

ON THE SHOULDERS OF GIANTS

EQUILIBRIUM

Edition 5

2026



ISAAC NEWTON



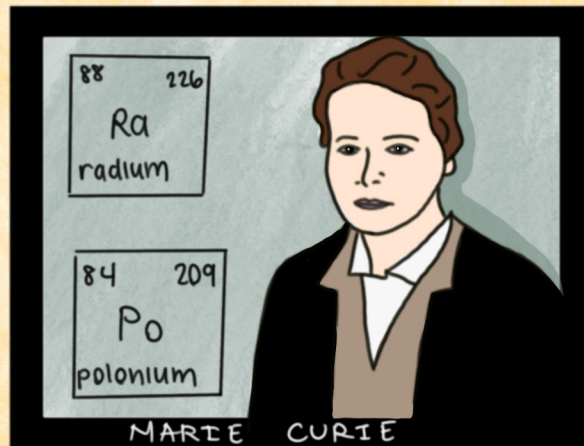
ROSALIND FRANKLIN



IBN AL-HAYTHAM



PYTHAGORAS



MARIE CURIE



JANE GOODALL



Science & Art Magazine

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Letter from the Editors

Alexander Ford, Jessica Li, and Julia Kravchenko

Progress appears in bursts. The philosopher Thomas Kuhn, in his book *The Structure of Scientific Revolutions*, has called these events ‘paradigm shifts’ – that moment when the world tilts on its axis and we see things in a new light. It is the moment when Darwinian evolution replaces Lamarckism. When the idea of microorganisms called ‘germs’ replaces miasmas. When atoms are split, vaccines eradicate smallpox, when the first cloth wings dance in the sky above Kitty Hawk Field. It is also when nuclear blasts scour away entire cities, when engineered bioweapons breed in the virulent dark, when supersonic drones on metal wings home in on their targets a continent away. Science is how we humans expand our knowledge of cause and effect in the physical world, and how we create wonders and terrors, save lives and destroy them. It is – fundamentally – a framework upon which we never stop building upon and one that spirals out ever outwards into the future. However, despite the objective nature of such pursuits, this expansion is guided by regular humans, everyday people that choose to take up the mantle of scientific advancement and take on the legacy of all those who have come before. Holding each of those discoveries aloft are the contributions of countless smaller findings, countless stories that push the peaks of new discoveries ever higher through the motivations, morals, and personal journeys of the myriad people who contributed.

The title of this 5th Anniversary Edition is inspired by the famous quote by Isaac Newton in his 1675 letter,

“If I have seen further it is by standing on the shoulders of giants”,

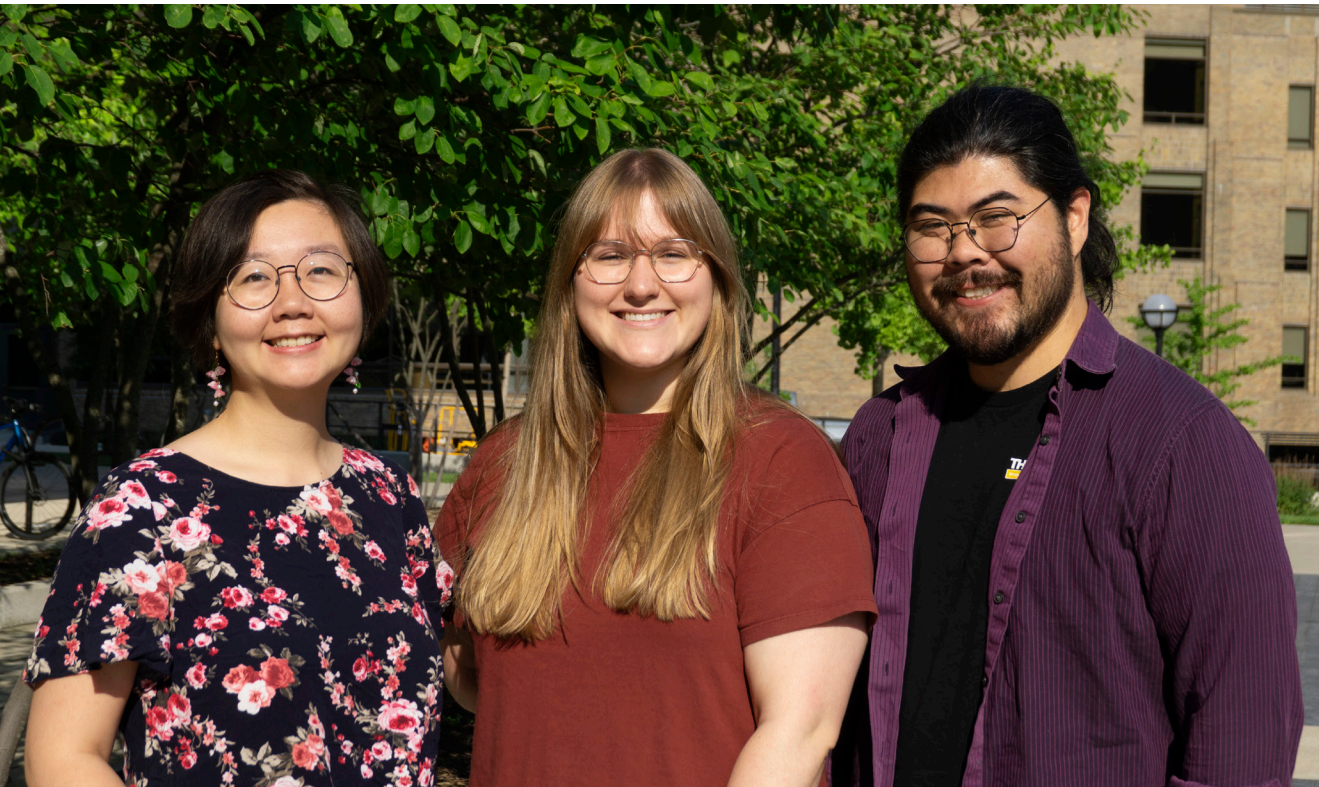
a metaphor for the great discoveries he himself had contributed to, from calculus to Newtonian physics, and how even these accomplishments are derived from a lineage of work stretching back to the ancient mathematicians. It emphasizes humility, and acknowledgement of the expansive roots of scientific advancement anchoring every discovery.

It is fitting that this quote itself rests upon older words – originating in the 12th century with the French philosopher Bernard of Chartres who wrote:

“We are like dwarfs perched on the shoulders of giants, so that we can see more than they, and things at a greater distance—not by virtue of any sharpness of sight on our part, or any physical height, but because we are carried high and raised up by their giant stature.”

But the idea of a “giant” goes far beyond the simple findings and pages of data collected. There are giants beneath every person who makes the choice to contribute to the body of knowledge. A giant is seen in the parent that worked three jobs to provide for their overly-curious child, the cheering crowds of the general public as the first lunar rocket launched, or even the colleagues and collaborators who bounce ideas off each other over coffee in the break-room. You may have heard the saying “it takes a village to raise a child”, and scientific discoveries are the precious children that take a veritable city to bring to fruition. In their own unique ways, all of these people and more bear the discoveries of the future on their shoulders.

So, within this edition, it is our great pleasure to share the science and stories that hold aloft the individuals and fields involved with scientific research. There are the great figures of science, Newton, Marie Curie, Pythagoras (*Portraits of Giants*), as well as ancient scholars who revolutionized their field (*Clearing the Optical Illusion*). There are scientists that study ancient diseases that are still plaguing humanity (*The Lysosome*), or describe how new models fold in the primordial building blocks of reality (*Building the Periodic Table*). Take a moment to look upon the portraits of scientists old and new (*What Does a Scientist Look Like*), and hear the personal connections to the familial foundations that make such work possible (*Where Scientific Lineage Begins*). Scientific lineages are observed in inkblots of



microscopic organisms (*Branching Through Time*), in the work of abolitionists like Harriet Tubman (*Cosmic Reparations*), and in the behemoths of entire nations (*On the Shoulders of Empire*). These are only the most infinitesimal fractions of the Atlas that holds up our world, but they are each and every one a part of us all.

The famous English poet John Donne perhaps said it best:,

“No man is an island, Entire of itself; Every man is a piece of the continent, A part of the main”

– and the institution of scientific discovery is no different in the reciprocal connections to the lives of nearly every human being who lives in modern society. The body of knowledge that the institution of science has produced over the thousands of years of human existence is a giant beneath you as well. It is in the MRI scanners, the cars on the road, the therapists and doctors and engineers; it is in the pre-natal incubators and the EMT helicopters, the hearing implants and artificial heart valves and glasses on your face. They underlie every purchase, every decision you make, and guide the policies and laws that shape the rules of modern life.

Scientific progress is a legacy gifted to all of humanity, and though it may remain still and silent as you stand upon its shoulders, know that it is *your* legacy as well. As we look ahead to the future, we encourage you to look down and remember that we all – in our own ways – are held aloft by giants of our own.

★ ★ ★

Alex Ford (right) is a PhD student and neuroscientist within the Department of Anesthesiology. He studies brain circuits that influence anesthesia and sleep states of consciousness. He has a tendency to seek out the adventurous and the absurd, and will often attempt to write creatively or create art. In his free time, he is with friends, family, or a good book under a tree.

Jessica Li (left) is a Ph.D. student in the Department of Microbiology & Immunology. They are interested in the hidden microbiology of the indoors, particularly in drinking water. In their free time, they enjoy making art of many kinds, from digital illustration to carefully tangled yarn, and aim to make science more engaging through these creations.

Julia Kravchenko (middle) is a neuroscience graduate student studying the relationship between sleep and Alzheimer’s disease. She is passionate about making academia accessible to the general public. Outside the lab she can be found reading fantasy novels amidst her growing collection of gnomes.

Photography by Paola Isabel Medina-Cabrera

Clearing the Optical Illusion:

How a Muslim Polymath Redefined How We See

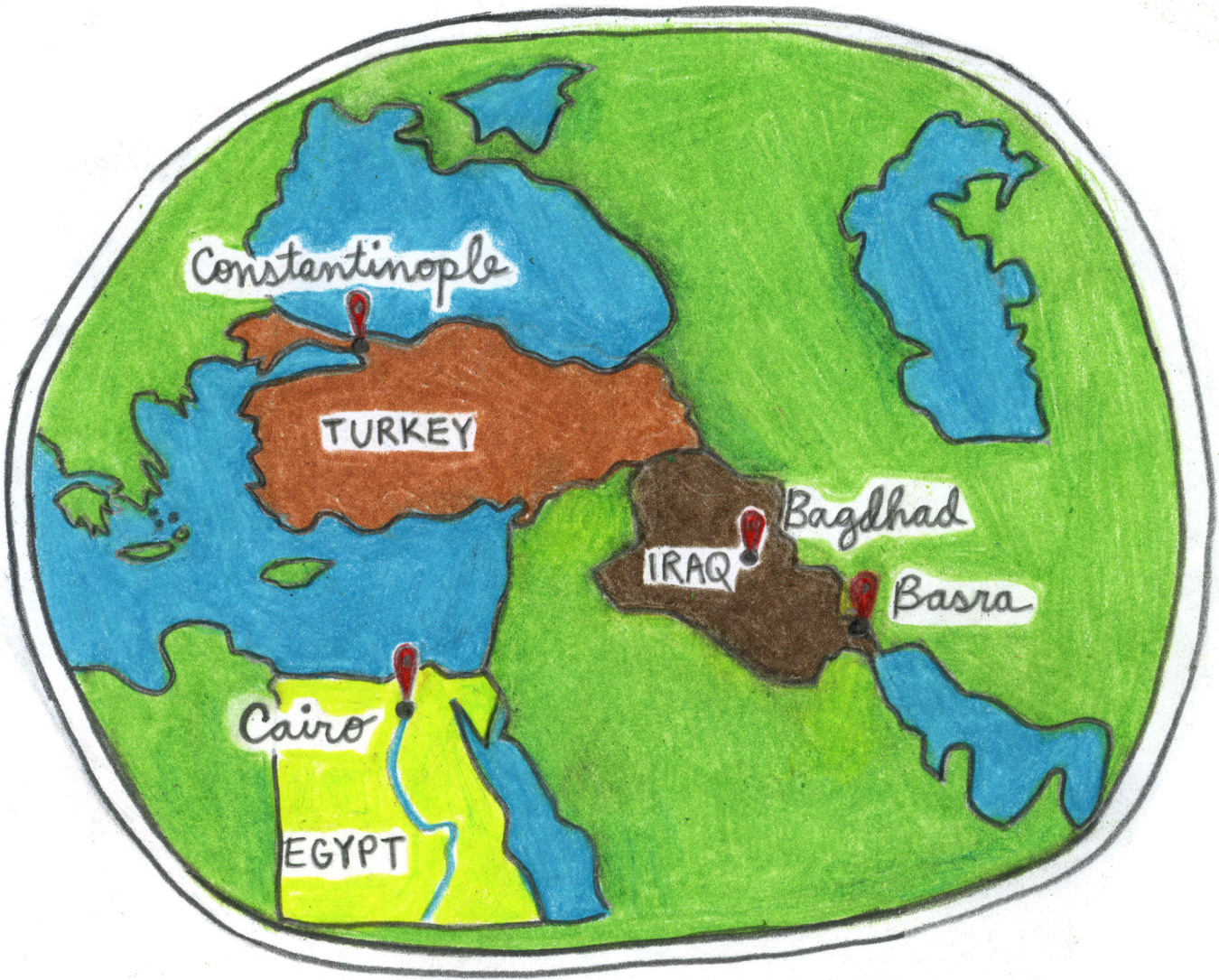
Hy Do

Five hundred years before the Renaissance, a Muslim polymath shattered the paradigm of optics while practicing elements of what we now call the scientific method. In 1021, Ibn al-Haytham, Latinized as Alhazen, completed his magnum opus, the Book of Optics, a seven-volume treatise with a revolutionary claim:

Vision occurs because light falls into the eye, not out of it.¹

Throughout human history, the eye has been the subject of imagination and inquiry, as well as an enduring symbol in diverse cultures. To the ancient Egyptians, the Eye of Horus symbolizes protection.² Amulets against the evil eye have been found in many cultures dating thousands of years ago.³ Interests in the eye naturally led to vision: how humans perceive the physical world. In the West, multiple theories of vision abounded. The emission

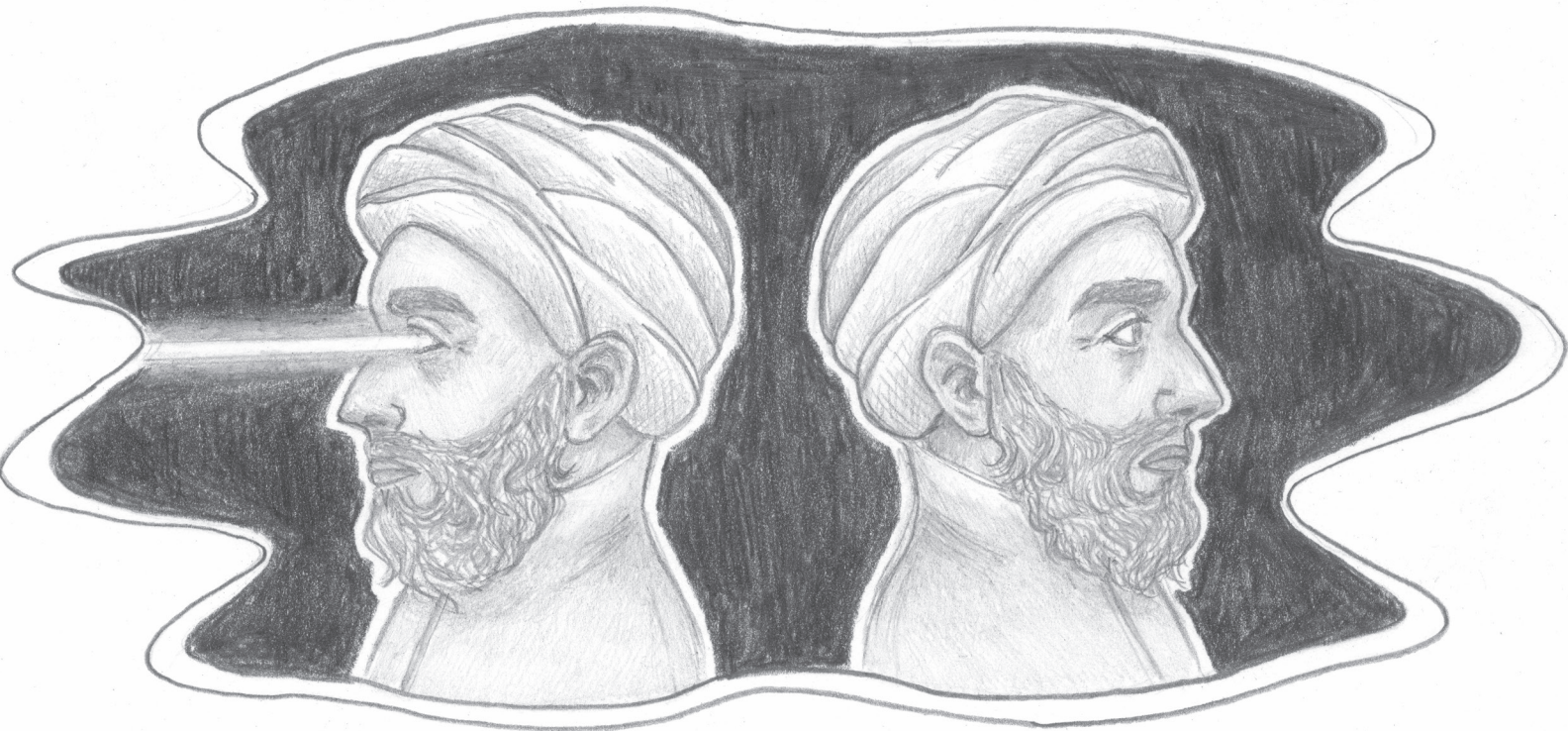
theory, advanced by ancient Greek philosophers such as Empedocles, Plato, and Galen, stated that the eye emits beams of light to produce sight.⁴ While this may seem counterintuitive in hindsight, the emission theory might actually be a commonly-held belief. As recently as 1996, a study found that when participants were asked to draw whether something comes in or out of the eyes when a person sees a balloon, 69% of adult participants drew arrows pointing *out* from the eyes.⁵



Ibn al-Haytham was versed in this intellectual tradition. Hailing from Basra,⁶ in present-day Iraq, he conducted his work during the Islamic Golden Age, a period of intellectual and cultural flourishing across the Islamic world.⁷ During this era, many scientific and philosophical works of classical antiquity, including those by Plato, Euclid, and Ptolemy, were translated from Greek into Arabic and Syriac in major centers of learning such as the House of Wisdom in Baghdad and Cairo.⁸ Ibn al-Haytham moved to Cairo and lived near Al-Azhar, one of the oldest and most prestigious institutions of Islamic education.⁶ It is easy to imagine Ibn al-Haytham consulting Euclid's or Ptolemy's *Optics* as he investigated the mechanisms of vision. Ibn al-Haytham was an extremely productive scholar, authoring more than 200 works, at least fourteen on optics. He was hardly alone in his

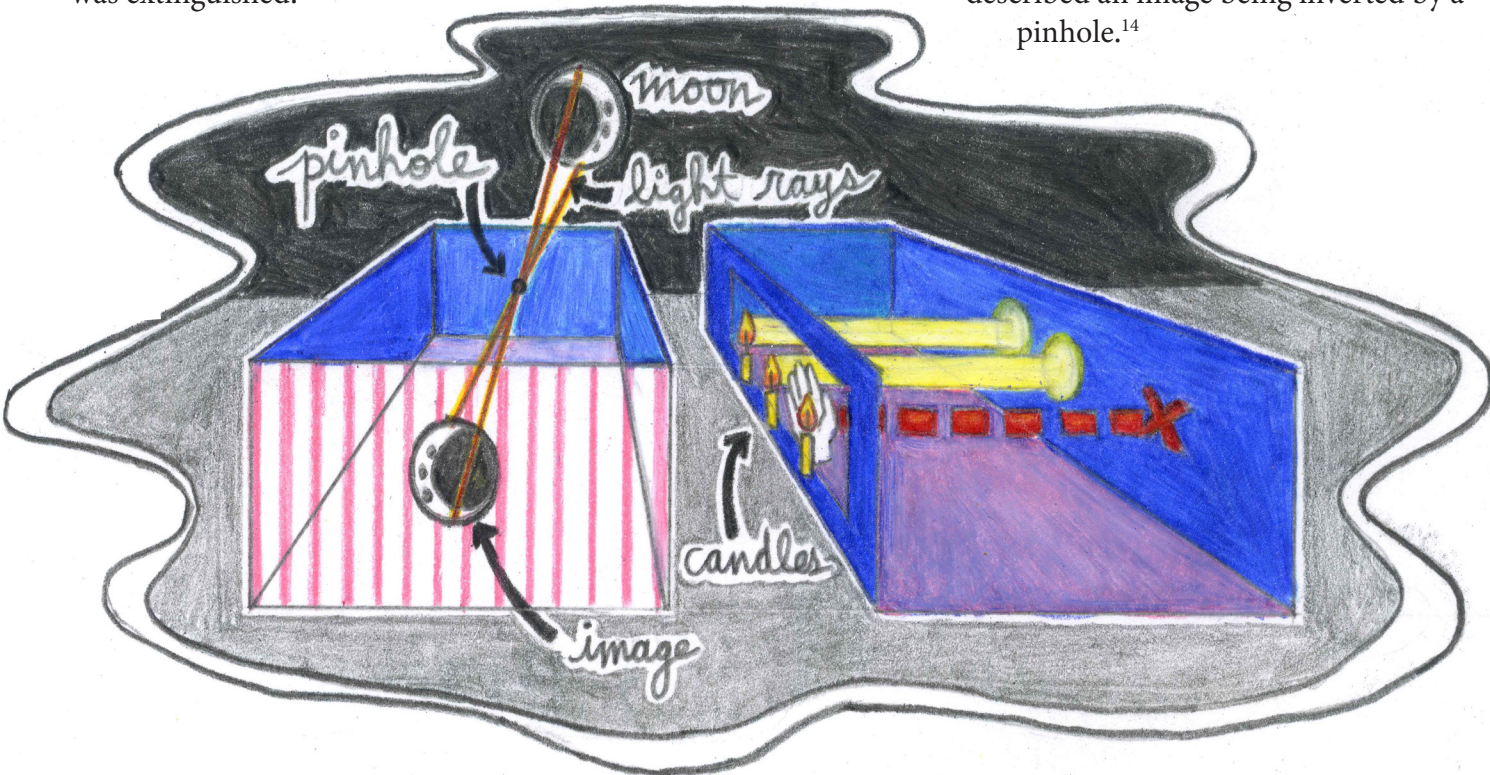
brilliance; his contemporaries included Ibn Sina, the author of *The Canon of Medicine*,⁹ which remained a standard textbook in European universities until the early modern period, and al-Biruni, who penned encyclopedias on Indian culture.¹⁰

The *Book of Optics* presented empirical evidence in support of the intromission theory of vision, which states that vision is produced when light enters the eye.¹¹ Ibn al-Haytham argued that if rays come out of the eyes as the emission theory claimed, then the eyes should not be damaged by those rays. Yet no one can stare directly at the sun for more than a few seconds without sustaining extensive eye damage. He concluded that objects themselves emit or reflect light in all directions and that only the light beams entering the eyes produce vision.⁶



A corollary of the intromission theory, Ibn al-Haytham argued, is that light travels in straight lines. Since humans see objects with defined shape, he proposed that each point on an object corresponds to a single point in the eye. In an experiment, he set up candles in front of a wall with a window that opens to a dark room. When he blocked one candle, only the light opposite that candle along a straight line through the window was extinguished.¹²

This phenomenon is called a camera obscura, which is produced when light passes through a small hole of a dark chamber.¹³ The hole restricts the paths that light can take. For example, moonlight from the top of the Moon passing through a pinhole will appear at the bottom of the image. However, Ibn al-Haytham was not the first person to describe a camera obscura; in the *Mozi*, a text from the 5th-3rd century BCE, the Chinese philosopher Mozi had described an image being inverted by a pinhole.¹⁴



The shifting tides of science brought Ibn al-Haytham's works to a wider audience in Europe. The *Book of Optics* was first translated into Latin in the late 12th to early 13th century.¹⁵ By this time, scientific activity in parts of the Islamic world had begun to decline due to a combination of factors, including the Mongol invasion of the Abbasid Caliphate, destruction of centers of learning like the House of Wisdom, conservative backlash against rationalist thinking, and political fragmentation and instability leading to loss of patronage for science and the arts.¹⁶ In 1453, the Ottoman Empire captured Constantinople, resulting in an exodus of scholars carrying Arabic, Greek, and Latin works to Western Europe.¹⁷

The *Book of Optics* influenced diverse fields such as art, astronomy, and philosophy.

Many luminaries of the Renaissance and Scientific Revolution had access to the *Book of Optics*, including Leonardo da Vinci,¹⁸ Galileo Galilei, René Descartes,¹⁹ and Johannes Kepler.²⁰ Leonardo originally subscribed to the emission theory of vision, writing in his notebook that "the eye transmits through the atmosphere its own image to all the objects that are in front of it and receives them into itself."²¹ By 1492, however, Leonardo began to accept the intromission theory of vision as argued by Ibn al-Haytham and other scholars.²¹ Leonardo's thinking can be seen in his paintings, which demonstrate complex representations of light and shadow. *The Last Supper*, one of Leonardo's most famous works, showcases his understanding of vision: Jesus's right cheek is placed on the vanishing point of the painting, directing the viewer's attention toward him. Kepler built his studies based on some of Ibn al-Haytham's ideas such as the

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one-to-one correspondence between points on the object and points in the eye.²⁰ Kepler demonstrated that the eye functioned as a camera obscura *itself* because every image must be inverted on the retina, much like the candles in Ibn al-Haytham's experiment.²²

Ibn al-Haytham died in 1040, but his legacy continues into the 3rd millennium. His work on refraction and lenses contributed to the development of the telescope and microscope.²³ In 1935, an impact crater on the Moon was named Alhazen.²⁴ In 2015, the UN International Year of Light celebrated Ibn al-Haytham's works to optics.²⁵ In 2021, researchers published novel solutions to Alhazen's problem, which Ibn al-Haytham formulated concerning reflection in a spherical mirror based on Ptolemy's works.²⁶

Arguably, the focal point of his legacy is not any particular work or his empirical approach to science, but the insight that scientists are not infallible and that doubt is the only measure of truth. In *Doubts concerning Ptolemy*, where he critiqued Ptolemy's astronomy, Ibn al-Haytham admonishes those who toil for discovery thus:²⁷

My name is Hy Do and I am a rising 3rd year graduate student in Dr. Lois Weisman's lab. My thesis project focuses on the regulation on myosin V motor transport using *Saccharomyces cerevisiae* as a model organism. I come from Vietnam. In my free time, I enjoy reading, jogging, and other outdoor activities.

Edited by Lauren Heinzinger and Naomi Raicu
Artwork by Naomi Raicu

The Lysosome:

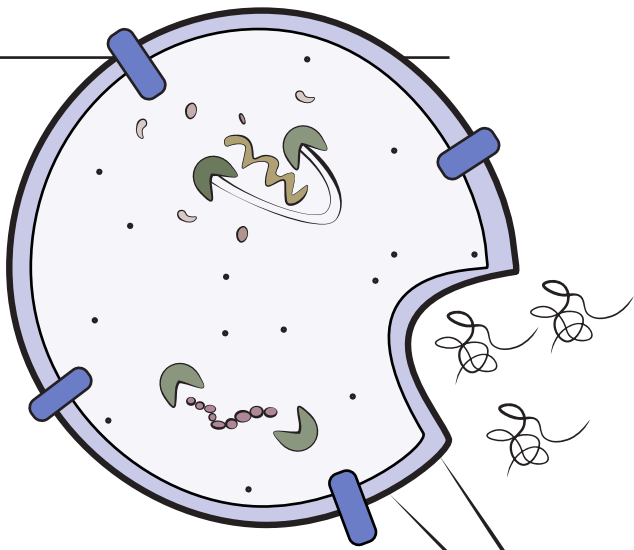
A Missing Puzzle Piece in Understanding Dementia

Kaitrin Freeland

Today feels wrong, but I don't know why. All day long the air has been heavy, suffocating. I feel like I can't breathe. Something is looming, the tension keeps building, and I swear my heart rate keeps increasing.

The phone rings, my father answers, and I can hear my grandpa's voice on the other side. Did my heart just stop? My father lifts his eyes to us, and we know - he doesn't have to say what has happened. He hangs up as tears roll down his face and his head drops into his hands.

The struggle is finally over. Dementia claimed my beloved grandmother.



Maybe my story about my grandmother sounds familiar to you. If it does, you aren't alone. Dementia is a common set of conditions that many families endure. Neurodegenerative diseases that cause neurological decline in old age lead to a range of symptoms classified under the umbrella term "dementia." These symptoms primarily impact cognitive skills, like short-term memory or reasoning, and eventually impair independent function and behavior.¹ It is estimated that 42% of Americans eventually develop dementia, accounting for more than 100,000 deaths each year, or about 11 deaths every hour, in the United States.²

Despite the high number of cases, researchers and doctors still do not fully understand these conditions. The unfortunate reality about these diseases is that

dementia symptoms look different in every patient, making diagnosis and treatment difficult.³ The progression of these conditions in our loved ones can be so slow that a drastic decline in their quality of life is required for friends and family to notice. Currently, all that can be done for dementia patients is to treat the symptoms since there is no cure.

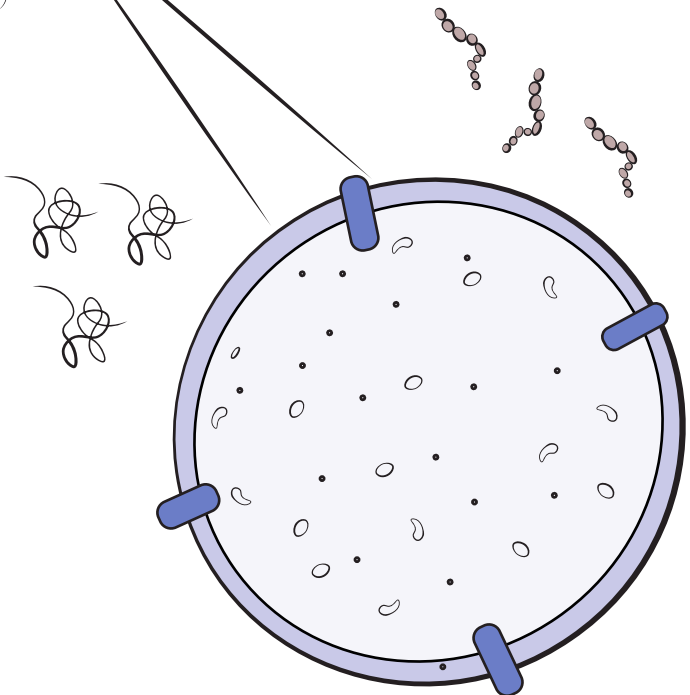
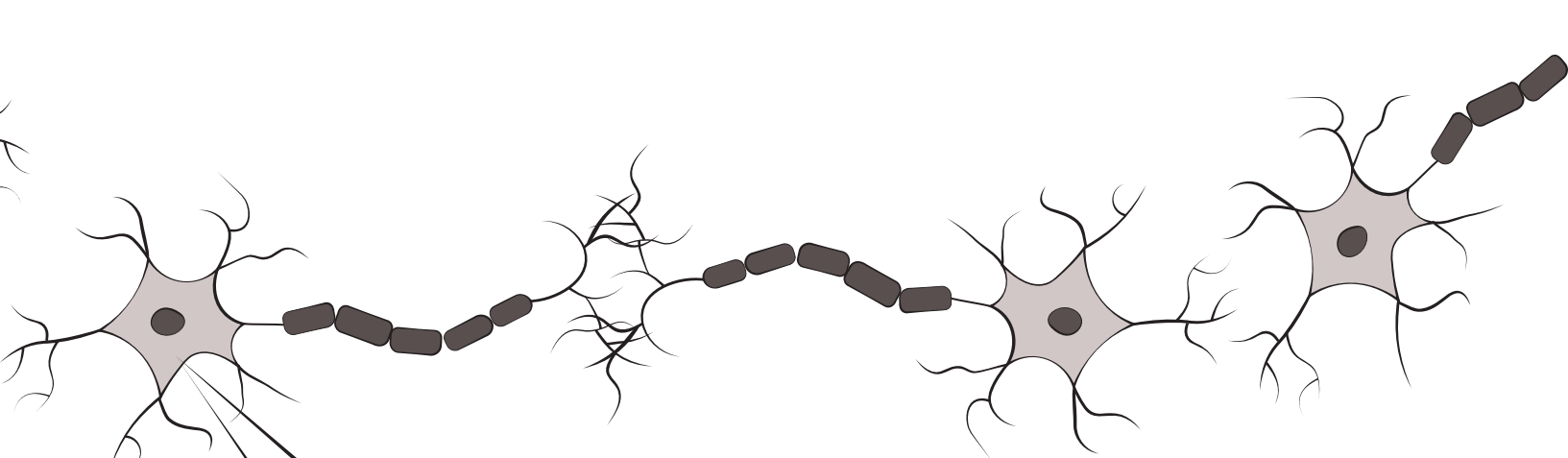
However, there is a new hope for dementia patients. That hope begins with an organelle that has previously been overlooked: the lysosome. While many of its mysteries remain unsolved, researchers understand so much more since this organelle's discovery, leading to potential therapeutic options for patients. The lysosome is now understood to be directly linked to neurodegenerative diseases, such as Parkinson's Disease and Alzheimer's.³⁻⁶

Christian de Duve began unraveling these mysteries when he officially discovered the lysosome 71 years ago. In 1955, de Duve and his team identified something that had never been seen before: "small acidic sacs" within the cell - organelles, containing acidic environments.^{7,8} This was groundbreaking because researchers at the time weren't looking for such small organelles in cells. His team was instead mostly focused on things like mitochondria and other cellular components.^{7,8}

Originally, de Duve was interested in studying carbohydrate metabolism, which is the breakdown of sugars to be used as energy in our bodies. His team wanted to examine the enzymes responsible for this mechanism in cells, particularly where those enzymes are located. To do so, his team used cellular fractionation, a technique that rapidly spins samples to separate cellular components by their densities and isolate specific biomolecules.⁷ The team's technique was novel compared to other procedures because

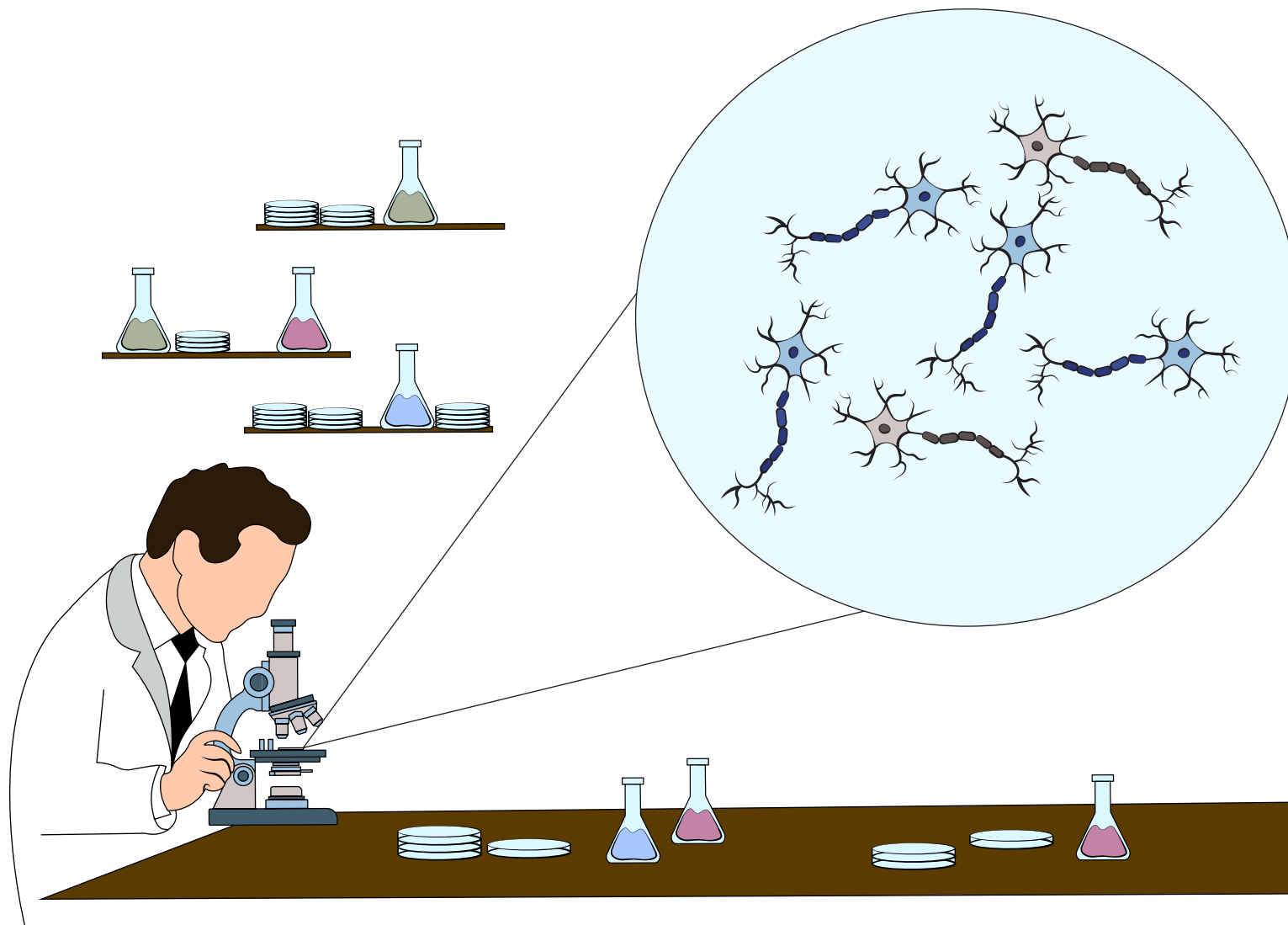
it was gentle on cellular samples, allowing them to separate small biomolecules.⁷ By doing so, they found that these "sacs" contained enzymes responsible for breaking down, or "lysing", cellular components. Thus, de Duve aptly named his newly discovered organelle the 'lysosome',⁸ which he would go on to dedicate his life's research to, setting the stage for the lysosome field that is known today. His discovery won him the Nobel Prize for Physiology or Medicine in 1974.⁷

Between the 1960s and 70s excitement around this organelle led to the identification of several genetic diseases that are directly related to the integrity of lysosomes,⁹ such as Niemann Pick disease and Fabry disease.¹⁰ By the 1980s, the focus of lysosomal research began to shift - scientists expanded their studies to cellular pathways that involved the lysosome for cellular digestion.⁹ Technology at the time wasn't advanced enough to uncover further information about the lysosome itself. However, de Duve still had



a vision for its therapeutic potential and remarked that there was more to be appreciated about this organelle.⁹ The early 2000s saw a resurgence of interest in the lysosome itself and a lot more is now understood about this organelle and its implications in neurodegeneration.¹¹ So, de Duve was correct in his hypothesis that the lysosome is far more important than meets the eye. Researchers continue to work diligently to uncover its secrets.

To understand how lysosomes connect to dementia, it's important to appreciate their function inside cells. Simplistically, think of the lysosome as the "stomach" of your cells.



When you eat, your stomach digests food into smaller parts that can be used by your cells. Anything that cannot be used is converted to waste and is removed from your body. Nutrients arrive at your cells and are used to carry out important functions like powering your muscles to walk or stand. During this process, your cells create things they need to thrive and naturally identify anything that's old or damaged. This is where lysosomes come in. Lysosomes break down and digest old cellular components, such as damaged organelles or long-lived proteins, like your stomach digests food.⁶ Once digested, some parts can be reused by the cell or excreted as waste. This makes the lysosome a major metabolic hub of your cells and integral to cellular and overall human health.^{10,12}

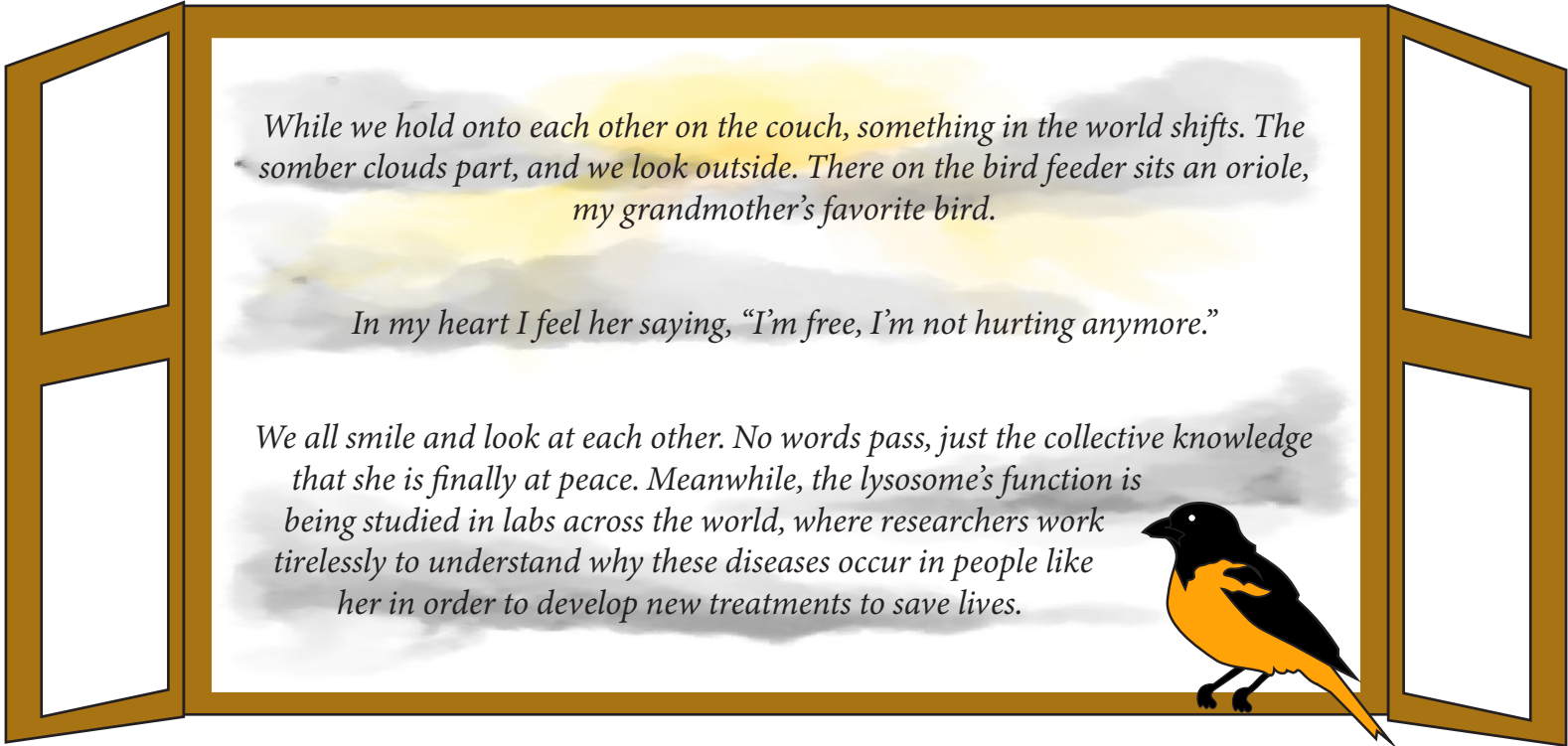
Researchers are learning more about the importance of lysosome stability and its implications in the health of the human brain. My grandmother suffered from Lewy Body dementia, which is a term that describes dementia symptoms caused by Parkinson's disease and accumulation of Lewy Bodies in the brain.¹³

Both are characterized by the presence of dense protein deposits in neuronal cells, mainly composed of a protein called alpha synuclein (α Syn), which can be thought of as a sticky ball inside cells. This is often attributed to a specific gene or set of genes no longer being able to maintain lysosomal health in old age. Lysosomes are key for removing these proteins that are dysfunctional in neurodegenerative diseases. In this case, α Syn aggregates instead of being degraded properly.⁴⁻⁶ These sticky masses with α Syn can trap other proteins and even grow and spread to other neurons, damaging lysosomes themselves, leading to cell death.⁴ As a result, not only are cells malfunctioning because of these aggregates, but they are also becoming sick and dying. Thus, the brain slowly degrades, leading to the impairment of motor function and memory, and eventual death of the patient.⁴⁻⁶

Lewy Body dementia and Parkinson's disease are not the only neurodegenerative diseases impacted by dysfunctional lysosomes in neuronal cells. Defects in

lysosomes and their associated pathways are also implicated in frontotemporal dementia (FTD), which is the most common cause of dementia, as well as amyotrophic lateral sclerosis (ALS or Lou Gehrig's disease).³ What's scary for researchers is that lysosome disruption can occur at many different stages in the cycle of lysosomal function, like waste degradation or how acidic they become. One underlying similarity in these neurological diseases is that the central nervous system is especially sensitive to lysosomal malfunction.³ This is why understanding basic principles about lysosomal function and maintenance, especially in neurons, is so important for medicinal applications. Since its discovery, researchers have considered using the lysosome as a candidate for therapeutic targeting and application.^{9,14} Several genes involved in lysosomal function, including C9orf72, TBK1,

OPTN, and p62, are currently considered targets in therapies for diseases like FTD and ALS.³ There are also ongoing clinical trials investigating therapeutics that would target specific types of Parkinson's disease. As novel technologies are developed to study lysosomes, additional biomarkers have been identified that can be targeted with therapies in the future.⁵ Currently, there are several therapeutic options for Parkinson's disease such as targeting dysfunctional lysosomal genes¹⁵ and reducing the production, aggregation, and spread of α Syn.¹² Some of these technologies and therapeutic approaches involve increasing lysosomal activity to target and degrade α Syn. Additionally, small molecule drugs can be used to block the aggregation of these protein deposits to stop their growth.¹⁶ There are also therapies that work to target genes that are involved in maintaining lysosomal health.¹⁷



While we hold onto each other on the couch, something in the world shifts. The somber clouds part, and we look outside. There on the bird feeder sits an oriole, my grandmother's favorite bird.

In my heart I feel her saying, "I'm free, I'm not hurting anymore."

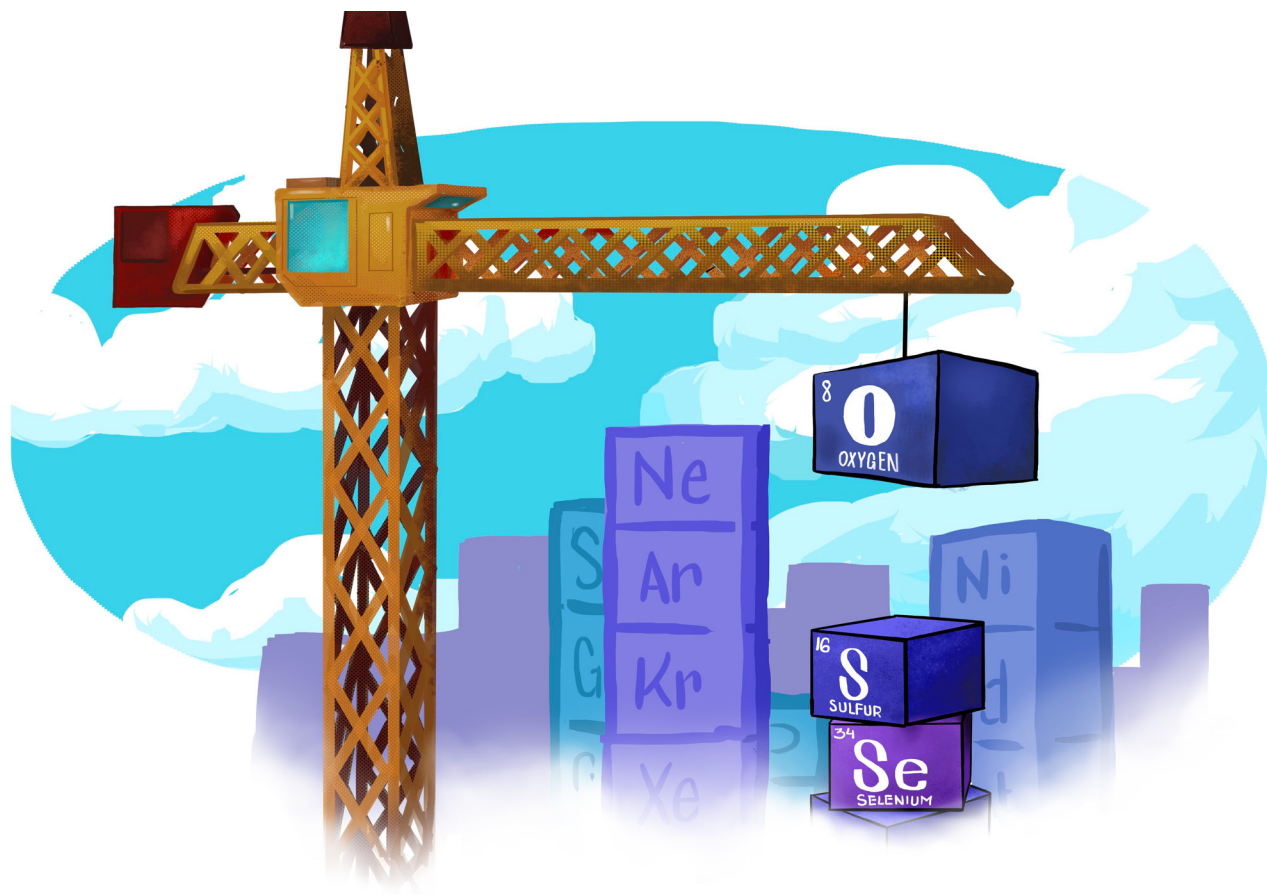
We all smile and look at each other. No words pass, just the collective knowledge that she is finally at peace. Meanwhile, the lysosome's function is being studied in labs across the world, where researchers work tirelessly to understand why these diseases occur in people like her in order to develop new treatments to save lives.

Kaitrin Freeland is a 3rd year PhD student in the Biological Chemistry department. In the lab, she uses fluorescence microscopy to study lysosomal repair mechanisms. Outside the lab she enjoys the outdoors, reading, and spending time with family and friends.

Edited by Emily Januck and Lauren Heinzinger
Artwork by Paola Isabel Medina-Cabrera

Building the Periodic Table

Camila Gonzalez Curbelo



Memorizing the periodic table of elements is undeniably one of the (slightly dreadful) science class rites of passage. Although most of us weren't expected to memorize the entire table, we had to learn enough of it to recognize what a few of the symbols meant. Growing up during the golden era of YouTube, I came to associate learning the elements with the iconic "The New Periodic Table Song" by AsapSCIENCE. The song consists of a rapid-fire list of the chemical elements in order, sung in an absurdly catchy melody. It is chaotic, distinctively nerdy, and unforgettable even a decade later.

Although I did enjoy singing along to the periodic table song as a student, I do remember wondering why we even had to memorize it when the chart was always with us in every science classroom. It's similar to how we also had to learn the multiplication tables despite always having access to calculators. I now see that memorizing the table was not without a purpose... It was about becoming familiar with the patterns and

relationships between all the elements. The more I have studied chemistry, the more I have grown to appreciate the periodic table as a collection of centuries of curiosity. It is a story built by many giants in chemistry, each contributing piece by piece to the chart I sang along to as a kid. Some of those scientists even walked the same university halls as many of us today.

The earliest giants behind the construction of the periodic table can be traced back to ancient Greece, around 300 BC, where philosophers tried to make sense of the world by pure observation.¹ They proposed that all matter in our universe was made of four elements: air, water, fire, and earth. I admit this classification does remind me of Avatar: The Last Airbender, but the simplicity was an admirable attempt to describe and categorize what makes up the world around us.

Fast forwarding to as early as the 8th century AD, early alchemists were discovering the first chemical

elements as we know them today.² Alchemists believed metals such as copper, lead, and iron could be turned into gold, which could be ingested as an elixir for immortality. While their goals were arguably not achievable, their labor still laid important groundwork. They developed early experimental practices to study how these metals would behave and transform, which shaped chemistry into a more methodological science. As more elements were discovered, alchemists became interested in organizing them in relationship to one another to create a useful tool for future scientists to use. Many elements could all appear similar at first glance as shiny metallic substances, yet behave very differently when exposed to air, heat, or water. For example, we now know that iron rusts readily through reactions with oxygen and moisture, while silver slowly tarnishes by reacting with sulfur-containing compounds in air. However, during the medieval period, alchemists did not yet understand the detailed chemistry behind these reactions. What they could observe was that iron corroded far more quickly than silver. Observations like these were enough to show that although both of these substances could be broadly classified as metals, grouping elements based on appearance alone was not sufficient.

A few centuries later, a broader question emerged: what actually counts as an element? A more defined unifying system was needed, and one was created in the late 1700s by Antoine Lavoisier,³ often known as the father of modern chemistry. He introduced a clearer definition in his book, *Elements of Chemistry*, published in 1789. There, he described an element as a basic substance that cannot be broken down into anything simpler by any chemical means. Interestingly, the same book also helped popularize another pivotal scientific concept: the law of conservation of mass, which is the idea that matter cannot be created or destroyed during a chemical reaction. No matter how hard you try, you cannot take an element apart into something more fundamental. This concept may seem obvious to us now, but it brought much-needed structure to a field that was not yet well defined.

Throughout the 1800s, scientists continued to organize elements according to their chemical properties. Some of the more widely recognized scientists in piecing the puzzle together include John Dalton,⁴ who arranged elements based on their atomic weight*, and Johann Wolfgang Döbereiner, who instead focused on the shared chemical behaviors between elements. Döbereiner noticed that some elements with comparable properties could be arranged into groups of three, which he called "triads."⁵ A notable example included lithium, sodium, and potassium, all of which react strongly with water. Döbereiner's triads were one of the earliest signs that elements could be organized into families.

By 1869, chemists had identified 63 elements,¹ which make up nearly half of the elements we see on the periodic table today. Around this time, a Russian chemist named Dmitri Mendeleev began arranging elements according to recurring physical and chemical properties,⁶ leading to what would become the first version of the modern periodic table.** Earlier scientists had already recognized similarities in how certain elements behaved chemically, but Mendeleev connected these repeating behaviors to trends in atomic weight.

The recurring, or "periodic," trends helped predict when certain expected behaviors were missing from the sequence.

Mendeleev was a true visionary. Rather than forcing his rendition of the table to appear complete, he intentionally left gaps where he believed undiscovered elements belonged. Gallium, scandium, and germanium were all found after Mendeleev published his table, and their properties closely matched his



*How heavy the atoms of an element weigh as compared to those of other elements.

**According to later accounts, Mendeleev's arrangement of the periodic table came to him in a dream after falling asleep at his desk. Upon waking, he immediately wrote it down, requiring only one later correction.¹¹

predictions. Big win for him. He even lived long enough to see some of those discoveries confirmed.

Unfortunately, other discoveries took much longer. One of the other gaps that Mendeelev anticipated lay between thorium and uranium. Filling that space turned out to be far more complicated, given some elements only exist for a very short time before transforming into something else. In 1913, Polish-Jewish chemist Kasimir Fajans identified a short-lived isotope*** of protactinium,⁷ the element which would eventually fill that gap. Because this element existed only briefly, he named it brevium, from the Latin word for “brief.” This particular form of protactinium decayed in just over a minute, making it extremely difficult to study.

What makes Fajans’ story especially inspiring is that he helped discover protactinium only a few years after earning his doctorate degree. Two decades later, by the early 1930s, Fajans had become the director of the Institute of Physical Chemistry in Munich, building an internationally recognized scientific career. In 1936, however, he left Germany as the political landscape under the Nazi regime became increasingly dangerous for Jewish academics like himself. Around this time, University of Michigan dean Edward Kraus invited Fajans via a telegram to continue his work in Michigan.⁸ Fajans accepted the invitation to relocate to Ann Arbor (Go Blue!), becoming a professor at U-M⁹ and spending more than twenty years contributing to the field of chemistry before retiring in 1957.



Despite the instability surrounding his early career, Fajans triumphed, and his work became part of how we understand the periodic table today.

At first glance, the periodic table can seem like a perfectly ordered progression, where elements have increasing mass when moving left to right, from one box to the next. In reality though, the modern periodic table is organized by atomic number****, rather than atomic mass. Interestingly, atomic number does not always correlate perfectly with atomic weight. Because of this, there are a few unusual cases where an element can appear after another

element despite being slightly lighter.

Protactinium [element 91] is one of those interesting exceptions. This rare, radioactive element appears after thorium [element 90] in the periodic table despite actually having a slightly lower atomic mass.

Similar examples are potassium

[element 19] and argon [element 18] - potassium is slightly lighter but comes later in the table. This is just one example of how the periodic table is not as straightforward as it appears.

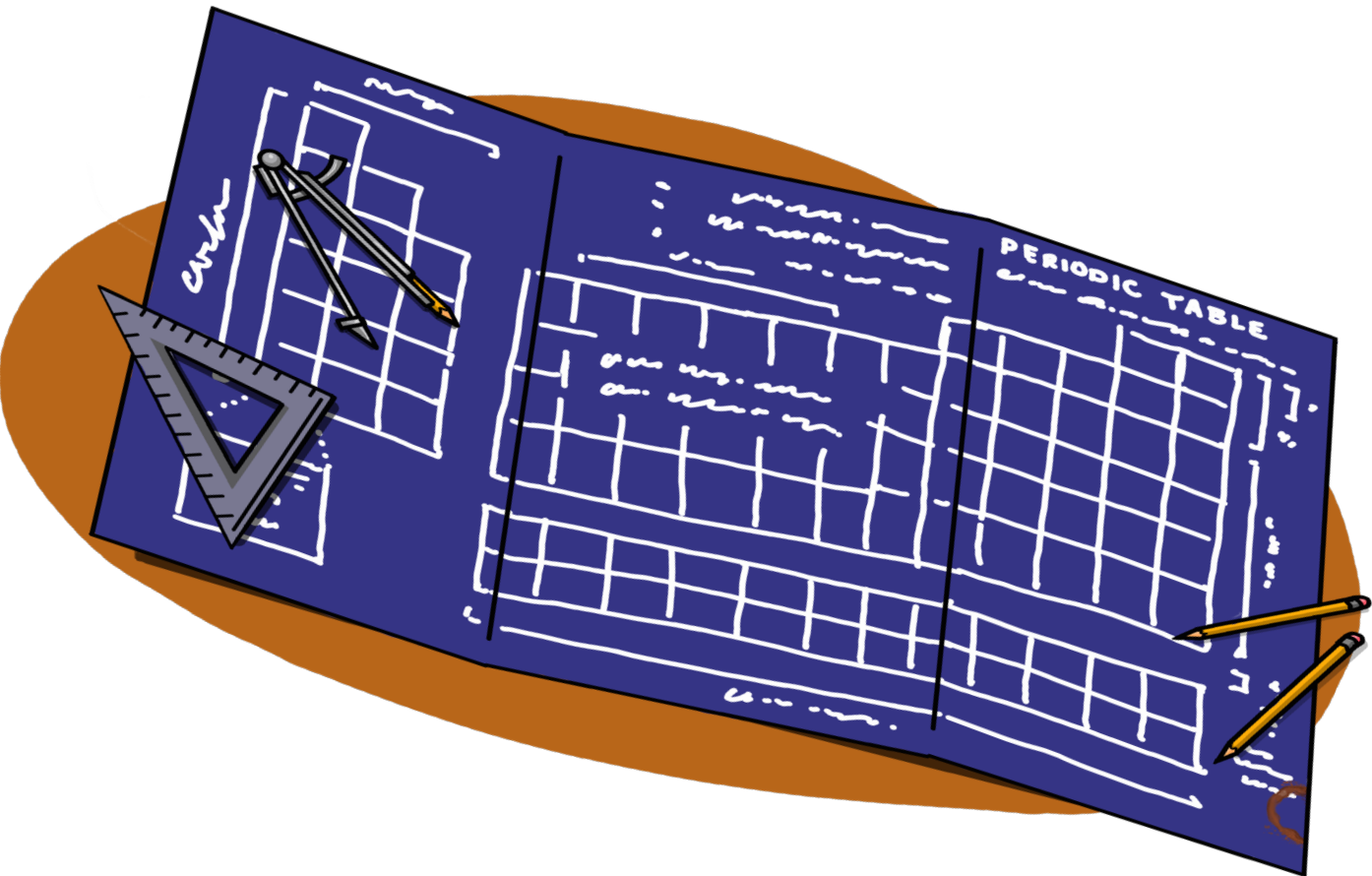


***An isotope, in this case, refers to a version of an element with the same number of protons but a different number of neutrons, often affecting its stability.
**** The number of protons in the nucleus.

As a graduate student, I have come to understand chemistry less as a set of strict rules and more as a series of exceptions to patterns.

So is our current periodic table truly complete? Or are there still gaps waiting to be filled?

The answer will likely not come from a single breakthrough, but from many small contributions. The most recently discovered element, tennessine, was officially recognized in 2016.¹⁰ In the grand scheme of scientific discovery, that was not very long ago.



The history of science has an amusing way of reminding us that what feels complete now might not stay that way. I have no doubt that someone, somewhere, is already working on filling the next gap in our table. Stay tuned, because the periodic table we learn for class today may not yet be its very final version.

Future generations of students may have a few more periodic table song verses left to memorize.



Camila Gonzalez Curbelo is a Chemistry Ph.D. student at U-M, where she studies how microfluidic tools can be applied to detect heavy metals in water. She is passionate about science communication and believes scientists have a responsibility to make knowledge accessible to everyone. In her spare time, Camila enjoys playing tennis and planning her next travel adventure with friends and family.

Edited by Emily Januck and Colter Giem
Artwork by Colter Giem



What Does a Scientist Look Like?

Hira Mirza & Josh Ghimire

Close your eyes and picture a scientist. Who do you see?

For much of history, the public image of a scientist was strikingly narrow. The faces remembered in textbooks and popular culture often reflected only a fraction of the people capable of contributing to discovery and innovation. Many others, despite their intelligence, curiosity, and potential, were excluded from these spaces due to barriers surrounding gender, race, sexuality, class, culture, disability, geography, religion, or access to education itself.

This collage exists in conversation with that history. By juxtaposing historical images of scientists with portraits of present-day researchers within our own community, this project reflects on how science continues to evolve, not only through new discoveries, but through increasing accessibility, representation, and opportunity.

Behind every face is a story: different paths, identities, struggles, and experiences that challenge the stereotype of who can become a scientist.

For many of us, simply being here is connected to generations of sacrifice, resilience, and change. This project honors both the giants who came before us and the growing diversity of people now helping shape the future of science.

Hira Mirza is a neuroscience graduate student researching how memories get stabilized during sleep. She is passionate about communicating science to the broader public and making STEM pathways more accessible to all.

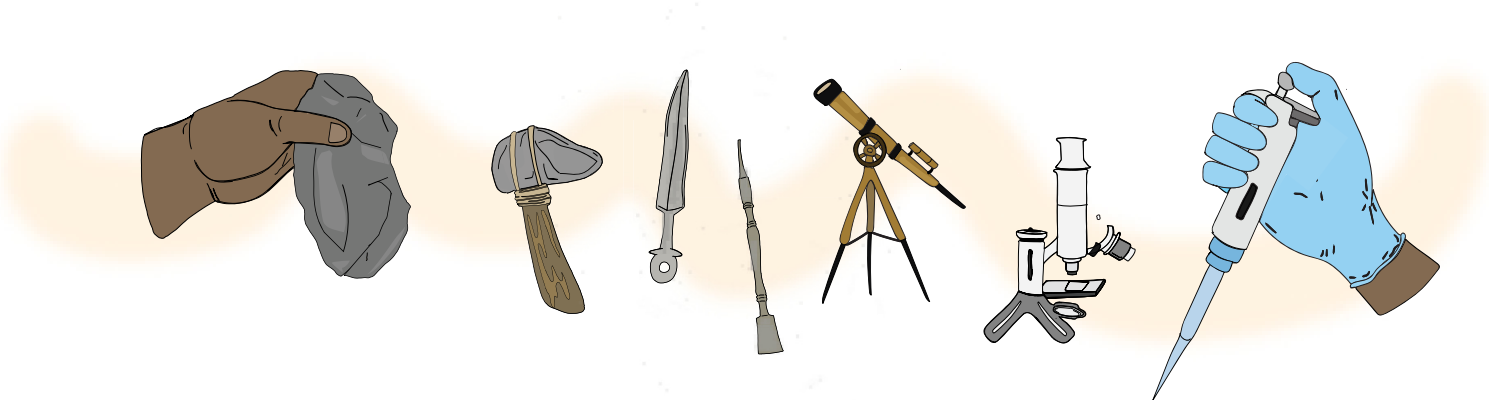
Anjesh Ghimire is a neuroscience graduate student researching whether the memory processes the brain uses to learn and store memories also play a role in forming strong social bonds. He loves his work, his friends and family, skiing, and he is perpetually struggling to keep his plants alive.

Edited by **Rebecca Taubitz** and **Daniela Pereira**

Where Scientific Lineage Begins

Kenia Contreras

Ancient hands pulled strings taut on bows beneath the young sun. Calloused hands spread tar across rooftops under summer heat. Tanned hands scrubbed grime from grout beneath crystal chandeliers. Now, gloved hands pipette beneath fluorescent laboratory lights.



Humanity has come a long way since Lucy, one of our earliest known human ancestors. Lucy, like many of our ancestors, had to put survival and instinct first; there was room for nothing else. Every hour was spent hunting, gathering, building, and enduring. Survival was not a choice. Before humanity could advance, our ancestors first had to withstand the brutality of the world around them.

And then, somewhere along the way, someone stepped away from survival long enough to ask why. Someone stopped to think.

Why does the sun disappear each night and return each morning? Why do some plants harm while others heal? Why does a stone fall while a bird soars?

Those simple questions marked the beginning of something uniquely human: a desire to understand the world and our place within it.

When people hear “History of Science,” they think of the first microscope, the first equation, the first cell discovered, the first inventions, and the people behind these ideas and feats. These firsts get most of the credit. Yes, they were the first. But what circumstances made it possible and who sacrificed so they could get there? How did they come to have this opportunity?

For most of human history, science was a luxury, exclusive to certain individuals. Barriers like class, financial status, and even gender barred many from pursuing science as a career. Figures like George Washington Carver, who pioneered agricultural sciences, and Marie Curie, acclaimed chemist and physicist, had to fight against barriers that told them curiosity did not belong to their race or gender.

Curiosity is often treated as something natural and inevitable, but it isn’t. Curiosity is a privilege. Studying fire instead of simply basking in its warmth or shaping tools instead of using them to secure the next meal, required time spent questioning instead of on survival. It required sacrifice, the kind that makes it possible generations later for someone else to sit in a lab and ask questions of their own.

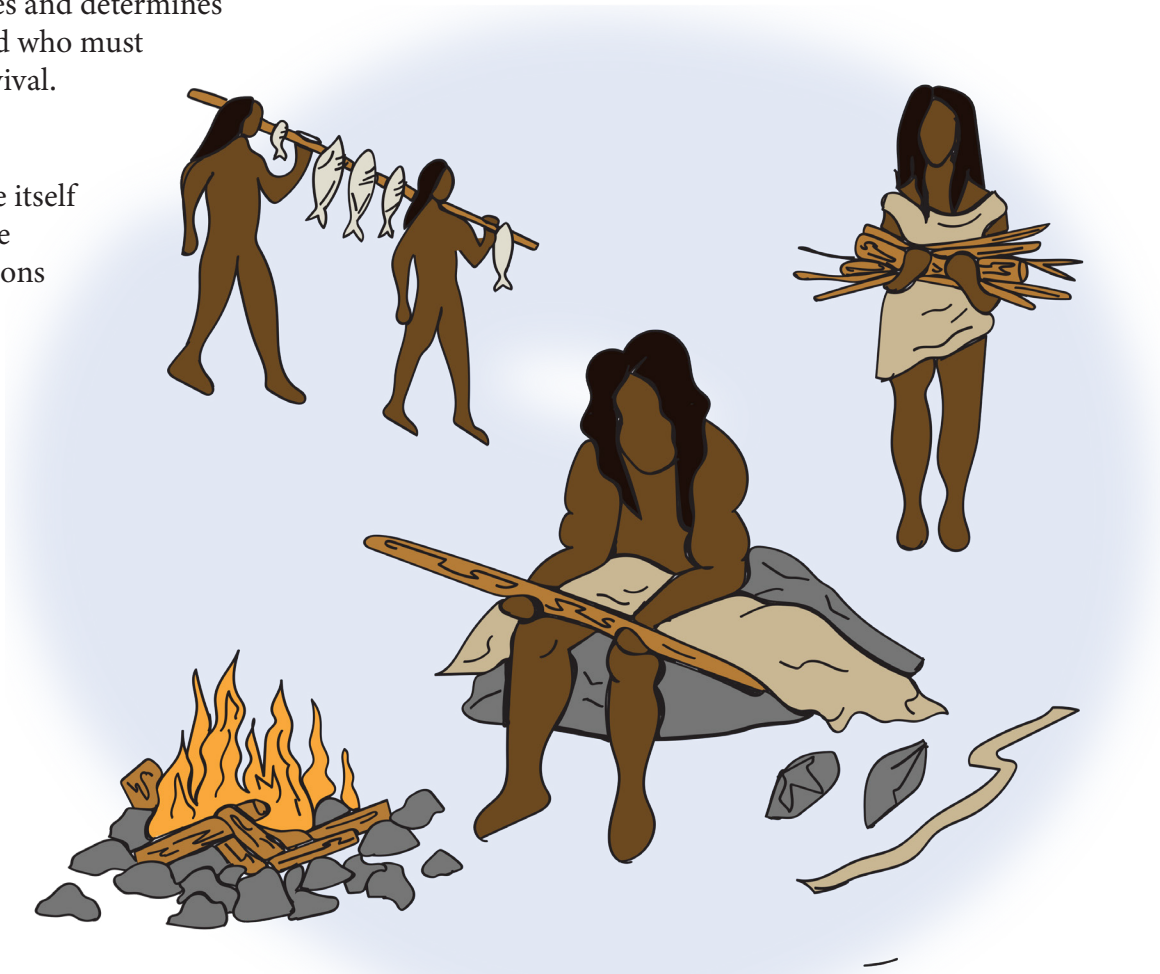
Survival was immediate and necessary when humanity began its course on Earth. Before there was discovery, there was endurance. Someone had to hunt the food, tend the fire, and stand watch through the night so the group could survive long enough for curiosity to emerge.

While one person imagined the first tool or discovered how to build a fire, someone else carried the burden of survival. Their labor created the space for curiosity to exist. Only when survival no longer consumed every waking moment did humanity finally have room for something more, the opportunity to question, to imagine, and to dream of a life beyond mere survival.

Humanity’s earliest questions and hypotheses were not funded by wealth, but by sacrifice.

That kind of sacrifice repeats itself across generations, it doesn’t just disappear. It repeats itself in different forms. It shows up in long shifts, tired hands, and heavy eyes. It quietly shapes and determines who gets to be curious, and who must spend their energy on survival.

Over time those sacrifices accumulate and knowledge itself becomes inheritance. Some families have long generations of scholars, philosophers, and scientists embedded in their blood. In others, survival leaves little room for that tradition to take root. But they have to begin somewhere.



I am one of those beginnings.

My mother left Mexico as a teenager when her family could no longer afford her education. She immigrated to the United States to clean and tend to strangers' homes, sending money back home with the hope that one day she might return to her education. Instead, she built a life here, she had children, and that dream slowly slipped out of reach.

In her world labor was valuable. It put food on the table; the pursuit of knowledge did not. Who cares about the inner workings of a cell when there are mouths to feed?

My father grew up on a small rural farm in Mexico. He found himself in the United States, searching for a better life in the kitchens of restaurants and on the damaged roofs of strangers' homes.

For many years, curiosity felt distant, impractical, and impossible to me. Something that was reserved for people with enough resources and time. I thought science belonged to people who came from generations of scientists, from people whose parents understood laboratories the same way mine understood kitchens, gardens, and construction sites.



My father understands the weight of shingles in the summer heat and the rhythm of a kitchen during a dinner rush. He often came home with sunburned skin, dust trapped in the creases of his hands, and paint stuck under the beds of his nails.

My mother came home exhausted too, her hands rough and raw from cleaning and tending to other homes. **She understood motherhood, the tight dust ridden corners, and the smell of fresh laundry.**

As a child I never saw these things as sacrifices, they were simply life. Work was what mattered. Labor kept the family afloat.

Their work was too different from mine. Theirs was physical, immediate, necessary. Mine felt abstract, distant, and optional. But the first time I stayed in a laboratory late into the night, I began to understand them differently. Now I see my parents' hard work paralleling my own. Incubators hummed in the background as I repeated experiments, failing, adjusting, and trying once more. My mother scrubbing the corners of homes that were never hers no longer felt separate from the repetitive motions of my own work. My father balancing himself on rooftops beneath unforgiving summer heat no longer felt distant from me. For the first time, the distance between my world and my parents no longer felt so large.

Long hours, failure and persistence, attention to detail, precision, endurance, repetition, and discipline, all qualities my parents practiced long before I ever stepped into a lab. Without even realizing it, my parents had taught me the endurance that science demands. The tools are different, but the labor remains rooted in the same hope: that the effort today will secure something better for tomorrow.

Somewhere between Lucy gathering food beneath an unforgiving sun and my mother scrubbing the floors of strangers' homes, the same pattern repeated itself: someone sacrificing so that someone else might have the chance to ask why. Survival and discovery were never separate acts. One made the other possible.

I used to think that becoming a scientist meant separating myself from where I came from. Now I realize that I am not separate from my family's history of labor, rather I am built from it. My mother and father spent years performing exhausting labor so their children could have choices they never did.

Humanity itself is built upon generations of labor. Hands that planted crops and built homes carried an entire species forward. As our ancestors worked to secure survival, each generation gained a little more space to ask questions. The curiosity that drives scientific discovery exists because of the countless people before us that devoted their lives to creating opportunities for those who came after them.

Just as I stand on the shoulders of great scientists before me, I also stand on the shoulders of a man and a woman who crossed borders so that their children might have the possibility of choosing knowledge over necessity. For my parents, survival came first. Their sacrifices created the possibility of curiosity for me.

My scientific lineage did not begin with me. It began in the houses my mother tended to and on the foreign roofs my father fixed, **all so I could afford to ask why.**

* * *

Kenia Contreras is a graduate student in the Biological Chemistry department. Her research in structural biology focuses on understanding the molecular machinery of bacterial pathogens, particularly *Legionella pneumophila*. Outside of research, Kenia enjoys writing, biking, and trying new foods.

Edited by Kaitrin Freeland & Juan Mato
Artwork by Adriana Brown

Branching Through Time

The Art & Science of Microglia

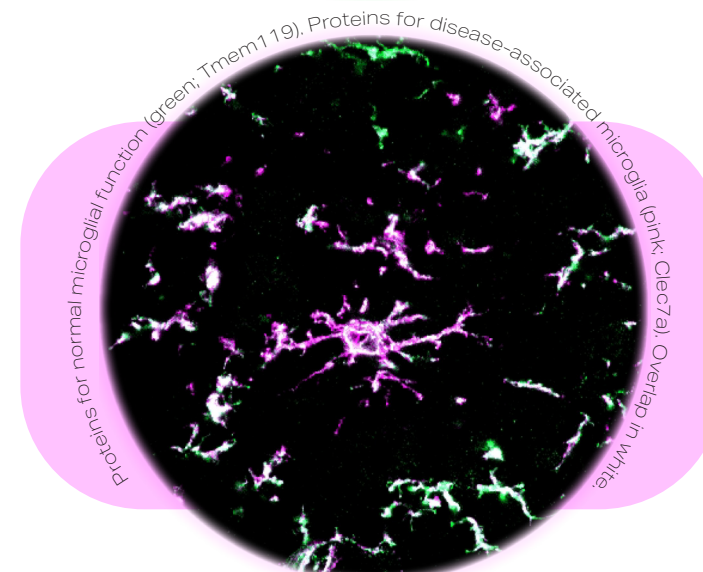
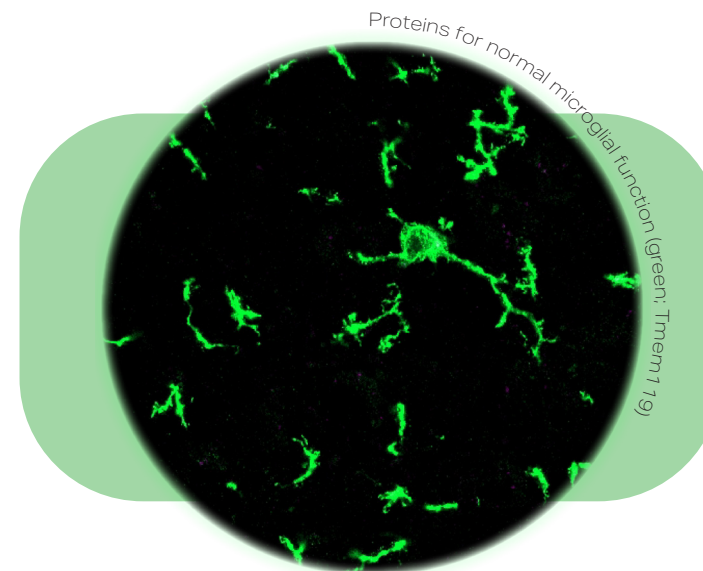
Kate Giffin



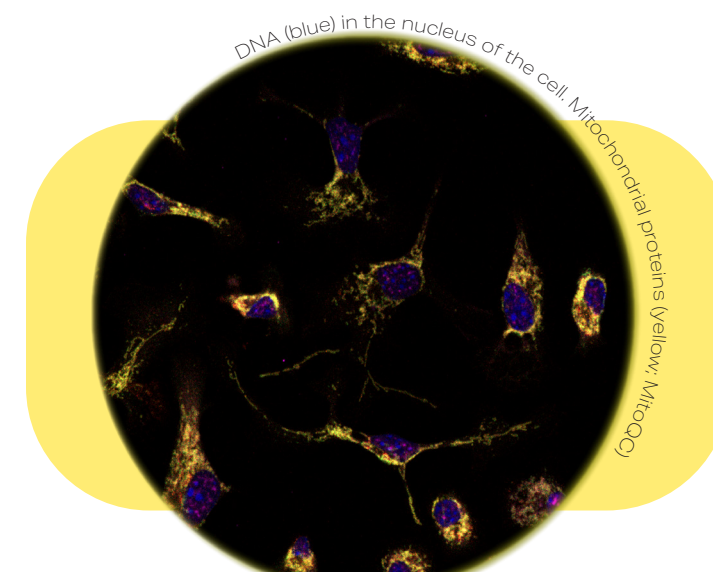
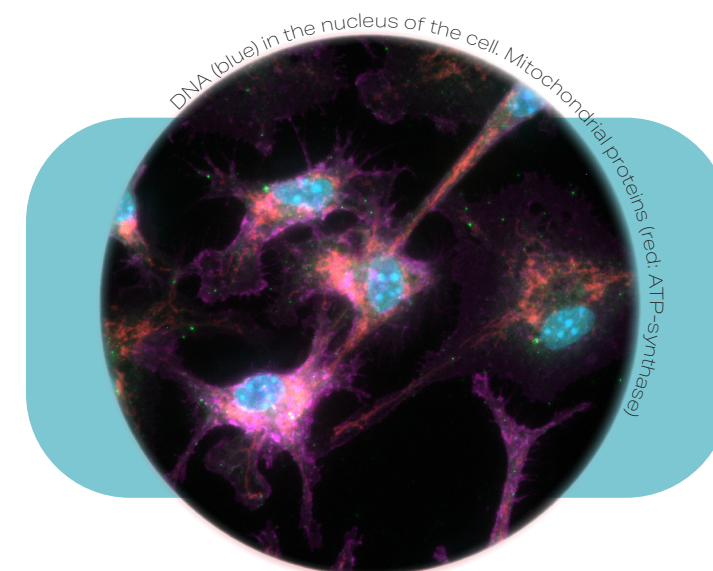
The first neuroscientists were artists. Using clever chemistry, they developed ways to stain brain tissue and then drew what they saw. Here, I have carved a block print based on one of the first published drawings of microglia,¹ the immune cells of the brain. In a series of four 1919 papers,² Pío del Río-Hortega described these cells and clearly showed that they were a different cell type from the other glial cells in the brain, astrocytes and oligodendrocytes. His conclusions about microglia, based almost solely on observations about how they look under different conditions, were startlingly accurate. For example, he noticed that microglia rapidly migrate to a site of

injury and transform in shape, even becoming, in his words, “monstrous.” He accurately hypothesized that they clean up debris through a process called phagocytosis. He also speculated that microglia have a different developmental origin than other brain cell types, a conclusion that wouldn’t be verified³ for over 100 years and which required the development of sophisticated genetic fate mapping techniques.

Current neuroscientists still visualize microglia in health and disease to answer important scientific questions. But instead of pencil and paper, we use high-powered microscopes and lasers.



These are microglia from mouse brains in a model of multiple sclerosis, used to study the brain inflammation that contributes to vision loss in multiple sclerosis. Image credit: Jenna Staples from the lab of Sebastian Werneburg.



These are microglia that are grown in a dish and used to study cellular damage during brain injuries like stroke. Image credit: Francisco Torres Torres from the lab of Thomas Sanderson.

Across hundreds of years, microglia inspire art and scientific discovery. While the tools may have changed, the beauty of biology remains.

Kate Giffin is a neuroscientist who recently defended her PhD. In her PhD, she studied how severe infections can lead to long-term brain issues like dementia, with a focus on the immune cells of the brain, microglia. She is passionate about telling scientific stories through unexpected genres to expand the way people think about science and the world. Recently, she has been learning new artistic mediums like linocut, watercolor, and zines. When Kate is not marveling at the brain, she is probably outside marveling at some strange plant.

Edited by Alexander Ford and Elise Tahti

Cosmic Reparations:

The Legacy of Harriet Tubman

K Wilson

The first question I ever thought to ask of the Universe was not how it came into being, not when it decided to be, nor even why it wanted to become. No, my questions were concerned with my own how, when, and why: ‘How did it come to be that I existed only in the liminal spaces?’ ‘Why was I relegated to them?’ and ‘When, if ever, could I escape into permanence and stability?’ In other words, my original motivations for studying the Universe were selfish. It seemed to me the source from which I could draw meaningful truths about my existence uncorrupted by mankind’s falsehoods it tried to project onto me.

Soon, it was just the Universe and me, and we were marked from the beginning to be tried and tested – just for existing. Not that I knew the full extent of this the day in fifth grade I picked up a book on the founding fathers of astronomy and resolved to continue their legacy. Galileo, Copernicus, Kepler. None of those men had anything on a lil Black girl from the hood. My family and neighbors were being brought before the court for ‘heresy’ every hour – the heresy of existing while poor and Black. My ancestors had been lynched and burned at the stake for centuries, their genius suppressed, their ideas and knowledge usurped; their bodies brutalized in the name of science and medicine. It seemed all those old, dead, venerated white men of science had endured nothing unfamiliar to me in their quest to uncover cosmological truths, so what had I to be afraid of? Considering the circumstances I was born into, with a world stacked against me, what had I to lose in daring to dream so astronomically?

To put it in other words:

The Universe became my escape.
Little did I know that somewhere in space,
separated by a mere century and three-quarters of time,
a great ancestor of mine
was using these exact same stars I gazed upon
to plot her own freedom.



Araminta “Minty” Ross, alias Harriet Tubman, is best known for her work as a fierce abolitionist, leading approximately 70 enslaved people to freedom through the Underground Railroad over 13 dangerous trips from Maryland to Pennsylvania. Her scientific merits, however, are significantly less recognized. Her lived experience growing up enslaved in the Chesapeake Bay region instilled within her an expertise of land, sea and sky to run an arduous mission of freeing the enslaved. In fact, her successful rescue of dozens of enslaved people and evasion of capture by enslavers for decades was a direct result of her mastery of several sciences. As an enslaved child, she was often leased out to farmers to set underwater muskrat traps,¹ which made her adept at swamp diving. She also worked alongside her father – a respected

lumberjack and forester – in timber fields.² This knowledge served her well later during her trips, where, with dozens of lives in her care and their freedom on the line, she expertly led her brigade through dense swamps, forests, and muddy terrain; hiding in potato holes³ by day and wading through marshes under the star-studded night sky. She was, without a doubt, an adroit geographer.

Her trips took roughly three weeks of traveling on foot at night and taking cover during the day. So her knowledge of plants, including which were poisonous and which were safe to eat, was a matter of life and death which prevented both herself and her posse from starving. She was rehearsed in making natural remedies⁴ from roots and herbs to heal wounds and



illnesses from her Civil War days curing Union soldiers of dysentery. She was familiar with local animal calls like the owl hoot, ⁵ and used them to discreetly signal her group when to hide to avoid capture and when it was safe to come out. Her ability to live off and blend in with the land not only served her abolitionist work, but it also made her a botanist and naturalist.

Furthermore, Harriet came from a maritime community of Black sailors ⁶ and mariners who read the night sky for navigation and taught her how to use the constellations and the North Star. She utilized this know-how to guide herself and others to freedom, which of course makes her an astronomer, too. Writing to her in an 1868 letter,⁷ Frederick Douglass says of Harriet, “The midnight sky and silent stars have been the witnesses of your devotion to freedom and your heroism.”

Harriet Tubman’s scientific knowledge and mastery of several disciplines enabled her to create powerful movements of freedom, autonomy and self-realization for a people who had the entire world against them. And for those she could not lead herself, an integral component of her abolitionist work was also sharing and passing on information to help others survive their own journeys to freedom. She built a community around sharing crucial knowledge of the Earth and sky to uplift those around her. Dr. Chanda Prescod-Weinstein, a cosmologist, activist, and professor of physics and women’s and gender studies, writes, ⁸ “As a conductor on the Underground Railroad and general expert on the social technology of liberation, [Harriet Tubman] understood and used this cosmos that includes Black people and freedom. This knowledge makes her one of the greatest astronomers in American history.”

So why isn’t Harriet remembered among the ranks of Hubble, Sagan, Rubin, and Leavitt? Why isn’t she regarded as the geographer,

botanist, and naturalist she was? The answer, in short: epistemic apartheid.⁹ Or, the devaluation of knowledge, art, and work from marginalized individuals and communities – especially from Black people and Black women. This, of course, has been a critical component of the colonization framework for centuries. It is the reason that Black scientists are othered, their work rewritten or relegated to the margins of history. It is why, for instance, we remember Benjamin Franklin as a renaissance man, but we recognize Benjamin Banneker much less so; it is why every physicist can name the giants of the quantum revolution–Heisenberg, Schrödinger, Bohr, Born, but not Imes. Frantz Fanon details in his *Black Skin, White Masks* ¹⁰ that the way the colonized are dispossessed of their ability to name the world is by forcing them to speak the oppressors’ language. Indian literary critic Gayatri Spivak extrapolates this idea beyond literal language to include all the ways one can ‘name the world’ – i.e. via scholarship and the creation of new knowledge, particularly in the suppression of the colonized’s ability to engage in such scholarship and knowledge creation. She calls this suppression “epistemic violence”.¹¹

With this philosophical framework, it becomes apparent that it was no accident that Harriet Tubman is not remembered as the scientist she was – that this reality was in fact necessitated by the very foundations upon which the modern academy and scientific establishment were built; namely, white supremacy, elitism, exclusion, and yes, even the weaponization of knowledge and science by a select few to impose violence against those deemed inferior. Modern science is predicated upon white, Western epistemologies, where extraction and exploitation are a justified means toward knowledge generation and scientific discovery. One composed of a hegemonic oligarchy that gets to decide who is considered worthy enough to be a scientist, who gets to contribute to the system of knowledge creation, whose scientific work

is remembered, whose scholarly merit is recognized at all. One that leaves no space for the likes of Harriet, or even myself, centuries later still.



As a Black lesbian woman pursuing a PhD in cosmological physics, in a society in which Black women make up less than half a percent of physics PhDs, I must carefully navigate academia while often being told one way or another that I don’t belong. In my own journey toward academic freedom, Harriet’s story is a powerful reminder that there is a deeply rooted history and intimate relationship between my people, the Earth, and the Universe. I am a science communicator who is deeply passionate about sharing knowledge and resources in an effort to uplift marginalized communities in science. Even while I am accused of engaging in “identity politics”, I find immense beauty, joy, and comfort knowing that through this work, I am continuing a legacy of passing on my knowledge of the cosmos, just as Harriet passed on hers to guide others to freedom.

So, if denying us the ability to name the world is an epistemic injustice, then remembering and retelling the stories of our ancestors, like Benjamin Banneker, Elmer Imes, and Harriet Tubman, is epistemic justice. If the struggles I have endured in my brief tenure as a scientist thus far have been a continuation of the epistemic apartheid waged on my ancestors for centuries, then my very existence in the conference halls and auditoriums of academia is my cosmic reparations. And if Harriet Tubman was being disobedient by taking her freedom by force, with guidance from the Universe, then by physics-ing while Black, I am continuing her legacy in being epistemically disobedient ¹² via my pursuit of cosmological truth.

★ ★ ★

K Wilson is an astrophysicist, science communicator, writer and public speaker whose mission is to uplift and inspire individuals of all backgrounds who are interested in STEM, especially those of marginalized identities. With an ethos grounded in *unapologetic representation*, she uses her presence, voice, and passion for storytelling to make the wonders of the Universe more accessible to all. She is currently pursuing a PhD in cosmological physics at the University of Michigan.

Edited by **Daniela Pereira** and **Kaitrin Freeland**
Artwork by **Satabdi Mohanty**

On the Shoulders of Empire

Francisco J. Torres Torres

Dun-dun.

Dun-dun.

Dun-dun.

Benches shook. Monitors clattered off uneven tables. Reagents jangled and tumbled, spilling down the giant's mile long limb. The scientists, so enthralled in their thoughts and experiments, had forgotten how high up they really were! They buzzed around the ivory towers encrusted like pale honeycomb along the giant's monstrous shoulders.

Where is Uncle Sam going now... one scientist wondered, looking over the foggy mountain range. Villagers stirred like ants as the giant lumbered closer. Some admonished the giant, some welcomed the intrusion. Others went along with their day.

The giant was the greatest of them all; the strongest, with the best view, and dandruff the shape of dollar bills. Generations of scientists had labored there, proud of their commitment, even as the often fruitless hours dwindled away. There was a comfort there — intellectual stimulation and moral exemption. Science from a shaky shoulder beat science on trampled ground, after all.

Dun-dun. Dun-dun.
Crack.

A shiver rattled the ecologist's spine, afraid to face the trail left behind. Poisoned bootprints stamping precious nests, mangroves, and estuaries. The ghosts of birds left unnamed. Oceans blackened in its wake. The giant's stare remained on autopilot.

If only I were in Uncle Sam's head, directing its movements, the scientists collectively shrugged, turning to their expensive potions and magical machines. Within the ivory towers, centuries of knowledge accumulated. It was a position of honor and merit — saving lives through the intellectual pursuit they called academia.

The scientists had to focus. Just, focus. Otherwise their academic rivals would outdo them, and that wouldn't do. Many swarmed about, experimenting, gathering the crumbs that fell from the giant's gaping mouth. Though isolated from Gaia and her people, the scientists could at least share some facts that reached the giant's ear, even as some went out the other.

Dun-dun. Dun-dun.

The Gaians' screams followed them across sundered deserts and fragmented islands; the giant carried on, oblivious. Suffocated in a miasma of smoke, buried under an avalanche of plastic, drowned by a tsunami of chemical waste — Gaia and her people had long reached a boiling point. A missile peppered the giant's eyebrow and a swarm of armored flies descended in response.

Pop-pop-pop.

Annihilation in every flavor; now available by drone, joked the anthropologist. Gallows humor became a tonic to down the constant frustration. Research had been touted as a noble act, but the view from above complicated their belief. Once the doors of knowing were opened, they could be crossed in either direction. What did the drone and syringe have in common? Each could deliver life as easily as death. It was no wonder some of the Gaians' insults were hurled at the scientists, and not the giant that carried them.

Dun-dun. Dun-dun.

Psyches fragmented like discarded glass, the psychologist shook with fear and anger. Enough was enough. A meeting of the likeminded, across all fields, was called. Miraculously, the community agreed — It would be the last time

the giant would drag them into a wailing conflict. The methodology of their resistance was simple, though it went against their every instinct. The scientists stopped working. It wasn't long before the giant's steps paused, its smokestack hat no longer spewing. Only the forest's murmurs filled the air. Now the scientists could be heard.

Think of the environment!

roared the ecologist

And the erosion of ethics!

cried the anthropologist

Don't you feel the world's pain?

asked the psychologist

Q U I E T !

The word split the sky like a divine whip. A huge red iris narrowed towards its shoulder. The rebels looked around, suddenly afraid, and found that while some meekly returned to their work, others straightened and nodded in agreement. Cruel eyes could never change the truth.



P a i n . . . pondered the giant. The scientists were smart, but the giant was shrewd. It had heard of a theory of evolution, another of behavioral conditioning. If it punished the gnats at its shoulder, they would learn to never complain, or condescend, or rebel. Where had it heard the theory before? It didn't matter. Until then, the giant swatted at its shoulder.

Splat. Splat. Splat.

The giant stumbled along, having hurt itself in its frenzy. Its hypothesis was half-right. Nature abhorred the void — the rebels' absence would be filled. Troubleshooting, pivoting, thinking critically. Given time, science would find a cure for the giant's malignant heart. Until then, the remaining scientists went about grasping at dandruff the shape of dollar bills, just out of reach.

Dun-dun. Dun-dun.

Francisco Torres Torres is a Neuroscience PhD student and serial daydreamer. In the lab, he studies how mitochondria (the powerhouse of the cell) influence inflammation after stroke. In his free time (ha!), Francisco enjoys writing sci-fi, visiting art museums, listening to live music, and plotting the downfall of the bourgeoisie with his cat Piculin.

Edited by Juan Mato and Deanna Cannizzaro
Artwork by Rebecca Taubitz

Appendix

Clearing the Optical Illusion: How a Muslim Polymath Redefined How We See

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Cosmic Reparations: The Legacy of Harriet Tubman

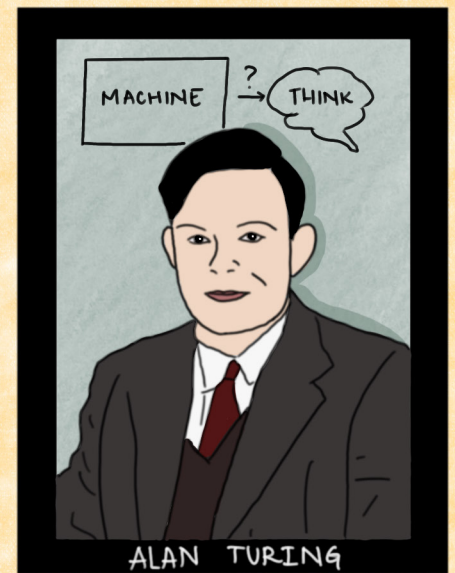
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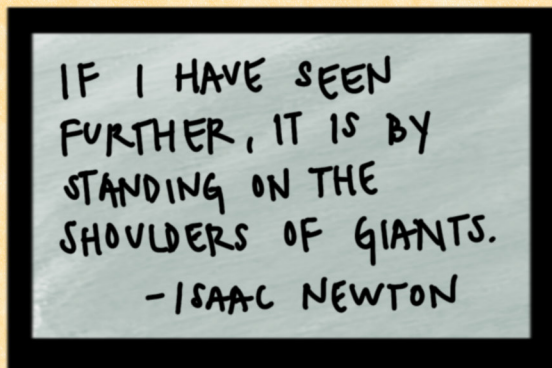
LEONARDO DA VINCI



BARBARA MCLINTOCK



ALAN TURING



SUBRAHMANYAN CHANDRASEKHAR



KATHERINE JOHNSON



Portraits of Giants

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