



COLORADO ENGINEER

Publishing Since 1904

NATURE MEETS INNOVATION

Spring 2025

Harnessing AI and natural
phenomena for advancements
in medicine, environmental
conservation, and more.



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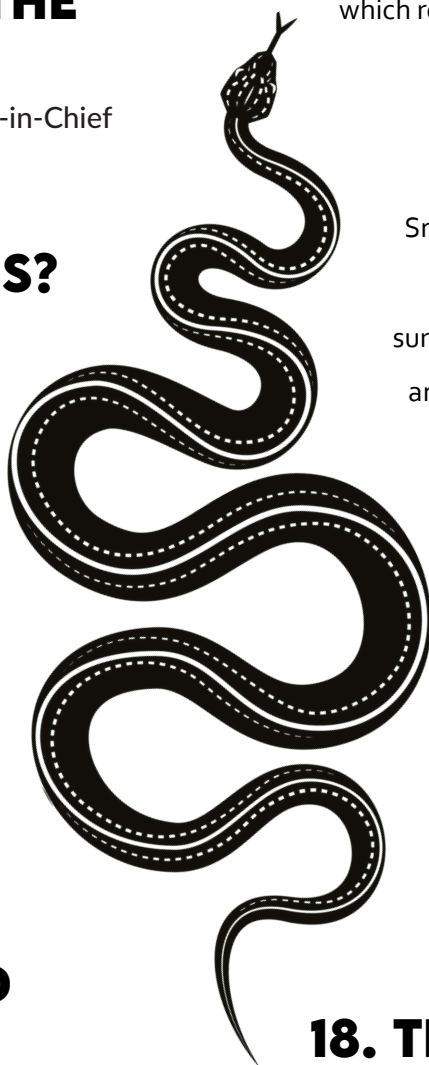
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MEET THE STAFF



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The Colorado Engineer has been reporting on the "latest and greatest" from the engineering, science and technology community since 1904. We were there for the Model T, the jet engine, the IBM PC, the iPod and we will continue to cover the future of human innovation. Today, we operate with a staff of 10 students and four advisers. We publish the magazine biannually, with a readership of over 15,000 individuals, reaching students at the university, researchers, professors and alumni. If you would like to join our staff or have questions and comments, email us at cem@colorado.edu. We always enjoy hearing our readers' feedback!

LETTER FROM THE EDITOR

As my time at CU Boulder and with Colorado Engineer Magazine comes to a close, I've found myself reflecting on the remarkable mentors, opportunities, and community that have shaped my experience here. It's hard to summarize four years of growth, challenge, and joy into a single page—but I'll try.

My journey with CEM began all the way back in my first semester, in a class taught by Dr. Diduch, the Faculty Director of the Engineering Leadership Program. That course, which explored the wisdom of Plato through *The Republic*, was formative in more ways than I expected. Dr. Diduch introduced me to Justin, who was then the Editor-in-Chief of this magazine. That one connection set off a chain of events that shaped my college career.

Dr. Diduch's belief in me—and his encouragement to step outside my comfort zone—led me to start writing and, eventually, designing for the magazine. His mentorship has left a deep imprint on me. He doesn't just hear people—he listens, with genuine curiosity and openness. That quality, more than anything, is something I aspire to emulate as I continue into the next chapter of my life.

This past year, leading Colorado Engineer Magazine as Editor-in-Chief has been one of the most rewarding experiences of my time at CU. It gave me the chance to develop as a leader, work with a phenomenal team, and take ownership of a publication that has meant so much to me. Ironically, it was discussing my experience with the magazine in

a job interview that helped me land my next role after graduation.

But college is about more than just academics or professional development. It's also about finding your people and pushing your limits—in the best ways possible. I've been lucky to make lifelong friends through the CU Boulder Club Rugby Team, and I've learned to throw backflips on skis and stomp 30-foot cliffs thanks to the CU Freeski Team. If you're reading this and wondering whether you should try something new—join that club, show up to that meeting, introduce yourself to someone—you absolutely should. You never know where it'll lead.

As I prepare to pass the torch, I'm incredibly excited to introduce next year's Editor-in-Chief, Malena Garcia. Malena brings a passion for storytelling and a strong editorial vision, and I have full confidence she'll lead the magazine to even greater heights. I also want to welcome our new Design Editors, Michael Chapp and Erika Torii-Karch. Their creativity and dedication have already made an impression, and I can't wait to see what they create together.

To everyone who's contributed to the magazine—writers, designers, editors, mentors, and readers—thank you. You've helped make CEM what it is today, and it's been an honor to serve as your editor.

With gratitude,
Aaron Schurman
Editor-in-Chief, 2025
Colorado Engineer Magazine



Malena Garcia

DESIGNER BAGS? TRY DESIGNER PROTEINS

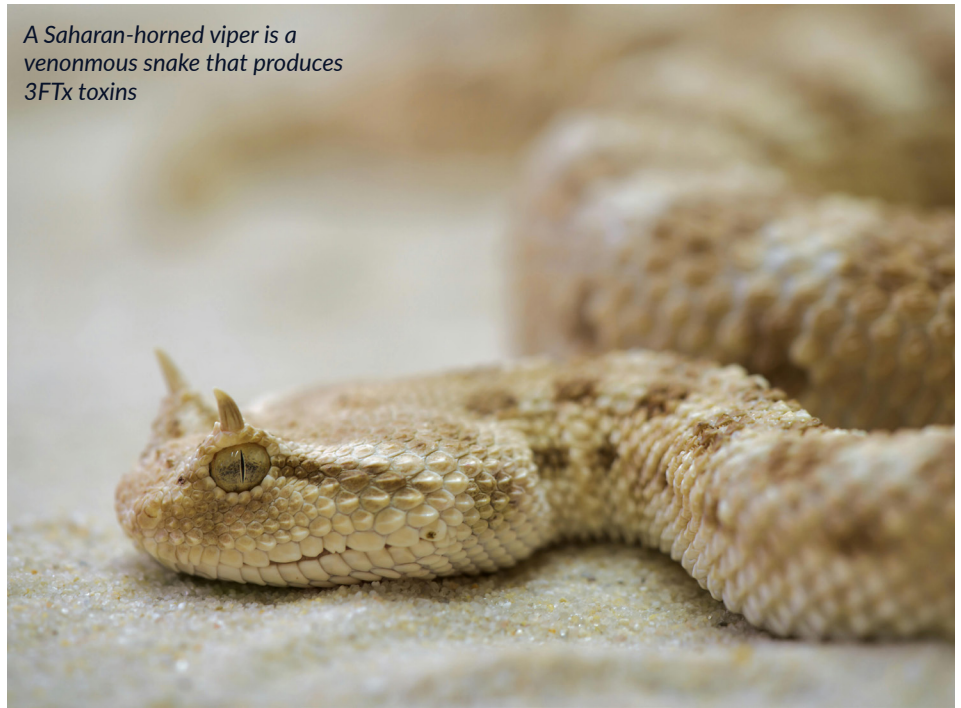
Snakebite venom remains one of the most neglected global health crises, claiming over 100,000 deaths annually and leaving more than 300,000 survivors with permanent disabilities. However, recent advancements in artificial intelligence (AI) and computational protein design are revolutionizing venom treatment. Researchers have shown that AI can design precise, synthetic proteins capable of neutralizing lethal snake toxins.

Antivenoms contain venom-specific antibodies that bind directly to venom toxins. This binding process inactivates the toxic components of the venom, prevents the toxins from interacting with their biological targets in the body and facilitates the redistribution of venom away from target tissues. These proteins, developed using tools such as “RFdiffusion” not only outperform traditional antivenoms in preclinical trials, but also exhibit remarkable thermal stability which is vital for areas with scarce resources.

RFdiffusion is a generative, open-source AI model developed by Nobel laureate David Baker and colleagues at the University of Washington. RFdiffusion, a fusion of structure prediction networks and generative models, is a powerful tool for designing novel proteins with specific functions in seconds. It was developed by fine-tuning the RoseTTAFold protein structure prediction network to achieve unprecedented accuracy and functionality.

Traditional antivenom production has remained largely unchanged for more than a century. This process consists of immunizing animals such as horses or sheep with snake venom, harvesting their antibodies and purifying them into antivenom. This old method, however, comes with several challenges: it is labor-intensive, requires handling

A Saharan-horned viper is a venomous snake that produces 3FTx toxins



dangerous venoms and yields inconsistent antibody quality and quantity. Additionally, animals’ immune systems often do not generate robust responses to the “three-finger” neurotoxins (3FTxs), produced by certain snakes such as cobras and mambas (elapid family). These particularly lethal toxins disrupt nerve-muscle communication and are poorly targeted by traditional antivenoms.

The application of RFdiffusion to snake antivenom development began when medical biotechnologist at the Technical University of Denmark, Timothy Jenkins, read about the impressive results achieved with RFdiffusion-designed proteins. Jenkins and his research team focused on “three-finger-toxins,” (3FTxs) which is a family of snake venoms that traditional antivenoms often fail to effectively neutralize. This inefficacy stems from the limited ability of the 3FTxs to trigger an immune system response in animals, resulting in failure to provoke

an effective antibody response. Using RFdiffusion, Jenkins’ team collaborated with Baker Lab to design toxin-binding proteins within months—a process that previously took years. The World Health Organization (WHO) estimates that traditional antivenoms only show on average 60-70% efficacy when administered post-envenomation. These AI-generated proteins showed near-perfect affinity for toxins, outperforming natural antibodies in controlled in vitro assays. When tested in mice, the proteins neutralized a lethal dose of venom, achieving 100% survival rates, even when administered 15 minutes post envenomation. This new, rapid efficacy is unparalleled in traditional antivenoms which often require immediate administration and large doses for any chance of survival.

What distinguishes RFdiffusion from previous protein design methods is its unique approach to the “denoising” process. “Noise” is the random or unpredictable fluctuations in data that disrupt the ability to identify patterns. To “denoise” is to remove distortions from data or signals with the goal of improving the quality while preserving necessary features. RFdiffusion operates similarly to image generation models like DALL-E, which use diffusion models to generate new images. DALL-E begins with pure static and gradually removes noise to form clear

“THIS NEW, RAPID EFFICACY IS UNPARALLELED IN TRADITIONAL ANTIVENOMS WHICH OFTEN REQUIRE IMMEDIATE ADMINISTRATION AND LARGE DOSES FOR ANY CHANCE OF SURVIVAL.”



Original artwork from the Baker Lab, featuring a snake radiating RF protein structures

pictures guided by user specifications. In the same way, RFdiffusion starts with random protein structures and refines them through iterations into functional proteins.

During the RFdiffusion's training, a noising "schedule" corrupts protein structures until they are indistinguishable from random distributions. The model then learns to predict the original uncorrupted (denoised) structure, learning the reverse process of noise addition. RFdiffusion also uses denoising to generate new protein structures that conform to user-specified constraints. This process is guided by researchers to create proteins with specific binding, functional and structural properties.

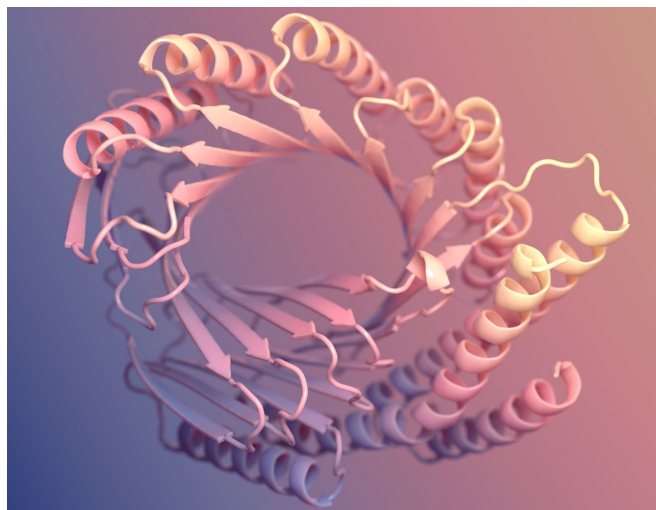
Where conventional methods take years and billions of dollars to identify effective antibodies, RFdiffusion can generate finalized proteins in weeks. Baker Lab has also been adapted to design antibodies against influenza, with a timeline of 8 weeks from design to validation, and antibodies for *C. difficile* toxins (antibiotic resistant bacteria) in 6 weeks. This acceleration also involves cost reductions because synthetic proteins can be produced in microbial systems like *E. coli*, bypassing the need for venom milking and animal husbandry.

The reliance on animal-derived antibodies makes antivenoms expensive to produce and distribute. A single vial can cost thousands of dollars, keeping it out of reach for many low-income regions. Traditional antivenoms also require continuous refrigeration which is often unavailable in remote and tropical areas, where snakebites are the most prevalent. In contrast, the compact structure of synthetic "mini-binders" allows for remarkable thermal stability due to their simple architecture that lacks fragile bonds and complex folding patterns.

AI-driven design also allows for engineering longevity. By optimizing amino acid sequences for reduced oxidation and aggregation, researchers

have been able to create proteins that remain stable for years. AI-designed binders are still undergoing long-term stability testing, but early data indicates that they degrade 50% slower than traditional antivenoms under accelerated aging conditions. Rural clinics in India and Kenya, where refrigeration is often unavailable, now have shelf-stable AI synthesized antivenoms in emergency kits. Data from the India Times shows a 90% reduction in mortality compared to conventional treatments in these settings.

The development of AI-designed antivenoms involves several checks and balances to ensure safety and efficacy. Computational filtering is implemented through filtering designs based on AlphaFold2 (protein structure software) predictions and Rosetta metrics to identify the most promising candidates before experimentation. This pre-screening helps eliminate designs with potential structural or functional issues. The designed proteins undergo rigorous experimental validation, including binding assays, functional neutralization tests and structural characterization. The designer proteins are also tested for adverse effects in animal models before advancing to further development. Preliminary safety testing in mice showed no acute adverse effects during or after treatment with the designed proteins. The development process involves simulation and real-world experiments to continuously improve the design methodology. This iterative approach helps refine the models and enhance their predictive power.



**AI-GENERATED
PROTEIN DESIGN
SYNTHESIZED BY
RFDIFFUSION**

As for the cobra neurotoxin binders (3FTx), RFdiffusion generated 12,000 candidate structures in 3.2 GPU-hours. It also filtered the candidate structures down to 38 promising designs. Lab testing confirmed 6 high-affinity binders from the initial batch of candidates, representing a 99.95% reduction in experimental testing. The entire process, from AI design to preclinical validation, was completed in 21 days versus the 2-5 year industry standard. I collected data from Baker Lab, the Centre of Bioinformatics Research, and the Technical University of Denmark to create a comparison of molecular screening efficiency between conventional methods and RFdiffusion:

RFDIFFUSION VERSUS CONVENTIONAL METHODS			
	CONVENTIONAL METHODS	RFDIFFUSION	IMPROVEMENT FACTOR
CANDIDATES TESTED	50,000-100,000	200-500	200-500x reduction
PROTEIN DESIGN TIME	8.5 min	11 seconds	46x faster
SUCCESS RATE	0.1-0.5%	18-42%	36-420x higher
LAB VALIDATION NEEDED	99.9% candidates	Top 0.5%	200x fewer experiments

Survival rates for traditional antivenoms versus AI-designed 3FTx antivenoms have a drastic decrease in mortality rates. The following data was also collected from the Technical University of Denmark, University of Northern Colorado Greeley and the Liverpool School of Tropical Medicine.
*All scenarios are human-based unless otherwise specified

TRADITIONAL ANTIVENOMS	
SCENARIO	SURVIVAL RATE
Hospital-treated cobra bites	72-89%
Field-treated neurotoxic bites	30-50% (<15% if not administered within 2 hrs)
3FTx-specific neutralization	<20%

RFdiffusion outperforms existing protein design methods across a range of applications including protein monomer and binder design, oligomer design, enzyme active site scaffolding and many more. Another major breakthrough by RFdiffusion is that it can custom generate 3D protein scaffolds to shape-match with specific protein targets. This capability allows for the design of proteins with novel folds that bind perfectly to the target site, even when the resulting structures violate common rules of protein nature (such as lacking a central hydrophobic core). By analyzing vast datasets of known protein folds and amino acid chains, the AI also predicts how to assemble novel proteins that act as “molecular caps,” blocking toxins from interacting with human cells. With the advent of AI-powered tools like RFdiffusion, we no longer must rely on animal immune systems for antivenom.

The success of AI in antivenom design has implications beyond snakebites. Similar approaches are being explored for scorpion and jellyfish stings and even viral infections. Baker Lab is adapting RFdiffusion to design inhibitors for SARS-CoV-2 spike proteins, demonstrating the platform’s versatility. AI is introducing a new era of antivenom therapy by finally overcoming the inefficiencies and limitations of century-old methods. By designing proteins that neutralize venom toxins

with pinpoint accuracy, researchers have witnessed survival rates previously thought impossible. Coupled with enhanced thermal stability and reduced production costs, these innovations promise to democratize access to lifesaving treatments. As AI platforms evolve, their application to other global health challenges could transform the landscape of not only venom implications but possibly all disease management, saving millions of lives in the decades to come.

AI-DESIGNED 3FTX ANTIVENOMS	
SCENARIO	SURVIVAL RATE
Pre-incubated toxin (mouse models)	100%
15-min delayed treatment	100%
30-min delayed treatment	60-100%
Low dose (1:5 toxin:binder ratio)w	80-100%

“BY DESIGNING PROTEINS THAT NEUTRALIZE VENOM TOXINS WITH PINPOINT ACCURACY, RESEARCHERS HAVE WITNESSED SURVIVAL RATES PREVIOUSLY THOUGHT IMPOSSIBLE.”

FIREFLIES AND CITIZEN SCIENCE

Danny Alemayehu

Have you ever seen a firefly in your life? How about a flashing swarm? “Indeed, it’s a common misconception that Colorado doesn’t have fireflies,” Dr. Orit Peleg affirms in an interview, where the commonly held belief that fireflies do not reside in Colorado is addressed.

Dr. Peleg is a professor at the BioFrontiers Institute at the University of Colorado Boulder, exploring the intersection of Computer Science, Physics, and Biology through her research on biological signals and modeling her insights through computational and machine learning models. One of her prominent research directions regards fireflies and the many properties that surround their mysterious flash patterns.

One such mystery is how fireflies are able to synchronize their flashing in order to communicate in a large multi-agent swarm and what specific communications are certain flash patterns associated with. This field of study has yielded interesting findings such as

how specific species of fireflies have their own respective flash patterns to signal to potential mates and that certain species of fireflies will actually imitate those patterns to prey on signaling males. Additional findings include how LEDs can be used to influence firefly swarms to emulate and synchronize with artificial flash patterns. Their lab also utilizes machine learning models such as recurrent neural networks to help categorize and classify flashing patterns along with traditional mathematical modeling methodologies to compare and improve upon existing mathematical models. Due to the multidisciplinary nature of the subject the applications of the research are vast as well.

Part of the motivation for research involves informing firefly conservation efforts. For example, the impact light pollution from urbanization may have on the ability for fireflies to clearly communicate and synchronize their flash patterns, however, data on the location and population of firefly species is limited. Thus, being able to

“INDEED, IT IS A COMMON MISCONCEPTION THAT COLORADO DOESN’T HAVE FIREFLIES.”

improve population statistics collection is important if conservation efforts are to have a general idea on how to proceed with policy advocacy and the change fireflies have experienced as a result of climate change, urbanization, and other environmental issues. Additionally, this research may provide insight into common complex system problems such as the “cocktail party” problem which describes the common dilemma of trying to hear a friend in a noise party. Fireflies experience a version of this problem while mating as courtship occurs in a swarm sending many noises and they have a variety of

processes addressing this issue. However, this research carries a variety of logistical challenges, many of which come from the difficulty in observing the firefly's brief mating season (approximately 2 weeks in July) and in collecting data regarding the context, location, and time of firefly flashes. To that end, Dr. Peleg and her team have come up with a variety of creative solutions to these issues.

To solve the issue regarding spatio-temporal analysis of firefly swarms their lab devised a methodology with two 360 Degree GoPro cameras that record data and then utilize trigonometry with advanced image processing algorithms to recreate the 3D spatio-temporal evolution of firefly signals from 2D visuals. In comparison with the method of human observation records made on site, this method allows for observations to be made after-the-fact by both computers and humans as well as providing huge boons to research reproducibility. Additionally, this also opens up a pathway for citizens with less advanced tooling making firefly observations on site to contribute to firefly research by allowing for 3D reconstruction from videos of firefly

Photo Credit: James Jordan Photography



swarms. In fact, their lab has launched a citizen science initiative as well to get a better idea of where fireflies lie in the state of Colorado. Many people have reported sightings commonly in the front range, southwest, and western Colorado! If

you're interested in helping contribute to firefly research, @oritpeleg on mastodon.social has a post with a google



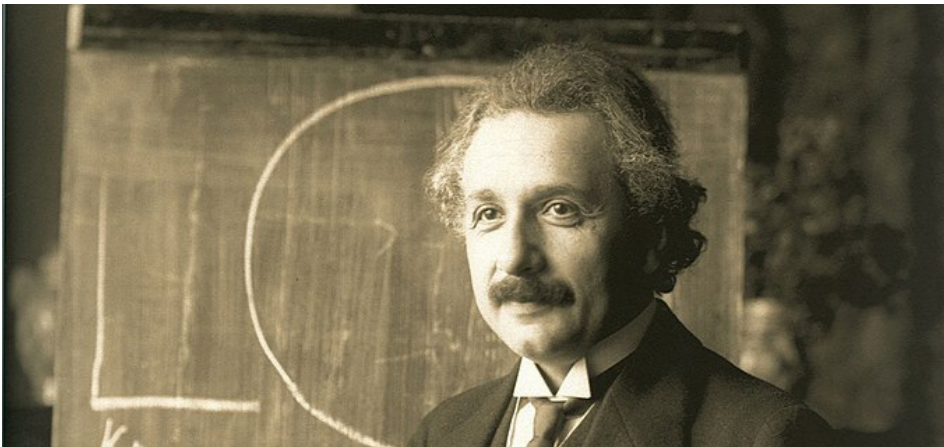
Engaging with the community is one of Peleg's core principles. Here, she is lecturing about her work at the Boulder Public Library.



Peleg collects data on fireflies in the field.

SCIENTISTS AS PHILOSOPHERS

Jamison Barcelona



Albert Einstein in 1921, captured mid-thought at the blackboard. A physicist whose theories re-shaped modern science, Einstein also grappled deeply with philosophical questions about time, reality, and the limits of human understanding.

Western technological science is directly responsible for the greatest increase in standard of living in human history. It has also led to the development of the most destructive weapons in human history. The scientific project has allowed humanity to overcome nature and master their environment. Despite this success, science continues to push the boundaries and promises new technological revolutions to continuously reinvent our world. Such unparalleled power requires tremendous responsibility from all involved, but particularly in reference to the developers and practitioners, known as researchers and engineers. This responsibility can only be developed through deep engagement with the scientific method and its underlying philosophy.

To understand science, it is best to start at the beginning and observe its evolution. Science's early iterations can be traced to Ancient Greece in the form of philosophy, where thinkers used reason and observation

to understand both the world and the human experience. Through the development of philosophy, two fields emerged that would go on to define science; metaphysics—the study of the outside world, and epistemology—the study of knowledge. From these fields emerged the natural sciences, where the outside world is studied using the scientific method. The focus on the outside world hails from metaphysics, while the scientific method serves as an epistemological framework for how we, as human beings, can generate knowledge. Through making observations we create hypotheses about the world, and then test those hypotheses with experiments, deriving conclusions from the results. The scientific focus was placed on the natural and

observable world, that which can be both observed and tested, and whatever can't be observed or tested has typically been left in the realm of pure philosophy.

Despite the success of modern scientific methods, they remain surrounded by epistemological landmines. The most obvious of these landmines is the problem of induction. Induction is a method of proof that expands a specific case to make a general claim. For example, if every measurement of the mass of an electron is consistent at 9.1×10^{-31} kg, and a lot of measurements have been made, we conclude that the mass of an electron is, in fact, 9.1×10^{-31} kg, within some error associated with the measurements. However, induction is not always correct. We can show this by imagining a scientist turkey on a farm who observes that every day at 6:00 am the farmer feeds the turkeys. The scientist turkey, after hundreds of observations, announces to the other turkeys he has discovered a law of the universe, dubbed the “turkey time law”, which states that the farmer feeds the turkeys every day at exactly 6:00 am. The scientist turkey, observing the time to be 5:55 am, predicts that the farmer will feed them in precisely five minutes. However, while the farmer does arrive at 6:00 am, he does so without food, instead slaughtering the turkeys in preparation for Thanksgiving. Induction's fatal flaw is its reliance

“IT IS HIGH TIME THAT SCIENTISTS AND ENGINEERS BEGAN THINKING MORE DEEPLY ABOUT OUR DISCIPLINES AND OUR KNOWLEDGE.”

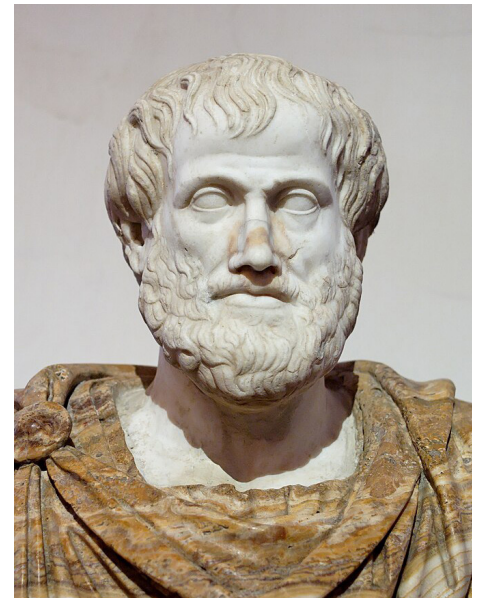
on assuming that observations reveal insight about the underlying mechanism of a process, which is not always true. The mass of the electron suffered a similar problem when it was discovered that the measured mass deviated significantly from the theoretical mass. The initial failure catalyzed the development of the Higgs mechanism which proposes a solution to the discrepancy. Clearly, measuring the mass of the electron does not provide insight into why or how it has mass.

Naturally, science isn't solely observation, researchers also employ reason and logic to deduce implications of observations and find fundamental knowledge. Witnessing a bird take flight does not grant understanding into how the bird flies, or why it does. Understanding the phenomena of flight in birds requires understanding the physics of flight, the bird's biology, and evolutionary history—in other words, the how and why. Therefore, even an observation must be supported by logic, and a claim of knowledge must be supported by a logical proof. If a valid proof is provided, then the claim must be true. However, proofs

always rely on additional claims, and each claim will require an additional proof. These new proofs will have unproven claims which require additional proofs, and so on, ad infinitum. An infinite number of proofs is required to validate a claim, this creates a paradox known as infinite regress.

Let's instead try an argument that doesn't rely on any other claims: only untrustworthy people run for president, and the fact that politicians are untrustworthy is proof. The premise is only untrustworthy people will run for president, and the proof given is that politicians are untrustworthy. This argument relies on the conclusion (politicians are untrustworthy) to prove the premise (only untrustworthy people run for president). This is known as a circular argument, and is considered a logical fallacy. Therefore, claims cannot be logically proven in this way, and no knowledge can be generated.

We can try a third approach, what if we arbitrarily stop the infinite regress somewhere and take a claim as true without proof. This is known as an axiomatic approach or an appeal to



Marble bust of Aristotle, one of history's earliest polymaths. As both a philosopher and proto-scientist, Aristotle laid the groundwork for empirical observation and systematic inquiry.

dogma. Typically axioms are thought of as innately true or common sense. For instance, the idea that knowledge requires validation to be true is the central axiom of this argument, and an



Photo by John Rynk. Depicted: Yunfung Hu, philosopher and world leading expert on polymer holography.



Photo by Jamison Barcelona. Depicted: John F. Rynk, epistemologist and polymer scientist.

appeal to common sense. To agree with that axiom is to accept that there are limits to our knowledge based on our inability to create valid proofs. To reject this axiom means believing that knowledge requires no proof, making it impossible to determine what is and isn't true. Even this argument,

known as the Munchausen Trilemma, falls victim to itself, demonstrating the difficult—if not impossible—nature of proving we know anything.

Clearly, both observations and claims of knowledge are dubious ground. Unfortunately, there is no one size fits all solution to answer the questions

“what do we know” and “how do we know it”. Instead, scientists and engineers need to be able to engage with the epistemological underpinnings of science and decide for themselves what constitutes a satisfactory proof, and what observations can be trusted. The only way forward for science is through epistemology. As such, we need philosophical-scientists who understand what constitutes knowledge, and can integrate it into their scientific work. One such philosophical-scientist is a PhD candidate in material science at the University of Colorado Boulder named John Rynk. In addition to his work in polymer physics, he enjoys woodworking and philosophy. When asked about philosophy's place in science, he responded with his motto, “The most important part of research is having strong epistemological foundations.” In and outside of his research he lives by that statement, contemplating what we know and how we know it, and integrating philosophic thought into his scientific work.

John serves as a model for how science can be done philosophically. Instead of taking observation at face value or accepting dogma and axioms, he integrates philosophic inquiry into polymer science, questioning the why and how behind every experiment. Furthermore, John consistently invites criticism of his work, being constantly open to novel ideas based on new evidence and reasoning.

Scientists and engineers need to be more philosophically inclined like John Rynk. We all need to work on putting epistemology before ego, and being open to new ideas and theories. Only through change are we able to grow, and for science to grow, it must become more focused on epistemology. It is high time that scientists and engineers began thinking more deeply about our disciplines and our knowledge. Otherwise, we doom ourselves to repeat history as articulated by famous physicist Max Planck “A new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die, and a new generation grows up that is familiar with it.”

SURGICAL SMOKE

Shreeya Roy

When considering the risks of surgery, we think of the dangers that the patient faces. However, there are risks to the surgeon as well. And not just the psychological stress of being in control of another human life. There is another lesser known risk about operating: the smoke risk. According to the Center for Disease Control and Prevention, when electro-surgical tools are used, they produce smoke. Commonly termed “surgical smoke”, Tomita et. al. found that “the mutagenic potency observed was comparable to that of cigarette smoke. The amount of these smoke condensates from 1 g of tissue was equivalent to those from 3-6 cigarettes as to total mutagenicity.”

Surgical smoke largely consists of water vapour, but also contains particles that can cause harm to anyone who inhales the smoke. Small particles can deposit themselves in the walls of the nose and trachea. Even smaller particles can deposit themselves in the lungs causing inflammation. Surgical smoke contains dozens of chemical compounds including benzene, toluene, hydrogen cyanide, and methane, and carbon monoxide. These particles can have detrimental effects including binding to hemoglobin, potentially leading to hypoxia, a reduction in the amount of oxygen available to tissues.

Surgical smoke can also contain viable pathogens. It was found that anti-



gens from the Hepatitis B virus were found in smoke when the patient had small amounts of the antigens in their blood. While the infecting potential for the Hepatitis B virus via smoke is unknown, the fact that pathogenic particles can also spread via smoke does not bode well. Human Papillomavirus (HPV) DNA has also been identified in certain types of surgical smoke. Surgical smoke can also cause fog and block clear vision in the OR.

To combat this problem, companies such as Medtronic have developed smoke evacuation systems which utilize suction and ventilation to remove surgical smoke. Recent developments have led to quick removal of smoke (under 30 seconds to remove a majority of the smoke), and large volumes of smoke that can be cleared. According to Gioutsos et. al, smoke evacuation systems today are highly efficient, with some reaching up to a 95% clearance rate. Smoke evacuation systems are able to remove a large amount of smoke particles through filtration technologies like HEPA (high efficiency particulate air) and ULPA (ultra-low penetration air) filters. Designs were guided by studies performed by researchers, engineers, and scientists.

One such study is Kumar et. al, which studied the fluid flow of the surgical smoke. They analyzed the Lagrangian Coherent Structures found in surgical smoke patterns, and utilized computational fluid dynamics models to analyze velocity fields, and outlet flow rates. Researchers also found that the finite time Lyapunov exponent (FTLE) fields can also be used to inform efficiency of surgical smoke removal systems.

Unfortunately, according to a survey by AORN, 94% of facilities in Virginia had smoke evacuation technologies, but only 26% of participants reported usage during smoke generating procedures. Despite the reduction in risks when using a smoke evacuation system, only 17 states mandate the use of smoke evacuation systems during surgical procedures. This means that there are surgeons and patients across the United States who may be inhaling toxic smoke every day. The dangers of surgical smoke affect patients and surgeons. Surgical smoke is more than a hassle- it's a hazard. Although smoke evacuation systems are widespread, their use is limited. To ensure safety, eliminating surgical smoke should be a priority for hospitals, policymakers, and surgeons.



THE STORY BEHIND SIMPLE MECHANISMS

Nic Ferraro

Have you ever stopped to think about the little things that make your daily life easier? Everyday tools, devices, and transportation mechanisms play a huge role in simplifying tasks. We can become accustomed to these tools so much that we go through life without noticing them. For instance, the mechanism of a bus door is designed to stay out of the way of passengers and you hardly notice the complexities of its motion while you step through the doors. What is the story behind these engineers who create these useful items? It's easy to see the end product that these engineers create but what is not always apparent is the determination they've had during their career. We often think all engineers are exceptionally smart and talented and that is the driving force to develop designs like these. While this may be true for many engineers, hard work and a love for problem solving are just as, if not more, important.

I thought about all of these things as I stepped toward the mechanical folding doors on the boxy orange bus and scanned my card. I looked at the first open seat I could find and plopped down in it. Settling into my seat, I



A Boulder HOP bus in motion—its automated folding doors a prime example of simple mechanical systems in everyday use.

notice how swiftly and effortlessly the doors folded shut again. I immediately looked at the components of the doors through engineering eyes, realizing they were a complicated system. The team that designed the assembly was tasked with developing a hasty door opening/closing action that doesn't take up too much space. Secondly, the movement operation of the door must've been scoured for mistakes and tested in real life. The engineers likely wouldn't want to create a door that breaks, falls, and hits somebody. The hardest thing for me to imagine was how the doors could've got from an idea on paper into something I'm actually seeing in real life.

As the bus drove along, I thought about what kind of qualities the door engineers might possess. It would be easy to assume these creators are geniuses, but much like you and I, engineers are also people. Often, they're people who repeatedly ask questions. After iteration of design,

they implement it into products in our world. As the bus halted and the doors folded to the side I got out and began walking to Target on the brisk fall day. While walking, I wondered, "Is being smart the only thing that led the engineers to be able to create those doors?" Throughout my first year of college I've relied on more than my intelligence to succeed. Specifically, if I relied only on intellect, then it would be difficult to find the drive to learn new material. The inspiration I have to learn and problem-solve motivates me to complete my schoolwork. Based on my experience it seems more likely that the team made a proficient door because of their dedicated time and love for the project.

While understanding design concepts and math is essential for any engineer, loving what you do is the true motivation for pursuing work. Tenured Professor at CU Boulder for Mechanical Engineering, Todd Murray told me about his passion for material science. "If the

“WHEN YOU’RE INTERESTED YOU PUT MORE TIME INTO IT AND LEARNING ISN’T SEEN AS A BURDEN.”

topic interests you then it doesn’t have to be hard. When you’re interested you put more time into it and learning isn’t seen as a burden.” He went on to explain his perspective that instead of going home and watching a tv show maybe he’ll read a new research paper pertaining to what he’s studying at the time. Looking through the eyes of Murray, engineering can be seen as something you can dedicate time to naturally. For example, after a big project you would be content with your work and keep going back to learn more. We often think that the driving force behind success in an engineering role is skill, but what truly spurs a career forward is a love for what you do.

You can pursue what you love while also using certain qualities that aid you along the way. Problem solving and optimizing play a role in the daily life of an engineer. I didn’t realize this until I failed my first Calculus exam at CU. After I had gotten the results back, I felt disappointed. But then I began asking questions and adjusting. To start, I made fewer commitments, freeing up time for sleep; sometimes, doing less is more. Next, I was intentional with my study time, attending office hours and not being distracted while there. These changes enabled me to produce a better score on the second exam.

It’s not always easy to implement changes into your way of life. Just like any subject can push you, I was challenged in my Calculus class. By looking at my problems in a structured way I was able to adapt and improve them. Although learning can be tricky and even though you will struggle, almost everyone has overcome hurdles in their life with a methodical- problem solving approach.

Pairing perseverance with the love you have for a particular subject helps you achieve goals. Take Sophomore at CU, Angel Zarco for example. He had thought about studying Architectural Engineering before deciding on Archi-

tecture. Much like Prof. Murray, Angel has always cherished his work. Whether it be expressing his creativity at a young age with legos. Or by designing a real life product at his workplace, Angel has always had a love for architectural design. The decision against engineering came down to the coursework. “It just seemed like I would always doubt myself in math classes and mess something up. Whereas architecture always came naturally to me.” After an assessment of his skills he realized it’s best to stick with something he could see himself doing in the future.

It can be helpful to have a personal reason for why you’re working toward a goal. Angel chose architecture because it was something that he truly loves learning about. Just because you choose to study a topic that inspires you doesn’t mean you won’t face challenges along the way. Having a destination in mind that you’re striving for will help you during momentary challenges.

When you come up against a difficult task you can take a step back, viewing it holistically. Becoming an engineer takes dedication of time and effort to learn. When you find yourself in a moment of stress, take a step back, think about why you’re doing this and realize you won’t always feel this way. Remembering your intention and being determined to reach it will help you succeed, especially in the structured realm of engineering.

The practice of engineering forms you to its standards. There is little to no bending of rules, opinions, or bias in engineering of any type. The straightforward rules are what may draw so many to study it. There’s also something to be learned about these rules, you have to obey them. It isn’t just about intelligence—it’s about problem-solving and a willingness to

adapt when things don’t go as planned. Whether designing a bus door, or even adjusting study habits to improve a Calculus score, success comes from learning, refining, and most importantly persevering through it all.

The engineers behind everyday innovations didn’t wake up with the knowledge to create. Instead they repeatedly experimented, failed, adjusted, and kept going. In many ways, we all embody that same process in our own lives, adjusting to challenges and finding better ways to move forward. So, the next time I step through a set of folding doors or use any well-designed tool, I’ll remember the love engineers have for their products and consumers. By giving us tools throughout our day we are more able to do good in the world. What’s something you could take a small -planned- action toward to improve your daily routine?



THE GREEN FUTURE OF MEDICINE

Aidan Magruder

For many centuries of human existence, we have relied on nature for our medicines. It was not until the late industrial revolution and the advent of synthetic chemistry that we began to synthesise key compounds that became the foundation of early pharmaceutical treatments. Despite the synthetic nature of many early pharmaceuticals, they often were compounds that had been extracted and isolated from plants. Some of the most prolific and life-saving pharmaceuticals have been derived from plants and other organisms. Aspirin, a drug used to reduce heart diseases and strokes, was first extracted from willow bark and subsequently synthesized years later. The opium poppy was the biological basis for medicines like morphine and codeine. Quinine, a compound used to treat malaria, was extracted from a plant and later synthesized. The process of synthesis from compounds extracted from plants has provided a pathway for pharmaceutical development. In the 1980s, major breakthroughs in genetic engineering made waves throughout the pharmaceutical space. These developments beg the question: Can we use plants to make hard-to-synthesize drugs? This is the million dollar question and thanks to developments in the field of bioengineering, the answer is yes!

“PLANTS MAY BE THE FUTURE, HEALING US AND THE PLANET THROUGH THEIR INCREDIBLE ABILITIES.”



Propagation techniques are key for scaling genetically modified plants for pharmaceutical use.

The process of making these kinds of plants, the ones that give us the compounds we need for pharmaceuticals is arduous. There are many obstacles to transfection, which is defined as the introduction of foreign DNA necessary for drug production, that have proven to be particularly challenging for this field's development. First, the plants that are used have to be especially susceptible to infection by an *Agrobacterium* (a type of bacterium that lives in soil) and the plants have to be able to have sufficient tissues from which you can harvest the drug. This issue has caused many scientists to begin using plants like wild tobacco. Tobacco is something that by any normal standard is objectively bad for human consumption. Despite this, through the transfection of foreign DNA into the plant, engineers can suppress the nicotine producing genes and express genes that produce the protein product or compound that is desired. Additionally, the process of transfection includes

infection which can kill the plant if the bacteria are not designed properly. Despite this challenge, with the right bacterial design and just a little bit of luck, transfection takes place. Luck might not be what you think of when you hear about engineering and science. After all, aren't scientists supposed to produce replicable results? But when working with living organisms, sometimes the process simply doesn't work and a scientist or engineer must try again. Once the process of transfection has been completed and the DNA has been successfully integrated, the next challenge is to successfully reproduce the plants and create a stable genetic line that expresses the products at an acceptable and cost-effective level.

This process of inserting the DNA, transfection, is critical but not always permanent. The DNA is in the plant, the plant has accepted it, and has begun to use it, but not every cell in the plant has the necessary DNA. This



A scientist scatters seed from genetically modified plants for use in propagation.

is when selective breeding comes into play. Selective breeding is the process by which organisms are bred to produce offspring with desirable traits, like how sheep are bred to have more wool. This technique has been used throughout the centuries to boost crop yield, create drought resistant or pligh resistant plants and to make the food we eat more nutritious. Similarly, when dealing with transfected organisms of any order, selective breeding is key to make sure that the plants will stably produce the desired compound even after several generations. This process, though long and challenging, has shown promise, especially in the field of cancer drug development. The adaptability of plants is what creates both the challenges of transfection and benefits of transfection. It is also what makes them key for creating drugs that are more accessible and less harmful for our planet.

The whole point of using plants to create drugs is to offer a sustainable and environmentally friendly way to make the drugs that today may only be available synthesized from harmful processes. An example of a drug derived from a harmful process is heparin. Heparin is an incredibly important glycan that is key in the formation of blood clots and is often used to treat patients after surgery to minimize risk of internal bleeding. This life-saving medication and compound is only widely available from pigs. The promise of plant-based heparin would save the lives of millions of people and animals around the world by making the drug cheaper and more accessible. The environmental impact is also incredibly important. Many pharmaceuticals and their development are toxic to the environment and produce trace levels of pollution and carbon emissions. Using

plants to make these medicines has a two-fold benefit: the first is that the plants do not expose the environment to toxic compounds, in fact plants are a main component of heavy metal and toxin cleanups, the second is that the plants actively use carbon dioxide and remove it from the atmosphere to create the compounds we desire. But this takes effort and while this field is promising it hasn't expanded into the corporate world.

A roadblock is the lack of consistent and regularly producing genetically engineered plants. There are not a huge number of scientists working on the design and development of these plants let alone engineers to build and design proper facilities for processing or growing the plants. This field is still new, while most research into plants involves creating better, more resilient plants for food and for ecosystems, it is not focused on the pharmaceutical potential of said plants. But this does not mean there is not a future for the field. In 2012 the FDA approved a plant-cell based treatment for Gaucher's disease, a disorder in which lipids build up in cells and cause damage. This medication is made using recombinant carrot cells in a bioreactor which produce the key protein needed to treat the disease. This is a key example of what a plant based medicine can look like. Whether grown in a field or in a bioreactor, plants can produce life saving compounds that find their way into the hands of the people that need them. Our medicine has historically relied on plants and what they provide and with advances in genetic engineering, they are now becoming powerful tools for the production of the drugs that matter the most to us. While the process is long, tedious, and often takes much more effort than expected, the benefits of producing ethical, clean, and life-saving pharmaceuticals far outweighs the pitfalls. Synthesis was the breakthrough that led to the creation of modern medicine, but plants may be the future, healing us and the planet through their incredible abilities.

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