plans is deeply personal. Dr. Barker explains that she spends much of her time developing a plan alongside a patient, "It's really important to know who the patient is and how they want to approach treatment." While an algorithm can solve a medical mystery, even the most advanced AIs won't be able to empathize with a patient on a human level. With AI as a sidekick, doctors could increase accuracy and efficiency, freeing up time for increased patient interaction and medical access. But the keyword is sidekick.

The Problem

As AI becomes more advanced, even the model's developers have trouble understanding how a system arrives at a conclusion, earning AI systems the nickname "black boxes." Dr. Barker notes that physicians have trusted risk-predicting algorithms to help guide the diagnosis process for decades, but there is cause for concern.

Machine learning models reflect human biases when 'trained' on unrepresentative data or past cases echoing the structural racism that has long infested healthcare. A troubling example is a 2019 study published in Science, which exposed bias in a clinical risk algorithm used on an estimated 200 million people annually. The model targets patients with chronic illnesses for enrollment in increased care programs.

In theory, this could work. There is a strong correlation between healthcare spending and patient sickness: sicker patients require more care, generating higher medical costs. However, when comparing healthcare spending between Black and White patients at a given level of sickness, Black patients generate, on average, $1801 less per year. Given this gap, the research found that Black patients had to be much sicker than their White counterparts to be admitted into the program.

AI Reflects Structural Racism in Healthcare

Numerous factors could explain this gap.

- Black patients with White primary care providers receive fewer preventative care recommendations than those with Black providers, leading to consistent undertreatment.
- Patients could face barriers like transportation, jobs, and childcare.
- Black patients generally have reduced trust in health care, dating back to the Tuskegee experiments.

No matter the discrepancy's source, developers encoded existing biases into the algorithm, leaving Black patients with delayed care.

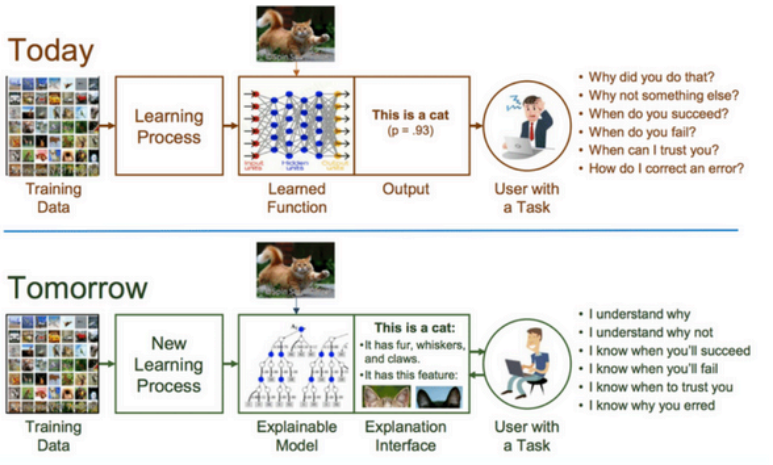
Risk algorithms aren't the only issue. Researchers at MIT found that X-ray analysis models underdiagnosed chest pathology in underserved patient populations. Many algorithms are not required to be reviewed by any regulatory body, and the FDA only recommends that developers test their products for potential racial or ethnic bias. So who gets to set the arbitrary threshold of harm allowed before a model enters the market? The predominantly white male data scientists and developers?

But we can fix these models! Researchers found that using the number of chronic illnesses as an alternative to health care spending, reduced bias by 84%, doubling the number of Black patients receiving care.

The improved algorithm outperformed individual doctors in enrolling patients without bias.

Explainable AI is Part of the Solution

To err is human. Dr. Barker mentions that doctors' mistakes are usually caught before harm is done. But when errors are serious, accountability processes range from hospital oversight to national regulation. Black box AI isn't traceable or transparent, making it challenging for developers, regulators, and users to hold these systems accountable for mistakes or biases. Enter explainable AI! Explainable AI (aka XAI) is a major research focus for industry leaders like IBM and Google and is applicable in fields from medicine to finance to criminal justice. XAI helps users understand a system's decision-making at every step, from a black box to a glass box, increasing accountability and trust in these systems.



XAI works to make sense of automated decisions in a variety of ways. For example, after an AI recognizes a cat (or diagnoses lung cancer), the system would explain why it made that decision. This could mean providing decision trees, written descriptions of a model's thought process, or regions of an image that contributed most to a prediction.

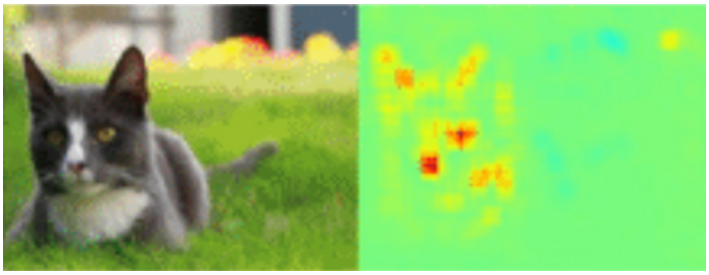


Figure 1. Image classified as "cat" because of cat's ears and nose.

Achieving full transparency in AI models can be challenging, as there might be trade-offs between model complexity, accuracy, and interpretability. With continued research and investment, physicians can trust these systems, interpret their decisions, and recognize where bias may stem from. Additionally, policymakers must respond to the rapid development of AI with stricter standards for transparency and guidelines for the amount of harm and error allowed before a system can impact the public. Research in XAI is still developing and it could be part of the solution for more accurate and fair AI systems.

Now, after the XAI detective solves a medical mystery, it can craft transparent explanations to convince stakeholders, just like a detective presenting evidence in court.

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Potential of Microrobots to Effectively Remove Blood Clots and Deliver Targeted Drugs

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Nearly 900,000 suffering Americans and over 100,00 deaths annually are attributed to fatal blood clotting conditions, particularly Venous Thromboembolism (VTE). Within the VTE classification, the most common dangerous blood clots are Deep Vein Thrombosis (DVT), where the blood clot is located within a deep vein (beneath layers of tissue and muscle), usually in an arm or leg, and Pulmonary Embolism (PE), where a blood clot travels from a deep vein to a lung (Ashorobi et al., 2020). Blood clots, which consist of platelets, proteins, and cells are often created to manage bleeding from damaged arterial or venous blood vessels. Without the formation of periodic blood clots, which promote healing, the body would lose a significant amount of blood through hemorrhages. However, blood clots can become dangerous when they obstruct blood vessels, resulting in various fatal consequences, including a heart attack or stroke.

Most often, blood clots are treated with anticoagulants, or blood thinners, to prevent the accumulation of platelets and proteins, allowing the body to break down the clots over time.

Although blood thinners are a potential treatment for blood clots, the side effects over time may override their potential benefits. For instance, some side effects of blood thinners include excessive bleeding and physical weakness during and after taking the prescription. My grandmother, who was placed on blood thinning medication to counteract the formation of blood clots, is at severe risk because of her tendency to fall during her sleep, which increases the likelihood of fatal blood loss. The risk of suffering a fatal physical injury while taking prescribed blood thinners is higher because blood thinners make it easier to lose blood quickly. Yet, despite blood thinners being prescribed in order to treat blood clots, they diminish the risk of blood clots blocking blood vessels, but they do not completely break down blood clots in the bloodstream.

For this purpose, a more direct approach to this situation would be more effective at preventing blood clots from negatively progressing. Surgical operations to remove blood clots from an artery or vein, called thrombectomies, have been performed before to completely remove the clump from blocking blood vessels. Surgeries are performed in more dire scenarios where a very large blood clot poses a threat to the life of the patient. Despite surgery being a more effective alternative for treating dangerous blood clots, it comes with limitations and disadvantages in and of itself. Any kind of surgical procedure, including thrombectomies, has the potential to cause infections, as the wound is open and is susceptible to contagions in its vulnerable state. Additionally, thrombectomies specifically can cause excessive bleeding that could potentially result in death and damage the blood vessel at the site of the blood clot.

One novel method of treating these deadly blood clots without non-targeted blood thinner medications or infection-prone thrombectomies is the use of nanorobots to effectively remove blood clots with minimally invasive surgery. Microrobots can be utilized in this capacity to carry out targeted tasks within the circulatory system, which would be much more effective than blood thinner medications which aren't able to reach specific parts of the body, or surgery, whose disadvantages outweigh the advantages. The specific tool used to detect the microrobots is Hall-effect sensors, which are able to detect the proximity and speed of the robots through their position and change in voltage on a magnetic field. Microrobots have access to deep-seated areas of the body that are otherwise unreachable by physical surgical operations; therefore, Hall-effect sensors can be used to steer and track the location of the technology within the body (Islam et al., 2019).

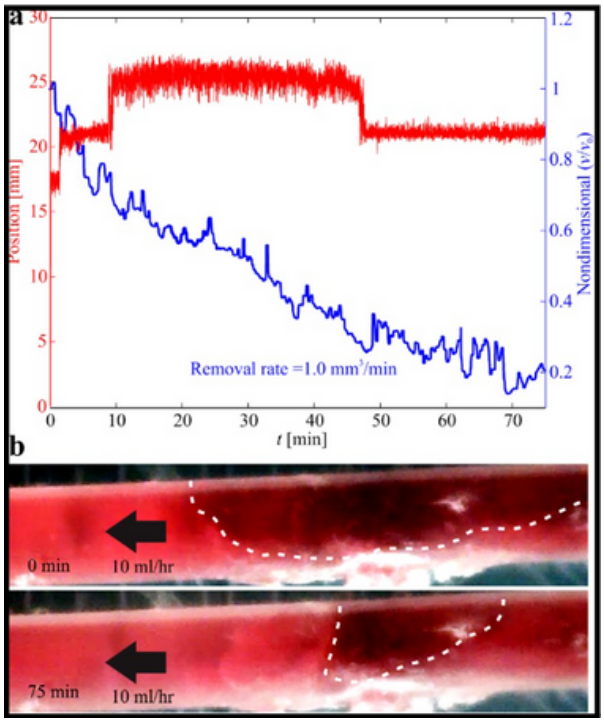


Figure 1. The removal of a blood clot over time with the assistance of a microrobot shifts the thrombus away from the middle of the blood vessel and towards the more open end.

In regard to the microrobot's ability to physically remove a blood clot from the blood vessels, they can be manually steered through magnetic fields to push against a blood clot and move it through and out of the vessel it was originally blocking, if the clot is small enough. In other cases, where the blood clot is of the larger variety, it can be burst by the microrobots, rather than removed. This happens through the process of the helical microrobot's tip puncturing and breaking the protein fibrin constituents of the blood clot. By breaking the fibrin structure of the clot, the thrombus (clot) begins to decompose and blood cells begin to break free, ultimately resulting in the large blood clot deteriorating within the bloodstream (Doutel et al., 2021). The microrobots can be inserted into the blood vessels in a minimally invasive way, making it a unique and important alternative method to consider when dealing with the treatment of a serious blood clot

. The capabilities of microbots are not only limited to the removal of blood clots, as targeted drug delivery is another pathway that can be explored. Most common drug delivery methods are non-targeted and generally travel throughout the body, limiting the amount of the drug that is delivered to the specific area that needs it. Microrobots can be an effective means to deliver drugs to targeted areas of the body, which would result in more effective treatments for the patient and quicker recovery times. Additionally, there are certain medicinal treatments that are prescribed to help treat a particular area of the body but can negatively affect other areas if they interact for a prolonged period of time. Through the use of targeted drug delivery techniques, such as the utilization of micro-robotic technology, these medications will be carefully delivered only to the specific areas that need them (Hu et al., 2020).

An additional potential use of microrobots that has not been explored as thoroughly but is still relevant to the discussion at hand is its possible role in identifying specific cells or regions to diagnose or treat. The use of a microrobot that is inside the body that could make these distinctions would revolutionize the scientific and medical fields, as a variety of new discoveries could be made with new foundational knowledge gained. Specific diseases and conditions could be directly and immediately treated without long testing periods to confirm which techniques are effective and accurate enough to be used.

Overall, the novel technology and techniques that helical microrobots can provide for the medical and scientific research community are unparalleled. Its contributions include a minimally invasive surgical approach to removing blood clots, a targeted method of delivering drugs within the body's circulatory system, and the possibility of being able to identify specific cells to treat in an effective and time-efficient manner.

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