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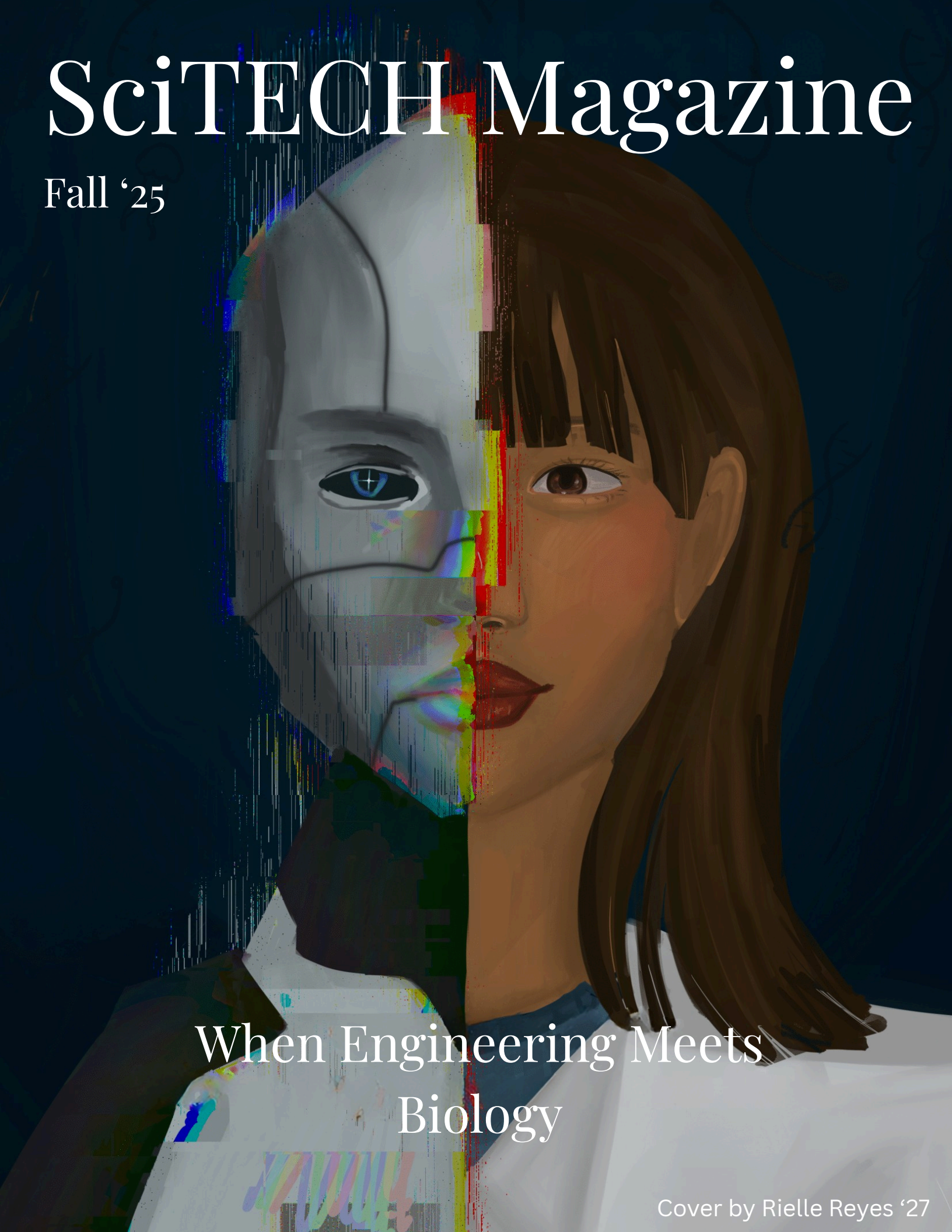

When Engineering Meets Biology

Cover by Rielle Reyes ‘27

Letter from the Editors

Dear SciTECH readers,

This term at SciTECH, we aimed to explore the current direction of science and what that means for all of us. Recent breakthroughs in biotechnology, artificial intelligence, and engineering provide promising foundations for revolutionizing healthcare, education, and our understanding of life itself, but they also spark urgent ethical and moral concerns. The rapidly changing landscape compels us to examine not only the science itself, but the deeply human dimensions of innovation as well.

The technological, economic, and innovative landscape of 2025 places us at an incredibly pivotal moment. As the pace of discovery accelerates, we are confronted with profound questions: What are our responsibilities to the technologies we create? Where should we draw the line between what we can do and what we should do? And how do we ensure that innovation serves humanity rather than the other way around?

The articles in this issue highlight some of the most transformative frontiers of our time. You'll find explorations of precision medicine and investigations into how AI is accelerating scientific discovery and genomics research, examinations of innovative solutions ranging from soft robotics to gene editing, and critical discussions of challenges such as antimicrobial resistance.

We hope these pieces inspire you to think critically about the future we're building together and, maybe even more importantly, the responsibilities that come with it.

Happy reading!

Nicha Tongdee '26
Editor in Chief

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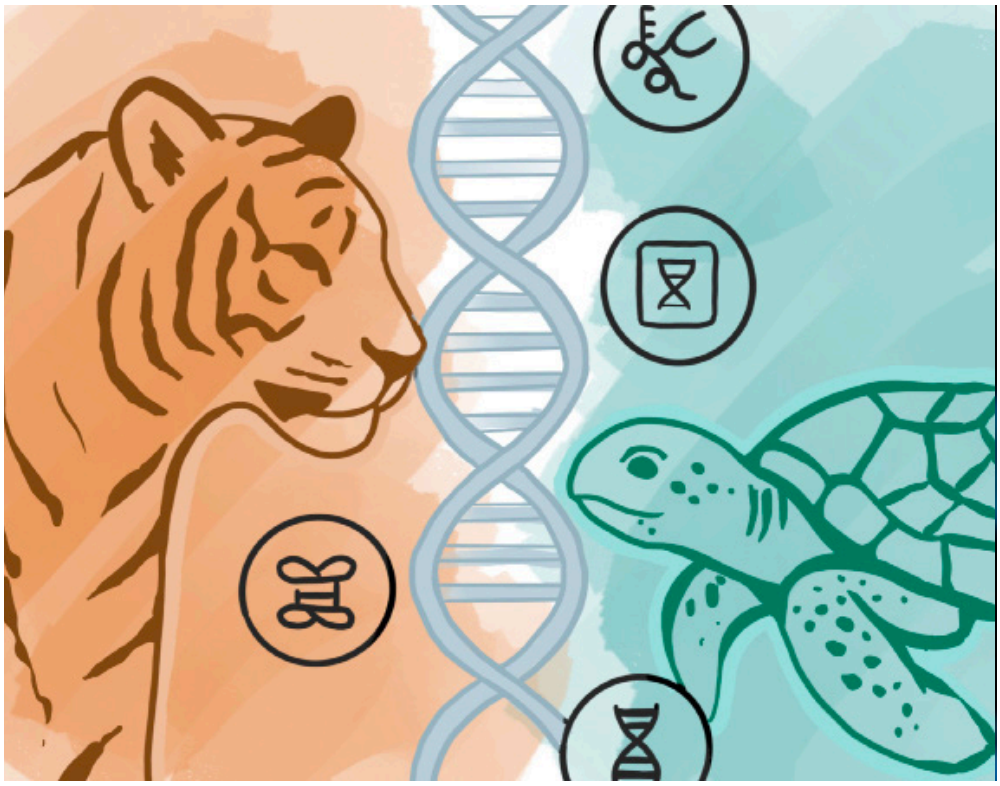
Managing Editor

Contents

GENETIC TOOLS VS. EXTINCTION: A SECOND CHANCE AT SURVIVAL



by SOPHIE LIU '29

Every hour, six species disappear; every day, up to 150 species vanish (Knight, 2012). Biodiversity is decreasing at an unprecedented rate worldwide. According to the World Wildlife Fund, there is a 73% decline in average monitored wildlife populations between 1970 and 2020 (Fallah, 2024). Recent studies have also revealed a trend of 48% of all species declining towards extinction, with only 3% showing recovery signals (Queen's University Belfast, 2023).

As ecosystems teeter under this pressure, a practical solution is urgently needed. With the advancements of genetic technologies, researchers use several methods utilizing these tools to save endangered species.

1. Environmental DNA (eDNA) analysis

Environmental DNA (eDNA) is a mixture of tissue, cells, subcellular fragments, and extracellular DNA released into the environment during the lifetime and death of a species (Holman et al., 2019). These genetic materials are often found in soil, sediments, water, or snow (Rees et al., 2014). eDNA surveys refer to the process of making millions of copies of the targeted genetic materials through polymerase chain reaction (PCR), then conducting DNA sequencing to identify the organism (EDNA Survey | InPort, n.d.). This approach would allow researchers to effectively monitor the biodiversity of a particular region by surveying the populations of both native and invasive species (Environmental DNA, 2018).

One of the significant applications of eDNA analysis is the early detection of non-indigenous species (NIS), as this would enable timely actions to mitigate the potentially deleterious effects of NIS. For example, Holman et al. (2019) used eDNA metabarcoding of COI (cytochrome c oxidase subunit I) and 18S (nuclear small subunit ribosomal DNA) genes collected in the UK marinas. They found 18 NIS in the study region, including a recently introduced Asian date mussel. These findings provide valuable guidance on further management of NIS in that region and highlight the effectiveness of eDNA analysis.

2. Genetic engineering

2.1 CRISPR

Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR) is a gene editing technology introduced in 2012. Engineered CRISPR systems have two components: a Cas enzyme and a guide RNA (sgRNA). The components target and cleave a specific locus within the DNA sequence (Addgene: CRISPR Guide, n.d.). Researchers have proposed using CRISPR to

rebuild the genetic diversity of endangered species, thereby helping to restore the ecosystem from the brink of extinction. Several possible ways include rectifying genetic flaws, introducing advantageous alleles, and eliminating detrimental mutations in threatened organisms (Malik, 2024).

To be more specific, after identifying historical genetic variation in an endangered species, gene editing technologies, such as CRISPR, can be used to reintroduce the lost genetic diversity into the selected species. For instance, scientists have used gene editing tools to save the pink pigeon population in the forests of Mauritius. They first isolate and culture primordial germ cells (PGCs), then introduce multiple edits into the genome. These genetically engineered PGCs are later inserted back into the surrogate birds, with their innate PGCs ablated. As a result, their offspring of the pink pigeons will inherit the engineered DNA sequences with the desired edits that mimic their ancestor's genome. This approach would significantly enhance their chances of survival, underscoring the benefits of utilizing gene editing technologies such as CRISPR in saving endangered species (Gene Editing May Help Save Species from Extinction, n.d.).

2.2 Gene drive

While CRISPR induces edits to specific genes, gene drives, another genetic tool, can ensure these desired edits spread throughout populations (Coffey, 2020). By applying this technology, scientists can insert gene-drive alleles into the protective genes of an endangered organism. As a result, the edited "beneficial" genes are more likely to be passed on to subsequent generations, ensuring the long-term survival of endangered species (Roberts et al, n.d.). According to Kosch (2025), gene drives offer potential solutions for saving endangered frogs by increasing their resistance to devastating diseases like chytridiomycosis, while gene drives can also be used for the conservation of the genetics of threatened plant populations by "driving adaptive traits before the arrival of the selective agent/threat" (Barrett et al., 2019).

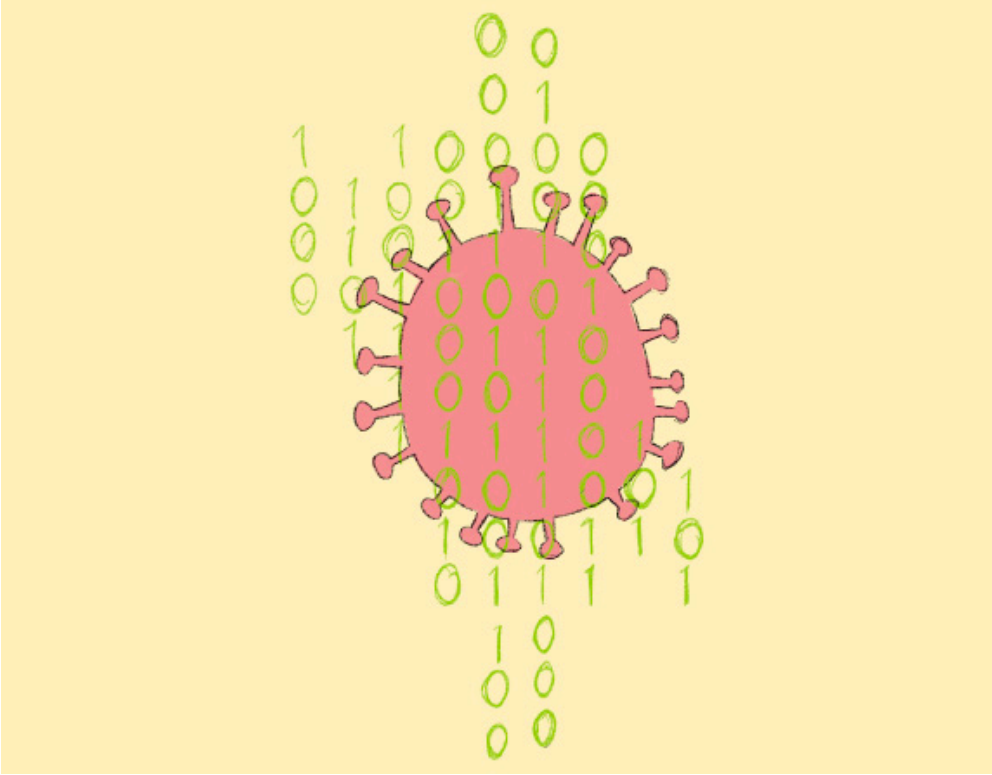
Overall, it is clear that genetic tools hold enormous potential in solving current environmental issues in biodiversity. We should further invest in the development, ethical evaluation, and responsible application of these technologies to save endangered species and create a sustainable living environment for every organism on this planet. •

BIBLIOGRAPHY

1. 1. Knight, R. (2012, April 24). Biodiversity loss: How accurate are the numbers? BBC News. https://www.bbc.com/news/magazine-17826898
2. 2. Fallah, A. (2024, October 9). Catastrophic 73% decline in the average size of global wildlife populations in just 50 years reveals a 'system in peril.' WWF. https://www.worldwildlife.org/press-releases/catastrophic-73-decline-in-the-average-size-of-global-wildlife-populations-in-just-50-years-reveals-a-system-in-peril
3. 3. Queen's University Belfast. (2023, May 23). Global loss of biodiversity is significantly more alarming than previously suspected. News | Queen's University Belfast. https://www.qub.ac.uk/News/Allnews/2023/-Global-lossofbiodiversityissignificantlymorealarmingthanpreviouslysuspected.html
4. 4. Holman, L. E., De Bruyn, M., Creer, S., Carvalho, G., Robidart, J., & Rius, M. (2019). Detection of introduced and resident marine species using environmental DNA metabarcoding of sediment and water. Scientific Reports, 9(1). https://doi.org/10.1038/s41598-019-47899-7
5. 5. Rees, H. C., Maddison, B. C., Middleditch, D. J., Patmore, J. R., & Gough, K. C. (2014). REVIEW: The detection of aquatic animal species using environmental DNA – a review of eDNA as a survey tool in ecology. Journal of Applied Ecology, 51(5), 1450–1459. https://doi.org/10.1111/1365-2664.12306
6. 6. Environmental DNA (eDNA). (2018, November 13). USGS. https://www.usgs.gov/water-science-school/science/environmental-dna-edna
7. 7. EDNA Survey | InPort. (n.d.). https://www.fisheries.noaa.gov/inport/item/75259#:~:text=Abstract:-,Scientists%20at%20NOAA's%20Northeast%20Fisheries%20Science%20Center%20(NEFSC)%20are%20using,of%20sampling%20and%20over%20time.
8. 8. Addgene: CRISPR guide. (n.d.). https://www.addgene.org/guides/crispr/
9. 9. Malik, P. (2024). Empowering biodiversity: CRISPR-based genetic rescue strategies for endangered species. Reseapro Journala. https://doi.org/10.61577/jec.2024.100016
10. 10. Gene editing may help save species from extinction. (n.d.). Nature. https://www.nature.com/articles/d42473-024-00109-z
11. 11. Roberts, R. (n.d.). CRISPR Gene Drives: Eradicating Malaria, Controlling Pests, and More. SYNTHEGO. https://www.synthego.com/blog/gene-drive-crispr
12. 12. Kosch, T. (2025, June 26). New tools for old survivors: frogs, disease, and the future of conservation. Gene Drive Network. https://genedrivenetwork.org/fr/blog/new-tools-for-old-survivors-frogs-disease-and-the-future-of-conservation/#:~:text=A%20central%20focus%20of%20our,without%20disrupting%20other%20important%20characteristics.
13. 13. Barrett, L. G., Legros, M., Kumaran, N., Glassop, D., Raghu, S., & Gardiner, D. M. (2019). Gene drives in plants: opportunities and challenges for weed control and engineered resilience. Proceedings of the Royal Society B Biological Sciences, 286(1911), 20191515. https://doi.org/10.1098/rspb.2019.1515

ADVANCEMENTS IN BIOMARKER RESEARCH FOR EARLY DISEASE PREVENTION

by HA JIN SUNG '28



As technological advancements give rise to new medical imaging techniques and tools, there has been a surge in the discovery of methods for identifying biomarkers, which are indicators in the body that can signal the presence of a disease or track a biological response (USA FDA, 2017). Biomarkers are particularly useful in predicting the onset of life-threatening diseases, and with advancements in biomarker research, medical facilities can help patients prevent disease early.

Positron Emission Tomography

Fluorodeoxyglucose positron emission tomography (FDG-PET) is a nuclear imaging technique that uses fluorodeoxyglucose (FDG), a radioactive tracer, to detect metabolic activity in the body (Ashraf et al., 2023). A small dose of FDG is injected into the patient's body, which is then imaged with a PET scanner.

FDG-PET is particularly useful for detecting and predicting neurodegenerative diseases such as Alzheimer's and Parkinson's disease. FDG-PET can act as a biomarker of brain metabolism, measuring glucose usage to detect early neuronal injury, synaptic activity loss, and a weakened blood-brain barrier (Kandiah et al., 2022). FDG-PET is especially effective in detecting cases of Alzheimer's, showing over 90% accuracy in correctly diagnosing the disease (Kandiah et al).

Along with FDG-PET, other PET scanners, such as amyloid-PET and tau-PET, can also recognize biomarkers for Alzheimer's disease and similar neurodegenerative disorders. These two PET tools detect the abnormal beta amyloid and tau proteins, which are closely associated with cognitive decline and neurodegeneration (Kandiah et al). Measuring these biomarkers can help diagnose or predict diseases like Alzheimer's early, so that patients can get adequate treatment as soon as possible.

MicroRNA

MicroRNAs (miRNAs) have become increasingly promising as biomarkers that can aid in the early detection of cancer, one of the leading causes of death in the world. MiRNAs are small RNA molecules that regulate genes and protein activity and gene expression (Nazir et al., 2025).

Coupled with machine learning algorithms, miRNAs can be profiled for their expression in tissues and therefore predict the presence of certain cancers. For example, in 2024, a study successfully screened the expression profile of a miRNA to create an algorithm that diagnosed early pancreatic cancer (Metcalf, 2024). Another study found that analyzing the expression of three unique miRNAs accurately distinguished patients with non-small cell lung cancer from healthy individuals (Metcalf, 2024).

Combining miRNA as a powerful biomarker with modern advancements in computer science is essential to detecting cancer early and allowing patients to obtain treatment.

Digital Biomarker Detection

As technology continues to advance, more convenient, everyday tools for biomarker detection have been developed. For instance, wearable devices such as smart contact lenses, watches, or pacemakers can serve as platforms that collect biosamples from patients, which can be used to detect biomarkers (Haghayegh et al., 2024). This can be particularly useful for patients who suffer from noncommunicable, or not transmissible, chronic diseases, such as diabetes, stroke, and cancers. (WHO, 2025). Digital biomarkers allow healthcare providers to collect health-related measurements to develop preventive measures and monitor how a disease develops in severity (Smokovski et al., 2024).

In essence, all fields of biomarker research have made significant advancements in recent years. From the detection of neurodegenerative disease to cancers to chronic conditions, many novel biomarkers and technologies have shown immense potential in predicting and diagnosing diseases early. With these tools, patients will be able to get proper treatment earlier, drastically increasing the possibility of a full recovery. •

BIBLIOGRAPHY

1. Ashraf, M. A., & Goyal, A. (2023, August 28). Fludeoxyglucose (18F). Nih.gov; StatPearls Publishing. https://www.ncbi.nlm.nih.gov/books/NBK557653/
2. Ivica Smokovski, Steinle, N., Behnke, A., Bhaskar, M., Grech, G., Richter, K., Günter Niklewski, Birkenbihl, C., Parini, P., Andrews, R. J., Bauchner, H., & Golubnitschaja, O. (2024). Digital biomarkers: 3PM approach revolutionizing chronic disease management — EPMA 2024 position. The EPMA Journal, 15(2), 149–162. https://doi.org/10.1007/s13167-024-00364-6
3. Metcalf, G. A. D. (2024). MicroRNAs: circulating biomarkers for the early detection of imperceptible cancers via biosensor and machine-learning advances. Oncogene, 43(28), 2135–2142. https://doi.org/10.1038/s41388-024-03076-3
4. Nagaendran Kandiah, Choi, S. H., Hu, C.-J., Ishii, K., Kensaku Kasuga, & Mok, V. C. T. (2022). Current and Future Trends in Biomarkers for the Early Detection of Alzheimer's Disease in Asia: Expert Opinion. Journal of Alzheimer S Disease Reports, 6(1), 699–710. https://doi.org/10.3233/adr-220059
5. Nazir, A., Nazir, A., Afzaal, U., Aman, S., Sadiq, S. ur R., Akah, O. Z., Jamal, M. S. W., & Hassan, S. Z. (2025). Advancements in Biomarkers for Early Detection and Risk Stratification of Cardiovascular Diseases—A Literature Review. Health Science Reports, 8(5). https://doi.org/10.1002/hsr2.70878
6. Office. (2019). FDA on Biomarkers and Surrogate Endpoints. U.S. Food and Drug Administration. https://www.fda.gov/about-fda/innovation-fda/fda-facts-biomarkers-and-surrogate-endpoints
7. World. (2025, September 25). Noncommunicable diseases. Who.int; World Health Organization: WHO. https://www.who.int/news-room/fact-sheets/detail/noncommunicable-diseases

PRECISION MEDICINE

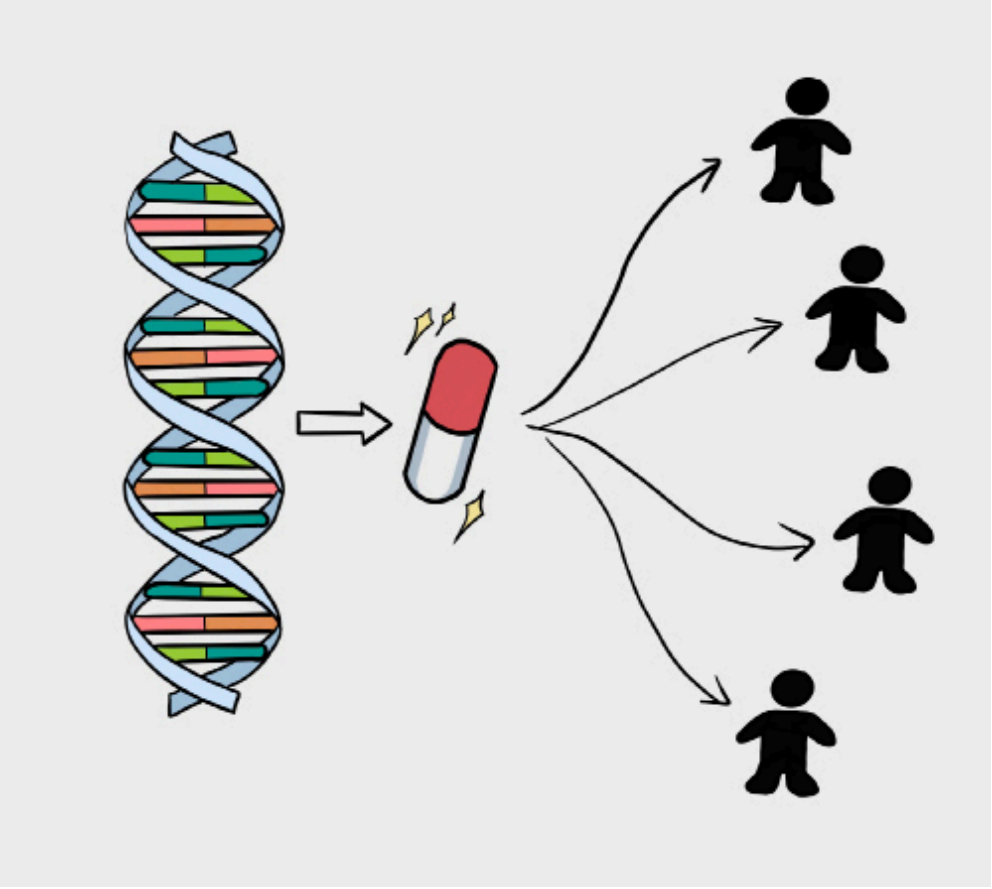
by ETHAN SUN '27

Have you ever wondered why we need an omelet station? Why the omelet out of all things? I pondered this for a second and realized it's because although we all want folded eggs, we all put different things in them. In other words, omelet stations allow for customization. Just like how omelets can be personalized, medicine can be personalized, too. Whereas traditional medicine relies on average results from large clinical trials, personalized, or precision, medicine, factors a person's biological circumstances and genetics into a treatment, which can result in greater treatment efficacy and less severe side effects (Personalized Medicine, n.d.).

What makes precision medicine possible is the Human Genome Project, in which scientists sequenced, or obtained information on, the entire human genome. Since the project concluded in 2003, DNA sequencing costs have been cut significantly, allowing clinics to scan the patient's entire genome to prevent, diagnose, or treat health conditions (The Human Genome Project, n.d.).

Cancer is one of the diseases that has benefited the most from precision medicine. This is because two people with the same cancer can have tumors driven by different DNA mutations, which causes them to react very differently to the same drug (A Close-up Look at Mutated DNA in Cancer Cells, n.d.). Precision medicine provides two important tools for handling diseases like cancer: genetic insights and pharmacogenomics. Genetic insights come from reading the tumor's DNA to find key mutations that really make the cancer grow. If the key driver mutation is found, doctors can pick a drug to target the mutation. The earliest success story of how genetic insights enabled by precision medicine can help treat cancer is with HER2-positive breast cancer. HER-2 is the name of a protein encoded by DNA, and scientists used genetic sequencing to find that this protein is a receptor that is overexpressed by tumors in 25-30% of breast cancers, making the tumors more aggressive. After learning about the HER-2 protein, scientists tested various antibodies and found that survival rates improved when the trastuzumab antibody was added to chemotherapy (Slamon et al., 2001). Similar breakthroughs followed, such as drugs targeting the BRAF V600E mutation improving survival for cancers like BRAF-mutant melanoma, a type of skin cancer (Chapman et al., 2011). As such, precision medicine can find effective treatments through testing the tumor's DNA, finding mutations, and matching the drug that will correctly target the mutation.

On top of genetic insights,



pharmacogenomics analyzes the patient's own genes to predict how they will respond to the drug and the potential toxicity of the drugs (Waarts et al., 2022). A common class of chemotherapy drugs in cancer is called fluoropyrimidines, like 5-fluorouracil(-Fluoropyrimidine - an Overview | ScienceDirect Topics, n.d.). However, people with certain variants of the gene DPYD can't break down these drugs properly and thus will face extremely toxic side effects. Precision medicine allows doctors to genotype cancer patients to check for DPYD variants and reduce doses accordingly. In this case, pharmacogenomics informs the doctors of the best dosage for the treatment to avoid side effects while maintaining effectiveness (Hertz & Venook, 2025).

Powerful technologies underlie the advancement in precision medicine. First, there is next-generation sequencing (NGS), which is fast and affordable DNA reading and can be conducted in hospitals at a relatively affordable cost (DNA Sequencing Costs, n.d.). Then, there are companion diagnostics, tests that help doctors determine what drugs to use for specific patients ("Companion Diagnostics", 2023). Lastly, liquid biopsies allow doctors to bypass tissue biopsies and use blood to track cancer DNA to match patients to therapies ("FDA Approves Liquid Biopsy NGS Companion Diagnostic Test for Multiple Cancers and Biomarkers," 2024).

And of course, it's an ongoing process with many challenges, but costs continue to fall while data, tools, and strategies continue to progress.

TL;DR (I guess scientists also call this the abstract) Precision medicine makes care and treatment for diseases that vary greatly amongst individuals, such as cancer, more precise and personal. By reading or sequencing the DNA of tumors, we can gain genetic insights, target specific drugs to important mutations, and check a patient's genes to avoid dangerous side effects through pharmacogenomics. Like Felix's omelets, precision medicine can change lives and tailor care to the individual. •

BIBLIOGRAPHY

1. A close-up look at mutated DNA in cancer cells. (n.d.). ScienceDaily. Retrieved October 9, 2025, from https://www.sciencedaily.com/releases/2020/02/200205132316.htm
2. Chapman, P. B., Hauschild, A., Robert, C., Haanen, J. B., Ascierto, P., Larkin, J., Dummer, R., Garbe, C., Testori, A., Maio, M., Hogg, D., Lorigan, P., Lebbe, C., Jouary, T., Schadendorf, D., Ribas, A., O'Day, S. J., Sosman, J. A., Kirkwood, J. M., … McArthur, G. A. (2011). Improved Survival with Vemurafenib in Melanoma with BRAF V600E Mutation. New England Journal of Medicine, 364(26), 2507–2516. https://doi.org/10.1056/NEJMoa1103782
3. Companion Diagnostics. (2023). FDA. https://www.fda.gov/medical-devices/in-vitro-diagnostics/companion-diagnostics
4. DNA Sequencing Costs: Data. (n.d.). Retrieved October 9, 2025, from https://www.genome.gov/about-genomics/fact-sheets/DNA-Sequencing-Costs-Data
5. FDA approves liquid biopsy NGS companion diagnostic test for multiple cancers and biomarkers. (2024). FDA. https://www.fda.gov/drugs/resources-information-approved-drugs/fda-approves-liquid-biopsy-ngs-companion-diagnostic-test-multiple-cancers-and-biomarkers
6. Fluoropyrimidine—An overview | ScienceDirect Topics. (n.d.). Retrieved October 9, 2025, from https://www.sciencedirect.com/topics/medicine-and-dentistry/fluoropyrimidine
7. Hertz, D. L., & Venook, A. P. (2025). Reducing Fluorouracil Doses in Patients With Partial Dihydropyrimidine Dehydrogenase Deficiency Is a Treatment Safety Strategy, Not a Panacea of Precision Dosing. JCO Precision Oncology, 9, e2500440. https://doi.org/10.1200/PO-25-00440
8. Personalized Medicine. (n.d.). Retrieved October 9, 2025, from https://www.genome.gov/genetics-glossary/Personalized-Medicine
9. Precision Medicine. (2023, August 18). FDA; FDA. https://www.fda.gov/medical-devices/in-vitro-diagnostics/precision-medicine
10. Slamon, D. J., Leyland-Jones, B., Shak, S., Fuchs, H., Paton, V., Bajamonde, A., Fleming, T., Eiermann, W., Wolter, J., Pegram, M., Baselga, J., & Norton, L. (2001). Use of Chemotherapy plus a Monoclonal Antibody against HER2 for Metastatic Breast Cancer That Overexpresses HER2. New England Journal of Medicine, 344(11), 783–792. https://doi.org/10.1056/NEJM200103153441101
11. The Human Genome Project. (n.d.). Retrieved October 9, 2025, from https://www.genome.gov/human-genome-project
12. Waarts, M. R., Stonestrom, A. J., Park, Y. C., & Levine, R. L. (2022). Targeting mutations in cancer. The Journal of Clinical Investigation, 132(8), e154943. https://doi.org/10.1172/JCI154943

FINGERNAIL-SIZED JELLYFISH: THE KEY TO REGENERATIVE MEDICINE

by MIA LO '29

When we think of immortality, we typically think of all-powerful gods and goddesses—a state unattainable in the modern world. What we don't think of are jellyfish the size of your pinky nail.

The *Turritopsis dohrnii*, or the 'immortal jellyfish', is hypothetically able to live forever.

A *T. dohrnii's* life begins as a larva. As they mature, they grow into polyps that join colonies. The polyps then turn into adult jellyfish. However, through a process called transdifferentiation, they are able to revert to an earlier stage in their life and essentially restart their life cycle. When injured or facing starvation, they can alter their cells to return to their earliest recognized form—the polyp. This process also makes it impossible to estimate the age of a *Turritopsis dohrnii* since it could have regenerated infinitely many times. Due to their unique regenerative ability, and in the absence of disease or predators, this species is rendered immortal.

What makes this jellyfish so different from other species? When compared to the *Turritopsis rubra*, a species related to the *T. dohrnii* but without its cyclical aging process, scientists found that "compared to its relative, it (the T. dohrnii) has double the amount of genes that repair and protect DNA", writes Jason P. Dinh for New Scientist. This was not the only difference between these two species' genetics. The 'immortal jellyfish' had more genes pertaining

to replication and had mutations that protected telomeres, DNA sequences that typically shorten with age. "The most interesting thing is that it (the aging process of the *T. dohrnii*) is not caused by a single molecular pathway. . . It is a combination of many of them," shares Jan Karlseder, a molecular biologist and director of the Glenn Center for Biology and Aging Research at the Salk Institute.

There is no one exact change or mutation alone that created this strange cycle,and if any one aspect were different, the cycle would be thrown off almost entirely. If we want to harness what we can learn from this phenomenon, even from one specific adaptation or mutation, we have to pay attention to the system as a whole: "we cannot just focus on one pathway. That will not be sufficient. We need to look at many of them and how they synergize," Karlseder continued.

Although this genetic adaptation does not directly transfer across species, we are still able to analyze how it works and "find better answers to the many diseases associated with aging that overwhelm us today," says Carlos López-Otín, a biochemist and molecular biologist at the University of Oviedo. But as López-Otín states throughout his interview, there are still so many unknowns. For example, if an adult *T. dohrnii* reverts back to the polyp stage, is it still considered the same individual? If this were to be used for humans, imagine a loved one receiving life saving care, but at the cost of their memories and identity. It sets up moral dilemmas: is it truly a life saved if that life loses its very meaning? It's much simpler to think of the cycle in terms of jellyfish—creatures who lack a central nervous system and other complex organs, not to mention the individuality and complexity of mankind.

Nevertheless, by understanding the genetic functions of the T. dohrnii, we are taken one step closer to simplified regeneration for humans. We are still far from understanding the absolute aging process of the T. dohrnii, but seeing the process laid out opens brand new doors shining light on the prospects of what this unassuming jellyfish and its hypothetical immortality could do for regenerative medicine. •

THE SCIENCE BEHIND RED LIGHT THERAPY

by BRUCE VAN WINGERDEN '28

From reducing facial wrinkles to treating neurological diseases, red light therapy is an emerging treatment with a wide range of applications. Used both in clinics and at home, it is easy to set up and is generally considered harmless. But what exactly is red light therapy, and how does it work?

Also known as photobiomodulation, red light therapy involves repeatedly exposing the skin to low levels of red and near-infrared light for periods typically ranging from ten to thirty minutes. Even though the light waves penetrate the skin one to two millimeters, they don't produce heat, making the treatment safe (Cafasso, 2018). Clinical trials have validated that in order for the light to have any effect, it must be absorbed. Targeted molecules that absorb the light are known as cytochrome c oxidase, which are found in the mitochondria. This process increases levels of adenosine triphosphate (ATP), reactive oxygen species (ROS), and nitric oxide (NO), enhancing mitochondrial function and other cellular pathways (David, 2022). The treatment itself shows promise in improving efficient skin repair and rejuvenation, cell growth, and may even stimulate collagen production, which is responsible for giving skin its structure, strength, and elasticity (Cleveland Clinic, 2023).

Red light therapy masks are commonly used to treat wrinkles, acne, and other facial skin concerns Pagan, 2019). People also use red light therapy beds, panels, and wands, all to manage skin concerns across the body.

But this treatment extends beyond dermatology. A specific form of light therapy called near-infrared (NIR) photobiomodulation has been used for a variety of neurological and psychological conditions, including Parkinson's disease, dementia, depression, anxiety, pain, insomnia, and traumatic brain injuries. According to one study, it has been shown to be effective for treating these conditions, along with peripheral nerve injury, pain, and wounds (Yang et al., 2020).

A 2021 research review found that, across ten studies, red light therapy beds appeared to benefit people with dementia. In one study, five people with dementia who had regular light therapy on their heads and through their noses for twelve weeks had a better quality of life. They had improved sleep quality, better memory, and less anger. However, it is important to note that these studies were small and lacked control. Larger trials are required before any of these benefits can be confirmed (David, 2022).

Red light therapy has been used since the 1990s, and its discovery can be attributed to a Hungarian scientist named Endre Mester. He was initially conducting an experiment on rats, implanting tumor cells beneath their skin and using a ruby laser to see if it would destroy the cells. To his surprise, it didn't. The laser actually healed the skin incisions made to implant the tumor cells instead. His accidental discovery paved the way for modern light therapy, which continues to evolve in the medical field today. •

Antimicrobial Resistance (AMR) and its Threat to Global Health

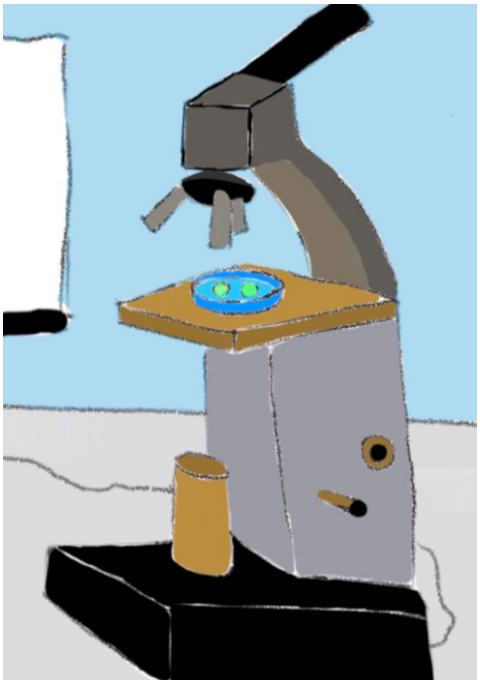
by TAEYOUNG KIM '28

Picture a world where routine surgeries pose risks and small cuts can spiral into a life-threatening infection. This troubling event is not what one would find in science fiction, but the growing reality of antimicrobial resistance.

In 1928, Alexander Fleming's accidental discovery of penicillin changed medicine. Bacterial infections that once killed millions became treatable for the first time, becoming the life-saving antibody for treating Gram-positive pathogen-caused diseases (Aslam et al., 2024). Penicillin revolutionized modern medicine. Antibiotics have since been deemed as one of the greatest discoveries of the 20th century, having saved millions of lives from infectious diseases. But now its effectiveness is under serious threat. Over the years, microbes have developed resistance to many drugs due to the selection pressure caused by antibiotics' abuse (Salam et al., 2023). Humans misuse antibiotics by taking antibiotics for viral infections, such as the common cold or flu, while animals and livestock overuse antibiotics, accelerating resistance. As a result, certain microorganisms, such as bacteria, no longer respond to antimicrobial treatments designed to kill them.

The impact of AMR is staggering. In 2019, antimicrobial resistance was associated with 4.95 million deaths and directly responsible for 1.27 million global deaths (World Health Organization, 2023). In fact, antimicrobial-resistant infection has been ranked third as the leading cause of death worldwide, following cardiovascular diseases and neonatal conditions. Therapeutic options for antimicrobial infection are increasingly limited, resulting in prolonged illness, greater risk of complications, and higher mortality rates. AMR also contributes to financial strain. According to World Bank projections, antimicrobial resistance may result in $1 trillion in increased healthcare expenses by 2050 and approximately $3.4 trillion in annual GDP losses by 2030 (World Health Organization, 2023).

While the numbers highlight the enormous economic and healthcare costs AMR imposes, they also mask differences. The mortality rate from AMR has leveled off at about 1.2 million annually, Dr. Christopher Murray writes (Stewart, 2024). This data, however, overshadows the decline in AMR deaths under the age of 15 and the rising deaths among people over 50. Despite vaccine coverage and greater access to treatment of common illnesses, which account for decreasing infections in the younger populations, the elderly are subjected to greater resistant infection rates. In the future, Murray notes that with the aging of populations, AMR deaths will grow in the coming years (Stewart, 2024).



Beyond mortality and economics, AMR, apart from adding to the challenges of disease management, also impacts the patient. It has been documented to compromise the human immune system and increase vulnerability after complicated medical procedures such as cancer chemotherapy, dialysis, and joint replacements. In 2016, a woman from Nevada died from a bacterial infection caused by *Klebsiella pneumoniae.* This bacterium was resistant to all 26 antibiotics available in the United States (Cohen, 2017). This case serves as a warning of what a "post-antibiotic world" could look like, where common infections become untreatable and routine medical procedures carry greater risks.

Antimicrobial resistance affects communities worldwide and is an ecological phenomenon due to its rapid global spread and horizontal transfer across species. Antimicrobial resistance is an important reminder that progress in medicine also comes with resistance. •

HOW AI IS REVOLUTIONIZING GENOMICS

by JAMIE LEE '27

What if a computer could cure cancer? Surprisingly, or not, this question could be answered in the near future. With the rise of artificial intelligence (AI), humans are closer than ever to automating faster and more efficient medical processes.

Genomics is a field within molecular biology that studies the entire set of an organism's genes, or the genome. Researching genomics involves zooming out to understand how these genes interact with each other to influence health and traits. This holistic approach makes genomics crucial to our understanding of the human body and diseases, and also has applications in improving agricultural engineering for plants and animals (NHS). However, genomics isn't without its challenges: datasets are vast and complex, with around 3 billion letters per human genome. That's where AI comes in.

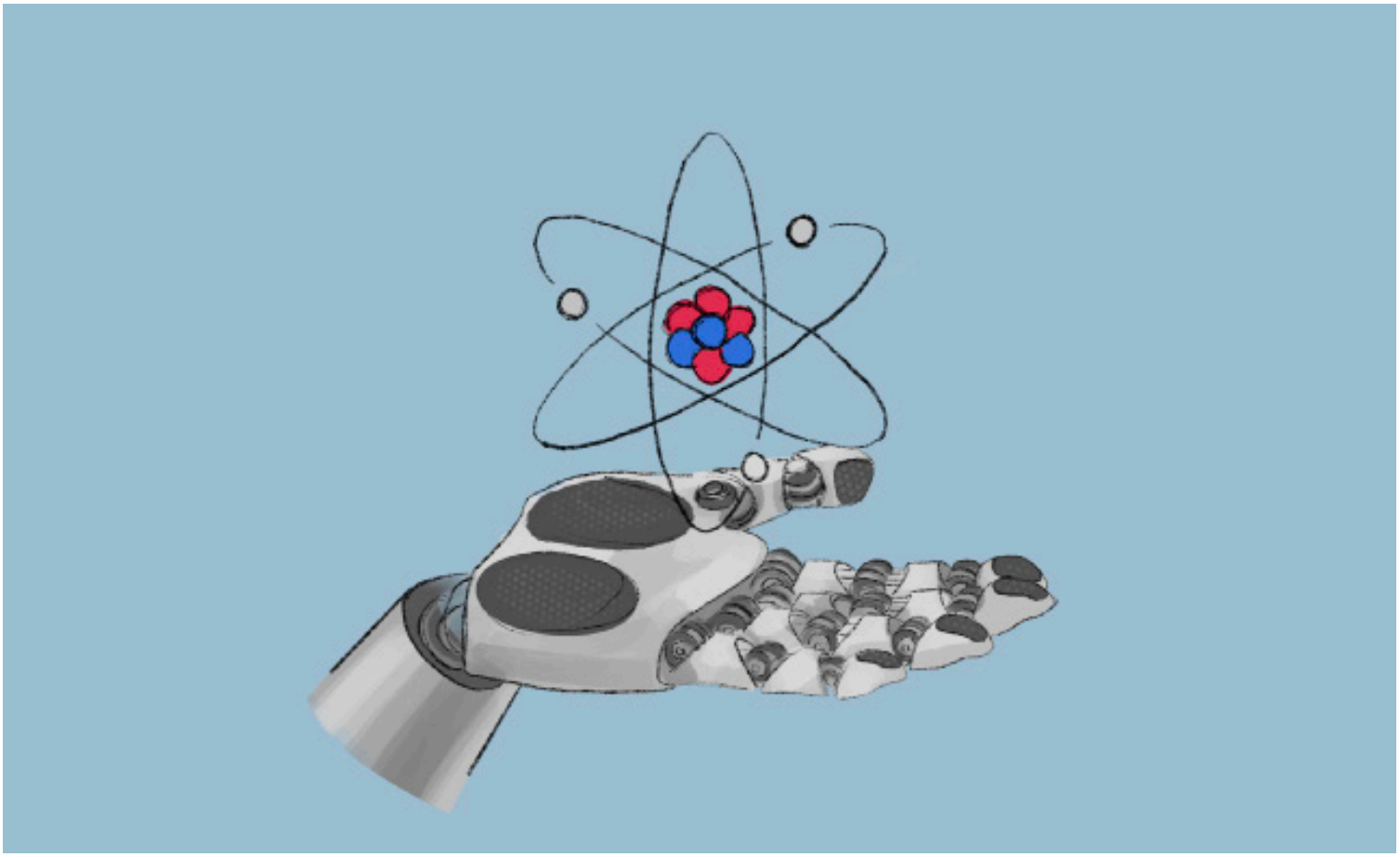
One of the key aspects of genomics is detecting gene variants in DNA. These variants are essential because they help researchers identify genetic mutations, which can cause diseases, including cancers. The strength of AI lies in its ability to analyze data efficiently. Researchers are now incorporating AI into gene detection in large datasets, as machine learning models can sift through entire genome sequences and differentiate between harmful and benign variants. Specifically, these algorithms have been used for cancer diagnosis to classify tumors and provide treatments tailored to patients (Dara, 2025). In a recent study, Mingyun Bae et al. used a novel computational model to identify cancer with 95% specificity and 91% to 98% sensitivity across two training sets, showing how AI can be used for on-screen cancer detection (O'Connor, 2025).

This tailored treatment is an example of personalized medicine, targeting specific individual needs instead of applying a one-size-fits-all treatment. Personalized treatment has many advantages: it improves treatment efficacy and reduces the side effects of standard medicine. AI has again shown promise for personalized treatment and drug discovery. It can identify biomarkers, signals for disease, and the targets, molecules that drugs can act on. Also, to address the issue of long and exhaustive clinical trials, researchers have implemented AI to optimize trial design and recruitment using past studies and patient data. For instance, a recent technology developed by Unlearn.AI can create virtual replicas of trial participants for the control group, increasing participation in the experimental group, thereby improving efficiency (Zhang, 2025). Many companies have taken similar approaches to advance clinical trial optimization.

Still, the bold term "AI" often comes with ethical dilemmas and considerations. One significant issue involves data privacy concerns. In an age when many are concerned about their iPhones watching them, or Instagram reels tracking behavior, trusting a computer to store and analyze our biological data can feel daunting. With genomic data being a highly personal and sensitive topic, robust ethical guidelines and data protection are needed for full-scale integration of AI. Another key problem is bias. All machine learning models are trained on data, but if the data is skewed in any direction, then outcomes can be inequitable (Dara, 2025). Genomics is a high-risk field as human lives are on the line.

Ultimately, AI is reaching far into the depths of genomics. What was impossible ten years ago is now at the fingertips of scientists who harness novel technologies. As society looks towards a better future for modern medicine, humans must guide artificial intelligence into redefining barriers to genomics. •

USING RETRIEVAL-AUGMENTED GENERATION TO IMPROVING FACTUAL ACCURACY FOR MEDICAL LARGE LANGUAGE MODELS



by EASON NI '27

Pre-trained Large Language Models (LLMs) have demonstrated incredible abilities of learning in-depth knowledge from training data without accessing any external memory. GPT-4 achieved an accuracy of approximately 80% in the US Medical Licensing Exam (Step 1, 2, and 3). Developments like Chain-of-Thought (CoT) prompting have attempted to elicit reasoning in LLMs and have improved their ability to handle complex tasks by breaking them down into multiple steps. CoT prompting has been shown to improve LLMs at biomedical tasks. However, these methods are prone to "hallucinations," where LLMs may incorrectly recall or make up facts, make it hard to update or extend the model's information, and don't provide transparency on generated responses. Accuracy and recency are vital in the biomedical field, where new advances and findings emerge rapidly. PubMed, an online database for biomedical literature, for example, increases by approximately 5,000 articles every day.

Retrieval-Augmented Generation (RAG) has emerged as a promising solution by adding a retriever that gets relevant information from a corpus, then combining the information with the question before having the model compose an answer. This pipeline mitigates the previous problems by grounding LLM answers in concrete and verifiable sources. Additionally, this allows updates in domain-specific information in the external corpus and the tracking of accessed knowledge to increase transparency. Since its proposal, this methodology has evolved from Naïve RAG to Advanced RAG, then to Modular RAG frameworks.

The RAG pipeline has been quickly implemented in biomedicine for its abilities to provide more accuracy and transparency. To improve performance on medical domain specific tasks, many RAG pipelines have

been developed with different retrievers and corpora and include different strategies.

MedRAG is a novel RAG framework designed to enhance diagnosis accuracy of LLMs. MedRAG uses Knowledge Graph (KG)-elicited reasoning with four tiers to capture the comprehensive differences essential for diagnostics. MedRAG also can retrieve data from Electronic Health Records (EHRs). Combining the retrieved data with an LLM, this allows MedRAG to provide precise and personalized diagnoses and proactively ask follow-up questions to clarify ambiguous patient information.

BiomedRAG is another novel RAG framework designed to enhance LLMs in biomedical Natural Language Processing (NLP) tasks by reducing hallucinations. BiomedRAG accomplishes this by employing a learnable tailored chunk scoring mechanism. BiomedRAG was benchmarked across four biomedical NLP tasks: triple extraction; relation extraction; text classification; and link prediction against other State-of-the-Art (SOTA) models, where the BiomedRAG framework produced superior results across the board. In triple extraction, BiomedRAG achieved micro-F1 scores of 81.42 on GIT and 88.83 on ChemProt. BiomedRAG improved the original MedLLaMA 13B and LLaMA2 13B by 34.67% and 22.43% respectively in Triple-F1 on GIT.

Despite these advancements, challenges still remain. As the well-known saying goes, "garbage in, garbage out." This is no exception for the RAG paradigm. By design, RAG systems rely on the corpus or corpora to act as the ground truth in response generation. Therefore, the output quality is only going to get as good as the input context, meaning that the curation of corpora is a cardinal part of the fine tuning. How LLMs handle context is another limit, as it would be great if you could give the LLM as much context as it needs, and have it pick the necessary snippets. However, LLMs suffer decreased performance in accuracy when given larger contexts, and especially have trouble recalling content in the middle of contexts, which is known as the "lost-in-the-middle" phenomenon.

While RAG has proven to be a promising solution to enhance LLMs in biomedicine, medicine, and healthcare by integrating real-time non-parametric memory retrieval to provide contextually relevant and up-to-date responses, its implementation raises several ethical concerns. These concerns are similar or stem from existing issues with LLMs that remain largely unresolved. RAG tries to address the main problem of transparency and hallucinations, but it does not eliminate all fundamental LLM challenges and even introduces new ones. One of the greatest concerns regards privacy and data security. LLM conversations are often stored, and it is the same with RAG enhanced LLM conversations. This raises issues regarding potential privacy breaches and data usage. Including sensitive patient data as context for LLMs introduces greater cybersecurity risks. The additional concern of transparency and explainability exists because even when augmented by RAG pipelines, LLM generations are still a black box, making them have some degree of unpredictability.

BIBLIOGRAPHY

1. Bainiaksina, J. (2024, March 10). LLM RAG Paradigms: Naive RAG, Advanced RAG & Modular RAG. Medium. https://medium.com/@drjulija/what-are-naive-rag-advanced-rag-modular-rag-paradigms-edff410c202e
2. Bunnell, D. J., Bondy, M. J., Fromtling, L. M., Ludeman, E., & Gourab, K. (2025, April 1). Bridging AI and healthcare: A scoping review of retrieval-augmented generation—ethics, bias, transparency, improvements, and applications. Cold Spring Harbor Laboratory. https://doi.org/10.1101/2025.04.01.25325033
3. Gao, Y., Xiong, Y., Gao, X., Jia, K., Pan, J., Bi, Y., ... & Wang, H. (2023). Retrieval-augmented generation for large language models: A survey. arXiv preprint arXiv:2312.10997, 2(1).
4. He, J., Zhang, B., Rouhizadeh, H., Chen, Y., Yang, R., Lu, J., ... & Teodoro, D. (2025). Retrieval-Augmented Generation in Biomedicine: A Survey of Technologies, Datasets, and Clinical
5. Applications. arXiv preprint arXiv:2505.01146.
6. Lewis, P., Perez, E., Piktus, A., Petroni, F., Karpukhin, V., Goyal, N., ... & Kiela, D. (2020). Retrieval-augmented generation for knowledge-intensive nlp tasks. Advances in neural information processing systems, 33, 9459-9474.
7. Li, M., Kilicoglu, H., Xu, H., & Zhang, R. (2025). Biomedrag: A retrieval augmented large language model for biomedicine. Journal of Biomedical Informatics, 162, 104769.
8. Liu, S., McCoy, A. B., & Wright, A. (2025). Improving large language model applications in biomedicine with retrieval-augmented generation: a systematic review, meta-analysis, and clinical development guidelines. Journal of the American Medical Informatics Association : JAMIA, 32(4), 605–615. https://doi.org/10.1093/jamia/ocaf008
9. Lozano, A., Fleming, S. L., Chiang, C. C., & Shah, N. (2024). Clinfo.ai: An Open-Source Retrieval-Augmented Large Language Model System for Answering Medical Questions using Scientific Literature. Pacific Symposium on Biocomputing. Pacific Symposium on Biocomputing, 29, 8–23.
10. Singh, A., Ehtesham, A., Kumar, S., & Khoei, T. T. (2025). Agentic retrieval-augmented generation: A survey on agentic rag. arXiv preprint arXiv:2501.09136.
11. Wei, J., Wang, X., Schuurmans, D., Bosma, M., Xia, F., Chi, E., ... & Zhou, D. (2022). Chain-of-thought prompting elicits reasoning in large language models. Advances in neural information processing systems, 35, 24824-24837.
12. Xiong, G., Jin, Q., Wang, X., Zhang, M., Lu, Z., & Zhang, A. (2024). Improving retrieval-augmented generation in medicine with iterative follow-up questions. In Biocomputing 2025: Proceedings of the Pacific Symposium (pp. 199-214).
13. Xiong, G., Jin, Q., Lu, Z., & Zhang, A. (2024, August). Benchmarking retrieval-augmented generation for medicine. In Findings of the Association for Computational Linguistics ACL 2024 (pp. 6233-6251).
14. Zhan, Z., Wang, J., Zhou, S., Deng, J., & Zhang, R. (2025). Mmrag: Multi-mode retrieval-augmented generation with large language models for biomedical in-context learning. arXiv preprint arXiv:2502.15954.
15. Zhao, X., Liu, S., Yang, S. Y., & Miao, C. (2025, April). Medrag: Enhancing retrieval-augmented generation with knowledge graph-elicited reasoning for healthcare copilot. In Proceedings of the ACM on Web Conference 2025 (pp. 4442-4457).

THE RISE OF AI DATA CENTERS

by NEIL ALEJANDRO '27

Artificial Intelligence, or AI, has become an everyday tool for people across the globe. From its broader uses, such as developing small businesses, assisting doctors in the healthcare industry, and enhancing productivity in workplaces, to smaller uses, such as voice assistants, social media, and on your phone, AI has become prevalent in everyone's lives. But at the heart of AI lies a critical piece that allows for this incredible technological creation to function: AI data centers.

AI data centers are specialized facilities designed to support the high computational demands of AI systems, playing a crucial role in advancing and operating their applications. AI data centers are built to handle the unique requirements of AI workloads, which involve massive amounts of data processing, storage, and computational power[1]. Unlike traditional data centers, which support general IT functions, AI data centers use high-performance technology in order to improve machine learning model training, deep learning, and inference tasks, making it possible to run sophisticated AI algorithms efficiently[3]. AI data centers also work to maintain these applications by managing energy, cooling systems, and high-bandwidth networking, allowing for the operation of AI in services such as autonomous vehicles, medical diagnoses, and natural language processing tools such as ChatGPT[2]. AI models require plenty of computational resources, particularly during the training phase. For example, training a large-scale natural language model may involve processing billions of parameters over weeks or months. These centers provide the scalability needed to accommodate the growing adoption of AI in industries like healthcare, finance, and education.

Former president Biden recently issued an executive order aimed at regulating and fostering the development of AI technologies[4]. This directive highlights the role of AI data centers in the nation's AI strategy, emphasizing the need for secure, energy-efficient, and sustainable facilities. The executive order seeks to balance the rapid growth of AI with concerns about energy consumption, security, and equitable access, stressing the importance of guidelines to ensure that AI data centers are resilient against cyber threats and operate in an environmentally friendly manner. As data centers consume significant amounts of energy, the administration's focus on sustainability includes incentives for using renewable energy sources and improving energy efficiency.

As AI becomes more common and used, the importance of AI data centers becomes increasingly emphasized and necessary. The rise of AI data centers signals a pivotal shift in how technological infrastructure is designed and implemented, showing advancements in science and engineering, while also paying attention to energy sustainability, security, and efficiency. AI continues to evolve, and the development of robust, sustainable, and secure data centers will remain a cornerstone of progress. •

SOFT ROBOTS PERFORMING GASTROINTESTINAL PROCEDURES

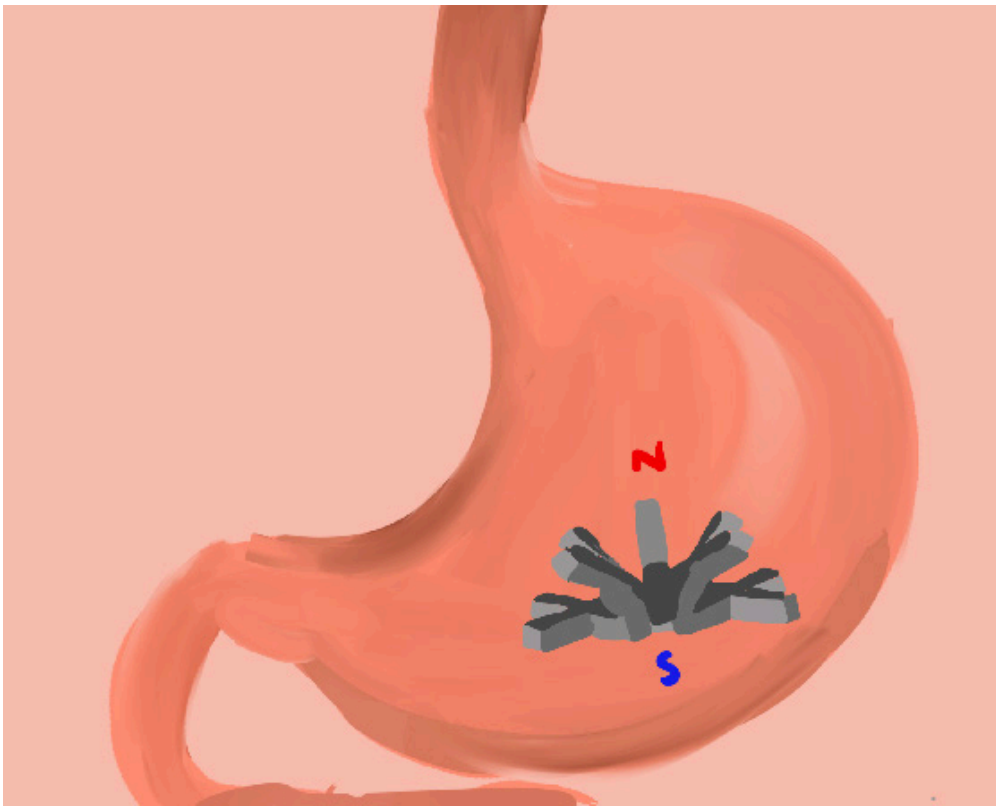
by LIAM MORRIS '28

In the world of healthcare, we have seen significant improvements in recent years, particularly due to new technologies that have enhanced the efficiency and affordability of medical procedures. One of the biggest advancements in this field is the development of soft robots. Soft robots are flexible, formable machines that are proven to be more efficient than humans at performing certain everyday procedures, specifically in the gastrointestinal (GI) field.

In most cases, smaller incisions typically lead to quicker recovery times and a less painful and prolonged experience for the patient. This is where soft robots thrive (Soft Robotics, 2023). According to an article posted by Queen Mary University of London, these robots can "deform, bend, shrink, and change stiffness," making them much more efficient for delicate and complex inner cavities of the human body (Low-Friction Soft, 2024). Unlike past designs, soft robots can reach places that were once thought of as inaccessible, opening the door to new possible treatments.

I've personally experienced the painful and frustrating limitations of the current devices used in our healthcare system. Back in 2019, I had surgery to remove my appendix after being diagnosed with appendicitis following a week of horrible stomach aches. After getting to the hospital, my surgery was delayed because I was not considered a top priority compared to other patients. During this delay, my appendix burst. This was by far the most painful experience of my life and led to a very elongated recovery. For the next 10 days, I had to take strong antibiotics, which severely weakened my immune system, and even today, I am more susceptible to illness than I was in my childhood. I couldn't go to school, keep food down, or even function like a normal human being. If the hospital had had access to these devices during the time of my surgery, it would have made my recovery significantly shorter and more comfortable for a 9-year-old me, which is why these advancements matter so much.

As technologies like soft robots continue to advance, surgeries will not only become more efficient, but healthcare as a whole will become more affordable. Imagine replacing a highly paid surgeon with a robot that can perform the same procedure in half the time and at a fraction of the cost. Is that even a question? Or are we prioritizing the salary of healthcare providers over the patients who can't afford these treatments? These are the ethical and economic issues that we face in the modern medical world. In the near future, with the help of the advancements of technologies, there is hope that healthcare can become more accessible and cost-efficient in the long term. •

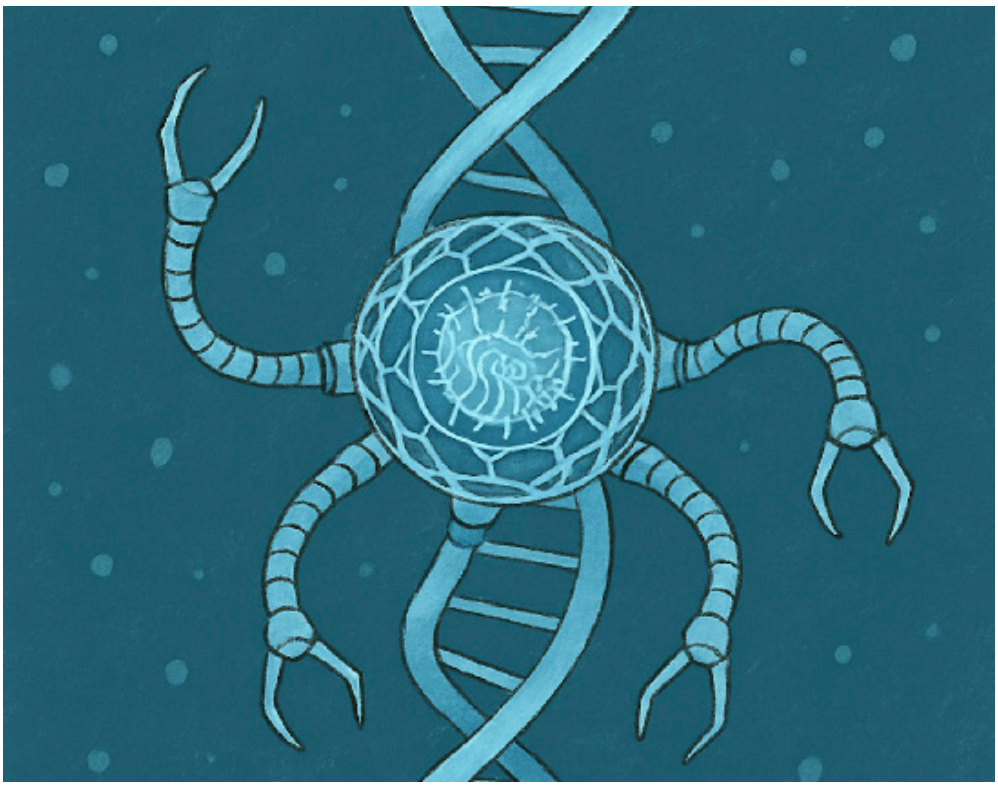


THE FUTURE OF MEDICINE: DNA NANOROBOTS

by ZAHABIYA KHOKHA '27

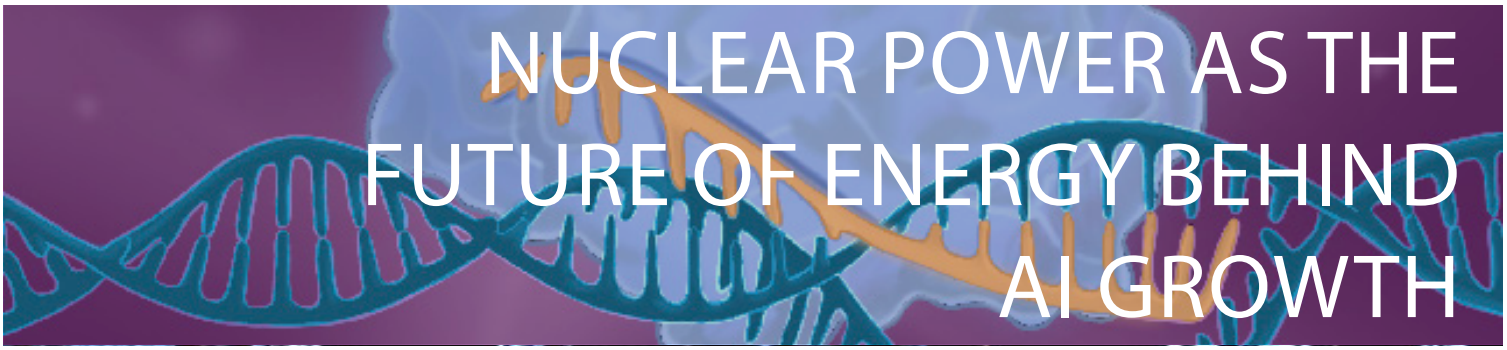
Imagine tiny robots made from DNA that can work inside your body to treat diseases. These "nanorobots" might soon change medicine by delivering treatments straight to specific cells with incredible accuracy. Researchers at the Wyss Institute for Biologically Inspired Engineering at Harvard University have created a DNA-based robot that can search for certain types of cells and deliver instructions to them. One potential use for this is instructing cancer cells to self-destruct. Dr. George Church at the Wyss Institute wrote in an article about DNA-based robots, "Researchers at the Wyss Institute … have developed a robotic device made from DNA that could potentially seek out specific cell targets within a complex mixture of cell types and deliver important molecular instructions," the institute explained (Tolikas, 2012).

The nanobots were created using DNA origami, a method that folds strands of DNA into detailed shapes. The robot looks like a barrel that can open and close. It stays shut with DNA "latches" designed to recognize specific proteins on the surface of certain cells, like cancer cells. When the latches find their target, they change shape, and the barrel opens to release its contents, which could be unique molecules carrying instructions to tell the cell what to do (Li et al., 2018). The researchers took inspiration from how the human immune system's white blood cells constantly move through the bloodstream, looking for dangers (like infections), attaching to them, and sending signals to destroy them. These nanorobots work similarly but at a much smaller scale. Dr. Church explained, "We can finally integrate sensing and logical computing functions via complex, yet predictable, nanostructures — some of the first hybrids of structural DNA, antibodies, aptamers, and metal atomic clusters — aimed at useful, precise targeting of human cancers and T-cells" (Tolikas, 2012).



The programmable DNA nanorobots are modeled on white blood cells, however, there are key differences between the two. DNA nanotechnology refers to the engineering of a synthetic structure using DNA molecules at the nanoscale, while white blood cells are much larger living cells with complex biological functions.

Dr. Donald Ingber, head of the Wyss Institute, recognized it as a big step forward in the biomedical engineering community. "This work represents a major breakthrough in the field of nanobiotechnology as it demonstrates the ability to leverage recent advances in the field of DNA origami pioneered by researchers around the world … to meet a real-world challenge, namely killing cancer cells with high specificity" (Tolikas, 2012). While the safety and efficacy of these nanorobots are still being improved, they could change how we treat diseases in the future. Nanorobots could make it possible to treat or even prevent diseases that are currently difficult to handle (Church, n.d.). •



NUCLEAR POWER AS THE FUTURE OF ENERGY BEHIND AI GROWTH

by IRENE TSENG '27

The rapid advancement of Artificial Intelligence is triggering an explosive demand for energy. Due to the extensive amount of computational power required to run AI models, searches with AI use more than 10 times the energy of traditional search engines. According to the International Energy Agency, energy consumption from data centers is predicted to double by 2030 (Zewe, 2025). Nuclear energy is the only renewable source powerful enough to meet the energy demands of data centers.

Nuclear energy is generated through a process called nuclear fission, which commonly uses uranium-235 as fuel. In this process, protons and neutrons are held together by a strong nuclear force, the most powerful of the four fundamental forces of nature. When a neutron strikes the nucleus of a uranium-235 atom, it causes the nucleus to split into smaller nuclei, releasing a large amount of heat energy in the process. The heat is used to boil water, producing high-pressure steam that spins a turbine in a generator. This is the process that converts heat energy into electrical energy that is used to power data centers.

Unlike fossil fuels, such as coal and natural gas, nuclear energy produces large amounts of energy without emitting carbon dioxide. Additionally, while most renewable sources, such as solar, wind, and geothermal energy, rely on environmental conditions, nuclear energy does not. Thus, it is the most sustainable and reliable energy source. Although nuclear energy offers significant benefits, many people are hesitant to support it due to safety concerns. Past accidents have released large amounts of radioactive materials, which can negatively affect human health and contaminate the surrounding environment. However, when comparing the number of fatalities relative to the amount of energy produced, nuclear energy outperforms wind, hydropower, and biomass, which are all renewable sources. Nuclear disasters can also be prevented through the development of safety protocols and cooling technologies.

In September 2024, Microsoft became the first tech giant to invest in nuclear energy specifically for AI. Microsoft signed a 20-year power purchase agreement with Constellation Energy to reopen the Three Mile Island nuclear plant in Pennsylvania. Shortly after, Google and Amazon made individual investments in smaller, safer versions of traditional nuclear reactors known as small modular reactors (SMRs). Many companies, concerned about negative public perception, prefer SMRs. Although SMRs produce less than a third of the energy of conventional plants, smaller reactors require simpler safety systems and less complex shut down procedures. SMRs also have faster deployment times, lower upfront costs, and flexible siting. These characteristics make SMRs favorable for efficiently meeting the energy demands of data centers, especially as digital infrastructures continue to expand.

As AI continues to evolve and consume unprecedented amounts of energy, nuclear power presents a viable and environmentally friendly solution to meet electricity demands. Several companies are reopening power plants and developing novel fission technologies. By embracing nuclear energy, tech giants can power the growth of AI while also paving the way for a more sustainable and resilient future. •

BIBLIOGRAPHY

1. Conover, E. (2024, October 23). Tech companies want small nuclear reactors. here's how they'd work . Science News. https://www.sciencenews.org/article/small-modular-nuclear-reactors-amazon
2. Ritchie, H. (2020, February 10). What are the safest and cleanest sources of energy?. Our World in Data. https://ourworldindata.org/safest-sources-of-energy
3. Towler, L. (2025, August 17). Search engines vs AI: Energy Consumption compared. Kanoppi. https://kanoppi.co/search-engines-vs-ai-energy-consumption-compared/
4. Zewe, A. (2025, September 30). Responding to the climate impact of Generative Ai. MIT News | Massachusetts Institute of Technology. https://news.mit.edu/2025/responding-to-generative-ai-climate-impact-0930

Bibliographies

Below are article bibliographies that, for various reasons, could not fit below their corresponding article.

FINGERNAIL-SIZED JELLYFISH: THE KEY TO REGENERATIVE MEDICINE

By Mia Lo '29 • P9

Osborne, M. (2023, May 18). 'Immortal jellyfish' could spur discoveries about human aging. Smithsonian. https://www.smithsonianmag.com/smart-news/immortal-jellyfish-could-spur-discoveries-about-human-aging-180980702/

Khedkar, S. (2025, September 15). An "immortal" jellyfish offers clues into biological aging. The Scientist. https://www.the-scientist.com/an-immortal-jellyfish-offers-clues-into-biological-aging-73346

THE SCIENCE BEHIND RED LIGHT THERAPY

By Bruce van Wingerden '28 • P10

Cafasso, J. (2018, May 11). What Is Red Light Therapy and How Does It Work? Healthline; Healthline Media. https://www.healthline.com/health/red-light-therapy#where-to-go

Clinic, C. (2023, September 7). Red Light Therapy: Benefits, Side Effects & Uses. Cleveland Clinic. https://my.clevelandclinic.org/health/articles/22114-red-light-therapy

David. (2022, July 6). Red Light Therapy For Neurological Conditions Explained. Occupational Therapy Brisbane. https://occupationaltherapybrisbane.com.au/red-light-therapy-for-neurological-conditions-explained/#:~:text=Photobiomodulation%20therapy%20(PBM)%20or%20Red,cell%2C%20an%20organelle%20called%20mitochondria.

Pagán, C. N. (2019). Red Light Therapy: What Is It? WebMD. https://www.webmd.com/skin-problems-and-treatments/red-light-therapy

Yang, M., Yang, Z., Wang, P., & Sun, Z. (2020). Current application and future directions of photobiomodulation in central nervous diseases. Neural Regeneration Research, 16(6), 1177–1177. https://pubmed.ncbi.nlm.nih.gov/33269767/

ANTIMICROBIAL RESISTANCE (AMR) AND ITS THREAT TO GLOBAL HEALTH

By Taeyoung Kim '28 • P11

Aslam, B., Asghar, R., Muzammil, S., Shafique, M., Siddique, A. B., Khurshid, M., Ijaz, M., Rasool, M. H., Chaudhry, T. H., Aamir, A., & Baloch, Z. (2024). AMR and Sustainable Development Goals: at a crossroads. Globalization and Health, 20, Article 73. https://doi.org/10.1186/s12992-024-01046-8

Cohen, J. (2017, January 17). A superbug that resisted 26 antibiotics. NPR. https://www.npr.org/sections/goatsandsoda/2017/01/17/510227493/a-superbug-that-resisted-26-an tibiotics

Salam, M. A., Al-Amin, M. Y., Salam, M. T., Pawar, J. S., Akhter, N., Rabaan, A. A., & Alqumber, M. A. A. (2023). Antimicrobial resistance: A growing serious threat for global public health. Healthcare, 11(13), 1946. https://doi.org/10.3390/healthcare11131946

Stewart, R., & Murray, C. J. L. (Hosts). (2024, September 18).

AMR is a major threat to global health [Audio podcast episode]. Global Health Insights. Institute for Health Metrics and Evaluation. https://www.healthdata.org/news-events/podcasts/amr-major-threat-global-health World Health Organization. (2023, November 21). Antimicrobial resistance [Fact sheet]. https://www.who.int/news-room/fact-sheets/detail/antimicrobial-resistance

https://pubmed.ncbi.nlm.nih.gov/33269767/

HOW AI IS REVOLUTIONIZING GENOMICS

By Jamie Lee '27 • P12

Bae, M., Kim, G., Lee, T.-R., Ahn, J.-M., Park, H., Park, S.-R., Song, K.-B., Jun, E., Oh, D., Lee, J. W., Park, Y. S., Song, K. W., Byeon, J. S., Kim, B. H., Sohn, J. H., Kim, M. H., Kim, G. M., Chie, E. K., Kang, H. C., Kong, S. Y., Woo, S. M., Lee, J. E., Ryu, J. M., Lee, J., Kim, D., Ki, C. S., Cho, E. H., & Choi, J. K. (2023). Integrative modeling of tumor genomes and epigenomes for enhanced cancer diagnosis by cell-free DNA. Nature Communications, 14(1), Article 2017. https://doi.org/10.1038/s41467-023-37768-3

Genomics Education Programme. (n.d.). What is genomics? Health Education England. Retrieved October 9, 2025, from https://www.genomicseducation.hee.nhs.uk/education/core-concepts/what-is-genomics/

O'Connor, O., & McVeigh, T. P. (2025). Increasing use of artificial intelligence in genomic medicine for cancer care: The promise and potential pitfalls. BJC Reports, 3, Article 20. https://doi.org/10.1038/s44276-025-00135-4

Zhang, K., Yang, X., Wang, Y., Yu, Y., Huang, N., Li, G., Li, X., Wu, J. C., & Yang, S. (2025). Artificial intelligence in drug development. Nature Medicine, 31(1), 45–59. https://doi.org/10.1038/s41591-024-03434-4

AI DATA CENTERS' RISING

By Neil Alejandro '27 • P15

The Impact of Artificial Intelligence on Data Centers: A Comprehensive Analysis. (n.d.). Digital Realty. https://www.digitalrealty.com/resources/articles/data-center-ai

Sayegh, E. (2024, September 30). The Billion-Dollar AI Gamble: Data Centers As The New High-Stakes Game. Forbes. https://www.forbes.com/sites/emilsayegh/2024/09/30/the-billion-dollar-ai-gamble-data-centers-as-the-new-high-stakes-game/

What is an AI data centre, and how does it work? (2024, July 15). Macquarie Data Centre. https://macquariedatacentres.com/blog/what-is-an-ai-data-centre-and-how-does-it-work/

Xenakis, N., Browner, C., Poloncarz, K., Guzy, G., Jack, A., Hein, J., Huffman, R., Burnette, R., & Gweon, R. (2025, January 21). Biden Administration Releases Executive Order on AI Infrastructure. Covington. https://www.globalpolicywatch.com/2025/01/blog-post-biden-administration-releases-executive-order-on-ai-infrastructure/

SOFT ROBOTS PERFORMING GASTROINTESTINAL PROCEDURES

By Liam Morris '28 • P16

Low-Friction Soft Robots for Targeted Bacterial Infection Treatment in Gastrointestinal Tract. (2024, July 5). National Library of Medicine.

Soft Robotics Revolutionise Minimally Invasive Surgery. (2023, july 13). Queen Mary University of London. Retrieved October 10, 2025, from https://www.qmul.ac.uk/media/news/2023/se/soft-robotics-revolutionise-minimally-invasive-surgery.html

THE FUTURE OF MEDICINE: DNA NANOROBOTS

By Zahabiya Khokha '27 • P17

Church, G. (n.d.). DNA Nanorobot: Cell-Targeted, Payload-Delivering [Video]. Wyss Institute. https://wyss.harvard.edu/media-post/dna-nanorobot-cell-targeted-payload-delivering/

Li, S., Jiang, Q., & Liu, S. (2018, February 12). A DNA nanorobot functions as a cancer therapeutic in response to a molecular trigger in vivo. Nature Biotechnology. https://www.nature.com/articles/nbt.4071#citeas

Tolikas, M. (2012, February 16). Researchers at Harvard's Wyss Institute Develop DNA Nanorobot to Trigger Targeted Therapeutic Responses. Wyss Institute. https://wyss.harvard.edu/news/researchers-at-harvards-wyss-institute-develop-dna-nanorobot-to-trigger-targeted-therapeutic-responses/