equilibriUM

a STEAMM magazine

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Letter from the editor

Welcome to *EquilibriUM*, a science, technology, enginering, art, math, & medicine (STEAMM) magazine brought to you by MiSciWriters! This print magazine project started as a way to celebrate *MiSciWriters*' fifth anniversary (in September 2020) and explore the interesting ways that science fits into other disciplines. I've had the immense honor of being a part of the *MiSciWriters* community during my entire graduate school career and have served as the editor-in-chief the past almost two years. But there's so much more in this world beyond science - even just within UMich research - and I wanted to bring the team's expertise in editing and storytelling to a more interdisciplinary space. This magazine serves as a sort of test bed, exploring what we could be doing and what stories we should be sharing.

Science, medicine, engineering, and technology have all fundamentally altered the way we structure our institutions. There are miracles and mishaps both in the uptake of STEM into the fabric of how we function as humans. The promise of science as a means to understand and better our world goes back to the age of enlightenment, where rationality and objectivity were seen as means to conquer Nature. In a boom of scientific exploration, fields like astronomy, psychology, and chemistry established themselves and are some of the foundations of science themselves, in the pursuit of overcoming Nature and tradition. It's easy to see how and where enlightenment thinkers went wrong, both in concept and in practice, in hindsight centuries later. That said, at the time critique was ongoing though in the space of art and literature. One must look no farther than Mary Shelley's *Frankenstein*, now integrated into science ethics curricula, to see where literature critiques research practices and personalities. As a scientist however, it's easy to feel hopeful at understanding the surrounding world without grasping the complex connections between entities until one is disturbed. While my research will never be extremely high-impact, I can imagine that the team on the Manhattan Project were excited to find a way to apply theoretical physics and end WWII, not really imagining, by naivety or avoidance, the impact it would have on international environment, culture, and politics, impacts we still feel today.

As naive as it was to think that society's solutions lie in science, thinking that incorporating arts

> Of course, man cannot live by engineering alone. He is a loving, playful, wisdom-seeking, beauty-adoring creature, and deprived of the animating spirit of art and philosophy, his life is barren and his greatest works are as naught.
>
> **Samuel C. Florman,**
> The Existential Pleasures of Engineering

and humanities will completely solve our problems is equally as shortsighted. Nevertheless, the dichotomy between arts and science has always been a fallacious one. Integrating culture, society, and craft into medicine, technology, and science opens the vague concept of "understanding" to mean so much more than the cartoon schematic in a textbook. Certainly such models display concepts in an accessible way, but complexity can be lost in this type of reduction. Here at *EquilibriUM*, we think that introducing complexity through lenses outside of science and outside of STEM brings a refreshing richness to our research narratives, by integrating mythology into psychology (Mocked, Garay), personifying scientific processes (Transformation, Lao), calling for accessible education (Mentorship, Ju), how our families shape our lives (No Lab Coat Required, Baker), changing theories based on new information (Recognizing the "I" in Science, DeLacey), and thinking about how technology impacts our thinking (Different Perspective, Kearns).

These articles and illustrations in this magazine by our amazing team of graduate students embody the etymology of our magazine's namesake: equal and balanced. While the world and our interactions in it will continue to fluctuate, I hope that you find composure and solace here flipping through tangible pages and engaging with these stories. Remember to take the time and dwell in the complexity and perhaps you'll find the answers to questions in unexpected places.

~sarah

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Synapse Enso
Sharena Rice

Neuroplasticity allows the nervous system to adapt to changes. Like muscles, the brain is a dynamic use-it-or-lose-it system. The building of new synapses, the strengthening and breakdown of existing synapses: neuroplasticity allows us to learn and remember. The enso is symbolic of "suchness", the essence of zen. It is entirely empty, yet entirely complete. Combined in art, these equilibriums fine-tune to the situation.

MOCKED

Patricia Garay

What separates a chortle from a snicker is your history. Your culture, your experiences, and your unique personality inform whether you interpret the little laugh as benign or mocking. Mocking, or ridicule, has always been one of laughter's facets across eras and cultures. Such cruel laughter is embedded in human folklore: in the Greek myth the goddess Demeter was searching for her kidnapped daughter, Persephone. When she collapsed exhausted at the edge of a town and was offered a flask of barley-water to drink, she seized the flask and chugged it down. As she drank, she heard a local boy, Ascalabus, laughing at the sight

of the goddess gulping greedily. Her inner turmoil sharpened into the need for revenge, and Demeter wiped her mouth and turned Ascalabus into a lizard[1].

Perhaps Demeter judged correctly that Ascalabus was a disrespectful kid who needed a violent dose of humility. However, Demeter—anguished at the loss of her daughter, traumatized by the time she was swallowed by her own father Kronos—might have added some of her own baggage and insecurity to her perception of a relatively innocent laugh simply because innocent laughs are often interpreted as mocking. In a study back in 2009, scientists played audio recordings of "joyful" or "ticklish" laughter to listeners and asked the listeners to identify the motive behind the recorded amusement. Joyful laughter was interpreted by listeners as examples of someone "laughing at someone else's misfortune" or "taunting laughter" nearly as often as it was interpreted as "joyful" or "ticklish". To extrapolate the numbers in this study, if you laugh your joyful laugh to a group of eight people, four of them would find it joyful, three of them would perceive it as you "laughing at someone's misfortune", and one would find your laugh outright taunting[2]!

To understand why we are so different in how we hear mocking laughter—and why in some rare cases, people hear laughter only as mocking—we have to look at our culture and our personal history, and this starts long, long ago, as little babies, when we were being mocked for the greater good-- a twisted version of it.

If we all had the powers of Demeter to exact revenge, we'd all have been turned into lizards by kindergarten. Mocking laughter affects us profoundly, starting when we are very young. Researchers have observed signs of embarrassment in babies as young as two years old[3]. No published studies have yet examined babies' recognition of mocking laughter, but non-academic knowledge provides a hint. According to a Sámi weaning custom in Swedish Lapland:

> [A mother suckles her child as a rule until 'it can understand when it is being laughed at.' For the other children tease it if it is still drinking at the breast when it can walk[4].

Since children start to walk before two years old, this custom corroborates the idea that as toddlers we start to comprehend that laughter is not only an expression of love and joy, but a judgment about us. Some judgment has a social purpose. In the case of the breastfeeding baby, mockery inspires the baby to trade the comfort of its mother for independence. Adults often are aware of the power of laughter or ridicule to shape a child's behavior. For example, the following is taken from a 1969 interview with a Western Apache man:

> Laugh at a child when he does something bad. Make fun of him and say, "Don't you know any better than to do that? Other people don't do such things." That is the way to prevent him from doing it again; to teach him what is wrong and what is right[5].

Mocking laughter, then, teaches social norms by making the individual being laughed at "ashamed of what he has done" [ibid]. What our society or culture laughs at shapes who we become.

While mocking laughter might teach children to behave, stay safe, and learn manners, it can teach us to change who we are in ways that are more harmful than beneficial. An interview from the 1990s with a Spanish-speaking Mexican-American man demonstrates how our personalities can be shaped by mocking laughter.

> I remember in the fifth grade studying Spanish and when we had to do class conversations out loud it was always traumatic for me. Most of the kids in my class were Anglo, so when I spoke Spanish I was careful not to have an accent, so I would not be laughed at. Perhaps I should have showed more will-power, but it's awfully

> damned hard when even the teacher snickers. This kind of experience gave me a shyness I have never been able to get rid of. Instead of mastering the language, it was, instead, taken away from me and replaced by the knowledge that Columbus discovered America and that Indians were savages[6].

In this classroom, speaking Spanish with a perfect accent in a Spanish class was outside of the local norms, and was laughable. The boy not only shaped his behavior accordingly in class, but the effect of this lived on into adulthood. This sort of experience, whether called bullying, racial trauma, or social exclusion, is known to be associated with certain types of social phobias: fear of speaking up, or fear of talking with new people. And in rarer cases, situations like this appear to lead to a condition called gelotophobia.

In 1995 a German psychologist, Michael Titze, described a set of patients who constantly interpreted laughter as having a mocking intent[7]. These patients physically froze up—"like [the wooden puppet] Pinocchio"— upon hearing laughter. Titze named this fear of laughter "gelotophobia," from the minor Greek god of laughter Gelos, a merry friend of Dionysus[8]. A few years later a pair of Swiss scientists, Ruch and Proyer, wrote a fifteen-point questionnaire, called the GELOPH-15, that captured some of the traits of their own clients who had similar responses to laughter[9]. The GELOPH-15 used a rating scale of strongly disagree (1), moderately disagree (2), moderately agree (3), and strongly agree (4). Take a look at the questions (next page) and find your average to see how you score.

In the original study introducing the GELOPH-15 test, gelotophobia appeared rare, at least in the group of Swiss and German university students that Ruch surveyed: only 6% scored as displaying slight gelotophobia and no one scored higher[11]. Given that roughly 25% of school children in Germany report being bullied[12], it's clear that many people can experience bullying without developing gelotophobia. Alternatively, it is possible that gelotophobes may be less likely to attend universities to avoid being excluded from their high social demands. Gelotophobia has been found at much higher rates (up to 45%) in people with autism spectrum disorders, eating disorders, psychiatric conditions, and a history of being over- or under- weight[11, 13, 14]. In these cases, the fear of laughter appears to be correlated with a childhood of teasing and high levels of distress[10]. Frequency of teasing is not as correlated with the harshness of teasing, so if your elementary school days were full of mildly hurtful teasing you might not experience high gelotophoba scores, but a year of miserable teasing could cause a lasting effect.

Even though the GELOPH-15 test was designed within the context of Western cultures, the statements have been tested in cultures around the world (though mostly in University settings). In an expansive study, people across 73 countries filled out translated GELOPH-15 questionnaires[15]. There were enormous differences between countries for each of the questions. For example, only 8% of Finnish respondents, but 80% of Thai respondents agreed with "When others laugh in my presence I get suspicious." This suggests an incredible distinction in the interpretation of laughter across cultures, though humor and joyful laughter is found abundantly across the world. Is laughter used more often as a rebuke in Thai culture? Are people taught to value their respectability to a greater extent? Are they taught to think carefully of others' opinions of them? While some differences in scores may be due to subtleties in translation, across all questions, individuals from Asian countries had the highest scores and those from Western countries the lowest. Cruelty, ridicule, and exclusion are universal: but it is interesting to wonder how the Spanish-speaking boy would fare in a country with higher overall GELOPH-15 scores than the US. In a community where everyone is taught of laughter's mocking power, and of the demand to self-assess, then laughter will be treated more carefully, as the weapon it is. However, in a community where laughter is less likely to be seen as a potent tool of shame—then mocking laughter might reign unchecked in his classroom, veiled in innocence.

Because really, is it just "fear of laughter" that is causing these distinctions in scores? The GELOPH-15 is nuanced. Some questions don't refer to laughter at all, and are instead an indicator of how much a person seems to be burdened by the opinions of others. Reexamine the statements: "control myself strongly in order not to attract negative attention so I do not make a ridiculous impression," and "especially when I feel relatively unconcerned, the risk is high for me to attract negative attention and appear peculiar to others." These statements probe how much someone is aware of others' viewpoints, how much someone is conscious of the fact they affect others and produce judgments in others' minds. This is where the GE-

GELOPH-15 Your/tu total: _______

☐ When others laugh in my presence, I get suspicious.
☐ I avoid showing myself in public because I fear that people could become aware of my insecurity.
☐ When strangers laugh in my presence I often take it personally.
☐ It is difficult for me to hold eye contact because I fear being assessed in a disparaging way.
☐ When others make joking remarks about me I feel paralyzed.
☐ I control myself in order to not attract negative attention so I don't make a ridiculous impression.
☐ I believe that I involuntarily make a funny impression on others.
☐ Although I frequently feel lonely, I have the tendency not to share social activities in order to protect myself from derision.
☐ When I have made an embarrassing impression somewhere, I avoid the place afterwards.
☐ If I did not fear making a fool of myself, I would speak more in public.
☐ If someone has teased me in the past, I cannot deal with them freely in the future.
☐ It takes me a very long time to recover if I've been laughed at.
☐ When I'm dancing, I feel uneasy because I'm convinced any watching thinks I'm ridiculous.
☐ Especially when I feel relatively unconcerned, the risk is high for me to attract negative attention and appear peculiar.
☐ When I have made a fool of myself in front of others, I grow completely stiff and lose my ability to behave adequately.

☐ Si se ríen en mi presencia, me hace sospechar.
☐ Evito exponerme en público porque temo que la gente reconozca mi inseguridad y se puedan burlar de mí.
☐ Si desconocidos se ríen en mi presencia, frecuentemente lo refiero a mí.
☐ Me es difícil mantener contacto visual, porque temo que seré evaluado de manera despreciativa.
☐ Cuando hacen comentarios en broma sobre mí, me siento paralizado.
☐ Me controlo intensamente para no llamar la atención de manera desagradable y hacer el ridículo.
☐ Creo que doy a otros la impresión de ser raro.
☐ A pesar de que frecuentemente me siento solo, tiendo a evitar participar en actividades sociales para protegerme de las burlas.
☐ Si en algún sitio llamé la atención de manera embarazosa, después evito ese lugar.
☐ Hablaría mucho más en público si no tuviera miedo de hacer el ridículo.
☐ Si una persona se burla de mí no puedo volver a tratarla relajadamente.
☐ Me tomas mucho tiempo recobrarme cuando los otros se han burlado de mí.
☐ Me siento incómodo bailando porque estoy convencido de que les parezco ridículo a los que me observan.
☐ Precisamente en el momento en el que me siento relativamente despreocupado, es mayor el peligro de que llame la atención de los otros de manera negativa y les parezca raro.
☐ Cuando hago el ridículo frente a otros, me entiendo totalmente y soy incapaz de comportarse adecuadamente.

GELOPH-15 questionnaires to assess fear of laughter and ridicule in English and Spanish. Gelotophobia is related to, yet distinct from, social anxiety and social phobia[10]. An average score above 2.5 signifies gelotophobia (subdivided into slight, 2.5-3; marked, 3-3.5; or severe, 3.5-4).

LOPH-15 seems to test not just laughter, but social phobias and cultural norms of self-control. Although it specifies the avoidance of being "ridiculous" or "peculiar", many of us might control ourselves to defy other stereotypes.

Are we self-conscious about being perceived as "dangerous," "mean," "weak," "bossy," "dumb"? In a way, self-consciousness is a burden that grows heavier every time we are ridiculed--or every time we see others ridiculed--to conform to our communities. Conforming appropriately is another burden of self-control. The GELOPH-15 tests the shadow of these burdens: it captures whether your culture has tasked you with carrying the weight of others' opinions. In this sense, the distribution of GELOPH-15 scores across a culture—which has been barely researched so far— reveals how evenly this burden is shared.

Myths and folklore capture wisdom accumulated across generations, and so they can answer questions about societal burdens that have not yet been answered by research studies. One last myth, recorded in 1942 by a British anthropologist visiting the Nicobar Islands (north of the Western-most tip of Indonesia), warns us of a possible consequence of an uneven distribution of the burdens underlying the GELOPH-15.

Long ago, goes the story, trees could walk like humans. And when people would go on journeys, the trees would help, carrying heavy loads that a human would find hard to bear. One day the humans embarked on a great migration, and all the trees gathered together to help carry their possessions.

> [A]s the trees were going along, the people who were behind went into fits of laughter at the comical sight of trees carrying their loads and bumping up one against the other. So the trees turned stubborn and would not move any more, for they were angry at being laughed at. So nowadays we have often to overtax our strength in carrying our own loads when we travel, because trees have now become fixtures[16].

Whose loads are we carrying? Do we want to carry them anymore? And for those of us whose luggage has been tossed to the ground by the trees, we can pick up our luggage, and be grateful we weren't turned into lizards.

PG

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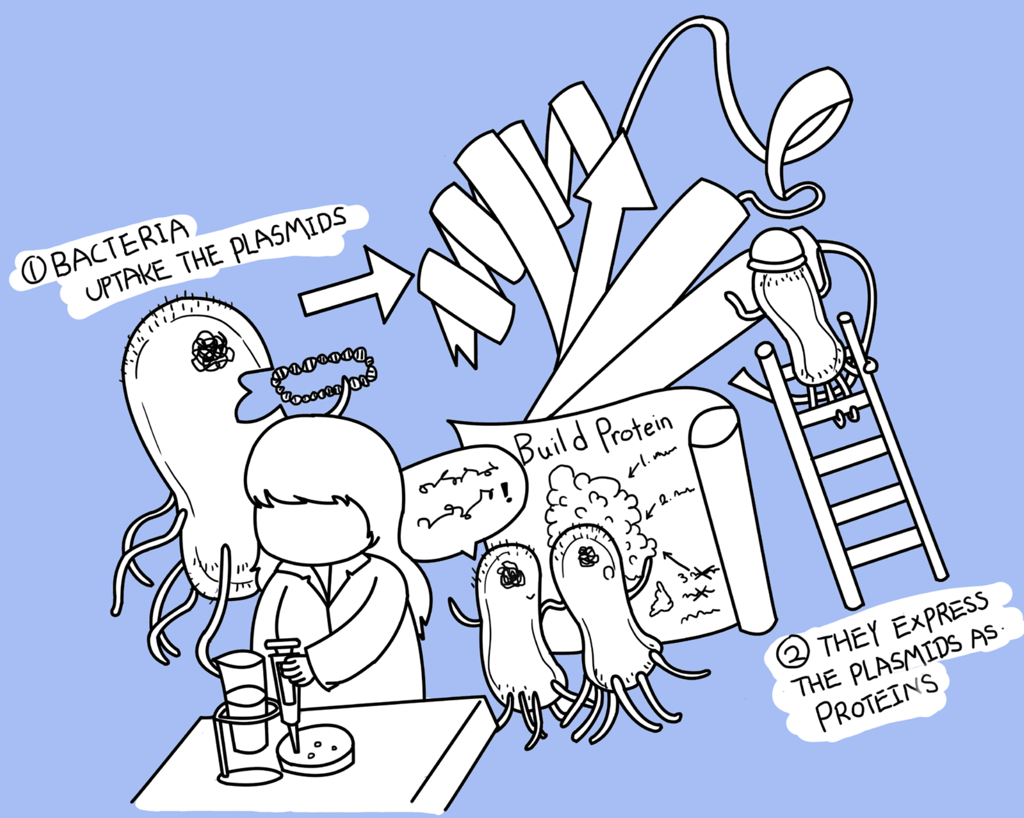
Building proteins with bacteria

Shero Lao

Transformation



Bacterial transformation is the process of inserting a foreign plasmid (a small, circular DNA strand) into bacteria, such as the bacterium *Escherichia coli*. Harmless *E.coli* strains are commonly used in a scientific laboratory to store DNA sequences and produce proteins because of how easy and fast these cells grow in the laboratory setting. During transformation, bacterial cells uptake the foreign plasmid, replicate the plasmid, transcribe the DNA into RNA, and eventually translate these RNA strands to produce an enormous amount of proteins of interest. This process of replication, transcription, and translation is known as the central dogma of biology. Not every bacterial cell takes up a foreign plasmid during the transformation process. Therefore, scientists use a foreign plasmid that also contains an antibiotic-resistant gene, so a bacterial cell that uptakes the plasmid can be selected on antibiotic plates or media.

SL

Mentorship Benefit of At-Risk Youth

Poverty-based performance gaps take root during the earliest stages of children's lives and fail to narrow in the following years. Students who start disadvantaged are less likely to equal their non-disadvantaged peers. As such, lower socioeconomic status (SES) correlates with lower academic achievement creating performance gaps between the lowest and highest SES quintiles. These performance gaps reflect extensive unmet need and thus untapped talents among low SES children. Introducing diverse and involved mentorship could increase interest and performance of students in our local communities.

Virginia Ju

Low educational achievement leads to lowered economic prospects later in life, perpetuating a cycle of poverty and social inequities across generations.[1] The relationship between economic inequalities and education inequalities is apparent when comparing two southeastern Michigan towns: Ann Arbor and Ypsilanti. To the University of Michigan community, the city of Ann Arbor is well known for its vibrant educational and international community of educators, physicians, engineers, technology developers, artists, and scholars. Across Highway US-23 lies Ypsilanti, a city home to Eastern Michigan University and Depot Town. Once thriving with thousands of manufacturing jobs supplying the local auto industry, Ypsilanti has changed tremendously over the past 50 years as jobs shifted out of Michigan. Since 2001, Ypsilanti lost over 13,000 manufacturing jobs[2] leaving 30.9% of the population living below the poverty line.[3] Unemployment impacts the whole family as indicated by the difference in standardized testing scores between children in Ann Arbor or Ypsilanti. According to the 2018 database of Michigan Student Test of Educational Progress (M- STEP) scores, 63.8% of students in Ann Arbor public schools passed, while a mere 9.6% of students in Ypsilanti Community Schools received a passing score.[4] The reasons behind performance gaps within an economic context are many. Lower income can mean fewer resources and limited access to quality education. Students may be bullied for low SES, which can lead to anxiety and negatively affect academic performance. Lower income can also be associated with less stability at home, which can make focusing in school difficult.[5]

Though poverty, especially intergenerational, is a complex problem further complicated when entangled within the education system, academic disparity could be addressed by introducing students to mentors who are actively pursuing degrees. Mentoring relationships provide critical development opportunities throughout one's career, especially in higher education by providing mentees with insight from an advisor figure.[6] Moreover, students seek out and get the most benefit when mentors mirror their gender, race, or SES. Mentorship programs have been installed at various universities. For example, the College of Engineering at Auburn University in Alabama created a longitudinal mentorship program to provide minority students with academic and psychosocial support during their transition from high

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Katherine Bonefas

school to college. First year students were matched with an upperclassman (3^{rd} or 4^{th} year) at the same school and followed over the course of the year. During this program, cumulative GPA for the mentees correlated with the number of participatory hours in the mentoring group, suggesting that the more mentorship increased academic success.[7] Similarly, when looking at how well underrepresented minorities integrate into the scientific community, informal mentorship programs along with training programs[8] influenced individuals to persevere in STEM.[9] When mentors are able to give an authentic experience of what it is actually like to be an academic, mentees are then able to build confidence, start to enjoy academic programs, and more likely enroll in higher education.

However, the aforementioned programs focus on transitioning high school or first year college students to higher education. Because performance gaps linked to low SES take root early on in student's education (as early as kindergarten[10]), programs ought to turn their focus towards younger students in elementary school. In practice, undergraduates, medical students, and scholars from various academic backgrounds can be brought together in an interprofessional effort to engage elementary school students in Ypsilanti.

Volunteers can not only provide mentorship but also small group instructional activities in order to empower the Ypsilanti elementary school students to take an interest in academics. Increased engagement and interest could additionally improve standardized test scores, a metric that is still important in advancing into higher ed and employment. Mentorship programs created to address a need right in our own community could foster a sense of curiosity and provide access to education that will inspire continued learning in following years.

Within the community of lower-east Michigan, outreach programs seek to provide mentorship programs to local students K-12. Indeed, organizations out of the University of Michigan have spearheaded programs that seek to increase diversity and education locally through hands-on activities and events (see panel). Many of these programs have a focus on STEM education, but some promote history, art, and literature.

While socio-economic and educational disparity are not unique to our area, mentorship outreach programs could make a difference in the lives of students in our local under-performing school district. While diversity and equal opportunity improve the overall quality of every occupation by bringing new ideas, experiences and perspectives to the table,[11] we should do more to ensure student success regardless of background. By providing high-quality mentoring relationships earlier on in our education systems, we can expect improvements in academic performance as well as lower drop-out rates, higher educational aspirations, and positive feelings of self-worth in underrepresented students.[12] Most professionals would not have made it to where they are today were it not for their mentors at many stages of their academic careers. As such, we should be developing mentorship programs that cater to students' needs, mirror their demographics, through combinations of formal and informal initiatives that combine STEM and humanities education to help students flourish. A consistent mentorship program created to address this need can foster a sense of curiosity that will inspire continued learning in the years to come.

VJ

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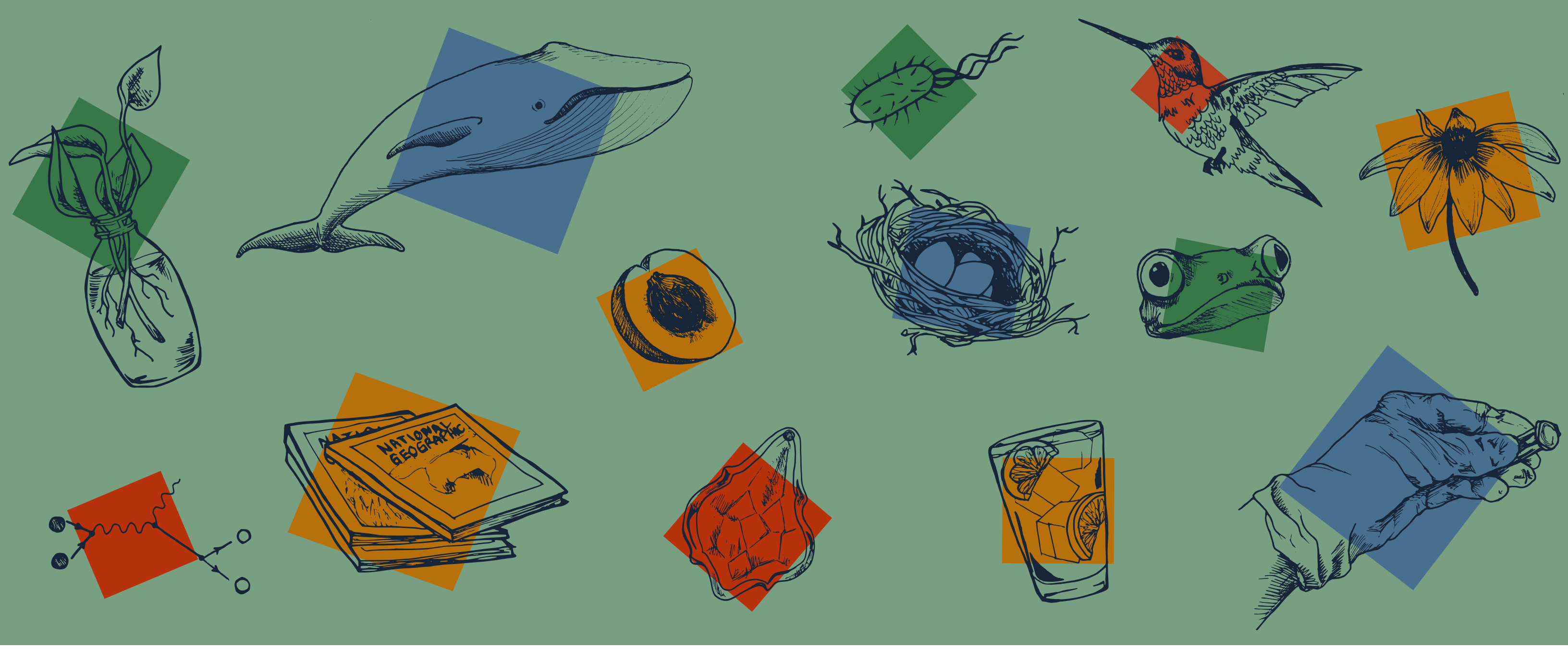


No Lab Coat Required

Lessons in Science from my Grandmother

Jennifer M Baker
Illustrations by Katherine Bonefas

What does it mean to be a scientist? Though the daily activities of researchers from diverse scientific disciplines may appear unrelated, all scientists fundamentally do the same thing: ask questions that lack answers over and over until an answer takes shape. This description may seem like an oversimplification of the highly technical work that scientists do, but I have yet to encounter a scientist that serves as a counterexample to this assertion. As a researcher who is still early in my career, the responsibility of answering life's answerless questions can feel overwhelming as I struggle to develop my scientific skills while attempting to answer research questions, a process that seems a little more daunting on some days than others. Despite the challenges that accompany my identity as a still-developing scientist, there is also a part of me that knows I am going to be okay. This self-assured perspective might sound like unfounded optimism, but this confidence comes from being trained by one of the best minds I have ever met. This person, my first scientific mentor, taught me the most important lessons I've learned about being a scientist. Oh, one more thing—she is not a researcher, she's my grandmother.

One of my earliest memories of my grandmother is sitting on her living room floor, my eyes climbing the yellow-spined stacks of *National Geographic* magazines under her coffee table. On the top of the table, piles of *Discover* and *Scientific American* magazines left just enough space for her glass of iced tea. Despite never having internet access at her home in southern Delaware, she kept up to date with scientific research as fast as the postman could deliver.

Those magazines comprised some of my earliest reading material, with dog-eared pages marking sections my grandmother eagerly waited to show me—blue whales in freezing Alaskan waters, lion cubs in African grasslands, an adventurer swallowed up by Yosemite's grandeur scaling stomach-sickening walls. Articles in scientific magazines were not only a source of entertainment for her, they made her marvel. As I sat cross-legged on the carpet and savored the staple-bound

pages, she would recount the particular lines or images that compelled her to crease their glossy corners in preparation for my next visit. Listening to her gush about the worlds she explored from her sofa, I joined in her enthusiasm. It was hard to imagine a person that could resist falling in love with biomedical breakthroughs or newly discovered species from the rainforest after hearing her describe them with such reverence and excitement. At the end of these conversations over magazines and iced tea, I met my grandmother's sparkling gaze and nodded emphatically as she said, "Isn't that just incredible?"

When the magazines did not satiate her curiosity, my grandmother would call and ask me to find the answers to her questions, inspired by her reading. Sometimes I would know something about the topic, but more often I would have to read more to give an answer, like the time she asked me what a Higgs boson, a recently discovered class of subatomic particle, was after hearing it referenced on a television show. No matter what, I would dutifully study the topic of interest and call her back, excited to tell her the facts I had learned, even if I lacked all the answers. Occasionally, my grandmother' home library and my internet research failed to placate her inquisitiveness. When this happened, I would rent and deliver books from the public library so she could read further on the topic, though sometimes I was doubtful that even experts would know the answers to the insightful questions she asked.

Though reading transported her to exotic lands and inspired "research projects" on all sorts of unfamiliar topics, my grandmother also loved the nature she observed from her window. The window above her kitchen sink overlooked a bush that housed the local robin's blue-egged family and the hummingbird feeder that, April through October, was never allowed to be empty. Her favorites were the bluebirds that nested in the backyard birdhouse designated only for them. In the spring, we would chase away the unwanted spider residents so the bluebirds could build their nest. If she didn't see a pair nesting, my grandmother would make us go check the box and clean it out again, evicting frogs and bees just as they had settled into their would-be home. Even in the winter, a stuffed toy bluebird peered out her kitchen window into the cold, gray skies, as if a lookout for the first signs of spring and the blue-winged visitors that came with it. When we visited, my sisters and I would sit barefoot at the bar, trying to catch the rainbows scattered across the counter by the faceted teardrop prism hanging from the window latch, while my grandmother would tell us about the birds she had seen since our last visit.

My grandmother did not limit herself to distantly observing the natural world through the glass of journalists' camera lenses, my computer screen, or her kitchen window. Her love of nature led her to, quite literally, get her hands dirty. While none of her work ever made the scientific journals, my grandmother did plenty of experimenting in one of the few ways accessible to her: gardening. She transformed her house into a well-loved and well-landscaped home with dormant, leafy stubs ordered from nursery catalogs, shaped through much trial and error by her patient hands into a vegetable garden, an orchard with apples, peaches, apricots, and pears, and a flower garden. With the same grit that enabled her to weather her first husband's departure and divorce, her second husband's death from cancer, and her son's death two weeks before his high school graduation, she spent hours relentlessly yanking the weedy invaders that threatened her tidy landscaping. In later years, when emphysema prevented her from working outside, plant cuttings in glass jars balanced precariously on her kitchen windowsill became her primary mode of gardening, while rogue black-eyed susans escaped the edges of her flower garden and dotted her backyard with warm, yellow bursts of petals.

My grandmother passed away when I was in college. At that point, I was a science education major and planned to teach high

Jennifer with her grandmother Dorothy, Delaware, 1996.

Photo courtesy of Jennifer Baker

school biology or chemistry after graduation. Twelve hours away from my hometown, I ditched my teaching assignment in a middle school special education classroom to say goodbye to her over the phone after her recovery from a broken hip took an unexpected turn. I cried the length of that phone call and her funeral a few days after.

The next summer, I came home from college in early July, determined to spend my time off in my coastal hometown reading and relaxing on the beach, a pastime my Midwest research gig had denied. Cross-legged on my crumpled bedsheets, I opened my laptop and logged into my public library account. Almost immediately, hot tears blurred the screen and spilled onto my keyboard. There, under the holds tab, was a book my grandmother had asked me to reserve over a year earlier, now available to pick up at my earliest convenience.

While I don't remember the title of the book that arrived many months too late for my grandmother to read, the sudden flood of memories that accompanied that moment has not faded. That moment was a potent reminder of my younger self, the one who, like my grandmother, was obsessed with answering life's answerless questions. My original choice to become a teacher was inspired by my grandmother's enthusiasm for sharing knowledge, but it did not quench my desire to experience discovery for myself. While my grandmother could only read about scientists, I realized I could become one of them. I stuck with my education major because I loved working with students, but ultimately my inherited fascination with catching glimpses of undiscovered knowledge compelled me to change my plans and pursue a career in research. Finally, I had found a way to search for the answers that library books had never offered.

While my grandmother served as the initial inspiration for my love of science and eventual choice of career, there are many other reasons why I chose to pursue a career in research. Scientists seek to understand the natural world for a litany of practical and noble reasons: to develop treatments for disease, to invent problem-solving technology, to preserve the natural order of the biosphere, or simply to understand the inner workings of the universe for future scientific endeavors. These reasons motivate scientists to spend hours reading about previous discoveries to inform their own ideas, develop the technical expertise necessary to test their ideas, and communicate their results to others. Scientists pride themselves on thinking critically about their topics of interest, rationally analyzing the evidence and testing their hypotheses from every possible angle. They find satisfaction in the hard work of scientific discovery and in the knowledge that our efforts can make the world a better place. I, too, share these sentiments as primary motivations for my decision to become a scientist.

Like many scientists who are trained to think objectively, these impersonal motivations often dominate the professional narrative I tell when people inquire about my career choice. However, I express the real reasons for becoming a scientist, the ones inspired by my grandmother, far less readily. My grandmother taught me curiosity, open-mindedness, relentless optimism, appreciation of life in all forms, patience for thankless tasks, and grit in the face of disappointment. Each of these qualities are those of a successful scientist, instilled in me by a woman that never donned a pair of gloves or stepped into a laboratory. My grandmother never intentionally set out to teach me these lessons, but they have equipped me to navigate an often-difficult professional journey. These lessons embody who she was and who I am as a result.

So, on behalf of my grandmother, Dorothy Fields, I humbly offer some advice for any scientist, but young ones especially:

Be curious.

Good scientists are great readers.

Ask questions and find out the answers. If the answers are not within your reach, ask someone with longer arms.

Love living things. Core for them, no matter how small.

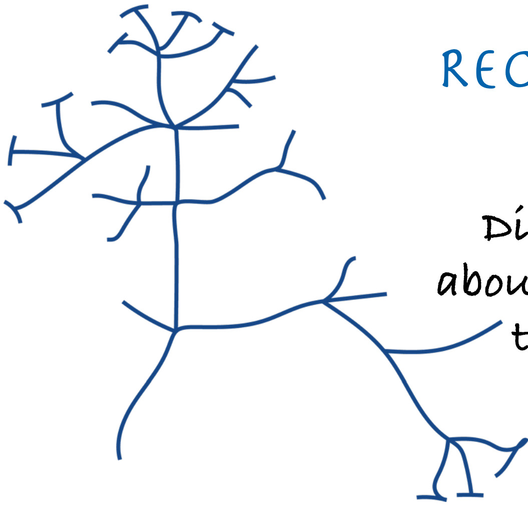
Refuse to let circumstances stop you from building a life you love.

And most impontantly: Pursue the things that make you wonder.

My grandmother's embodied advice is my training and scientific heritage. I wish I could pick up the phone and have one more hour-long conversation with her, detailing our shared obsession with how incredible the world is. But I have these pieces of wisdom and a windowsill full of plants instead, and I am grateful. Even when I doubt myself, these lessons remind me my grandmother inadvertently trained me to be a scientist from a young age. Instead of being limited by what I do not know, I reach out to the work of other scientists and to peers and mentors who help me interpret the unknown. I refuse to allow the value of life, human or otherwise, to depreciate in my eyes simply because I study it every day. I freely and enthusiastically communicate what I have learned through my teaching and writing so that others may also wonder at the world's hidden intricacies, which I have been privileged to observe. And I try to learn from, not dwell on, my failures.

When she passed away, my grandmother had no idea that just a few years later, I would publish original scientific research and go on to study for my Ph.D. Though my active choice to pursue research was recent, my identity as a scientist was formed long ago by a dear woman's mentorship, a woman that never wore a lab coat. It is in her honor that I wear mine proudly and look beyond the gray skies of inevitable setbacks for the spring-like hope of success and, hopefully—if I am lucky—bluebirds.

JMB



Recognizing the "I" in Science

Dispelling assumptions about sexual selection across the animal kingdom

Patricia DeLacey

It was a cloudless morning in the Simien Mountains National Park in northern Ethiopia. "There," said Esheti pointing down the cliff, spotting the geladas[1] with an expert eye. Through my binoculars I saw a line of geladas amble up the sheer cliff. Once they reached the grassy plateau, I collected behavioral data. Talisman, the dominant male of a unit, was groomed by the adult female, Coco, while he puffed out his chest. His bright red chest patch and golden-brown mane looked particularly impressive juxtaposed to Tecate, the subordinate adult male in the unit. Tecate's mane was short, his shoulders sloped inwards, his chest patch noticeably pale pink instead of red. Looking at the surrounding geladas, I noticed the variation in chest patch color across male dominance status.[2] What could be the purpose of exposed red skin in a cold, high-altitude environment, and why is there variation in red color? This puzzling unique trait is putatively linked to reproductive success and sexual selection.

1 A monkey species endemic to the highlands of Ethiopia

2 In male geladas, dominance status is determined by mating access to reproductive females. Dominant "leader" males mate with a group of 2-12 adult females, subordinate "follower" males spend time with this group but rarely mate, "bachelor" males spend time with only other males and do not mate.

Natural selection, proposed by Charles Darwin, is the most well-known and most taught theory regarding evolutionary biology. By exploring and observing nature, Darwin noticed species change over time by exhibiting variations in particular traits. In response to harmful environmental stressors, those that survive get the chance to reproduce and pass on their traits to the next generation.[3] However, not all variations enhance survival; he noted a trait that did not fit into his theory of natural selection: a peacock's tail. The tail's vivid, iridescent colors and five-foot length make it nearly impossible to hide and escape from predators, such as tigers and leopards. What pressure could have selected for such an extravagant tail? One word – females. The peacock's tail does not aid in survival, but it instead helps the peacock "woo" choosy females in a flashy mating display.

3 The theory of evolution by natural selection has continually been supported by evidence from the fossil record, biogeography, embryology, genetics, antibiotic/pesticide resistance, and even direct observation in experimental and natural settings.

Traits for my mate

Sexual selection focuses on traits that give an individual an edge for mating opportunities over the competition with members of their own sex. Charles Darwin first postulated the theory of sexual selection in *The Descent of Man, and Selection in Relation to Sex* in 1871 to explain ornamentation traits, such as the peacock's flashy tail, and weaponry traits, such as a ram's horns. These sex-specific physical traits appear at sexual maturity and are secondary to biological sex-specific traits of genitalia. To name a few examples: lions have manes while lionesses do not; male mallard ducks sport a bright green head while females are

A male gelada in Ethiopia, named Fabio. Courtesy of Patricia DeLacey.

note on gametes

SEX	GAMETE SIZE	NOTE
Male	Small	Sperm; genetic material only
Female	Large	Egg; nourishing cytoplasm and genetic material
Hermaphrodite	Both small and large	Can produce either sperm or egg
Intersex	Either or none	Combination of male & female chromosomes, sex hormones, & reproductive organs/genitalia

brown; wild male gorillas weigh up to 400 pounds while females only weigh up to 200 pounds. The more intense the mating competition, the more disparate the appearance between males and females.

However, Darwin focused on male traits that females *lack,* such as the weaponry for male-male competition or ornamentation traits used for attracting females. As such, he had a very male-centric focus and stated that traits arise from a "struggle between the males for the possession of the female."[4] Darwin was on the right track, though it's not as simple as competitive males and coy females. But can we blame him for his observations and conclusions?

Science prides itself in being objective. Scientific discoveries are based on evidence, systematically collected information gained through carefully conducted experiments or observations. This pursuit of objectivity has a caveat: science is conducted by humans. Each person brings a unique perspective to scientific research, but these perspectives can carry bias, unconscious or otherwise, that shape how they approach a question. An individual's biases determine what questions are asked, how they are asked, what methods are chosen, and what methods are excluded. The larger scientific consensus can further distort this goal of objectivity.

To approach questions, scientists form *testable* explanations for a phenomenon, based on preliminary evidence. Evidence they choose to collect is rooted in observation. Observations are rooted in the collective consensus or perspective resulting from previous experimentation. Like all things in science, theories are challenged, tested, and revised where necessary as additional evidence comes from new investigations. Theories sometimes have room to expand as data accumulates, and the theory of sexual selection is no exception. Darwin did the best he could interpreting the data available and creating his theory of sexual selection, but the true diversity of sexually selected traits go beyond what he could have imagined.

Stay at home dads and flashy females

Before we delve into sexual diversity, we must ask: what defines male and female? Biological sex is defined by the size of the reproductive cell (gamete) the organism produces (Note, left).[5] In sexual reproduction, a small and large gamete must be brought together to form a zygote which develops into an egg or fetus. The union of two dissimilar gametes, called anisogamy, is nearly universal in sexual reproduction.[6] The sex contributing the smaller gamete (male sperm) has a smaller initial investment in reproduction than the sex contributing the larger gamete (female egg). Males can produce hundreds of thousands of sperm with little energetic investment while females are rate limited in the amount of viable eggs. Unequal investment in gamete production often corresponds to unequal investment in offspring care. *Typically,* this looks like males competing with each other, males mating with as many females as constraints[7] allow, and females choosing high quality males to produce strong offspring.

Are males always competing for choosy females? In the Wattled jacana, a wading bird native to Panama, females are larger than males and have sharp spurs on their wings that females use to compete with one another to establish a territory and a harem of males.[8] Within each female's territory, one to three or more males defend a nest and incubate eggs laid by the singular female. In the broadnosed pipefish, a saltwater fish species in the same family as seahorses, females are again larger than males, develop brighter colors than males, and court males with a mating dance.[9] One female will lay

4 Darwin C (1871). The Descent of Man, and Selection in Relation to Sex. New York: D. Appleton Company. p. 72.

5 This should not be confused with gender identity, gender expression, or sexual orientation.

6 Some species of fruit flies that have multiple sperm sizes and a few fungi have one gamete size. (Roughgarden J (2004). Evolution's Rainbow: Diversity, Gender, and Sexuality in Nature and People. Berkley: University of California Press.)

7 Environmental and social

8 Emlen S T *et al.* (2004). *The Auk*, 121(2), 391-403.

9 Rosenqvist G & Berglund A (2011). *J. Fish*

her eggs in several male's brooding pouch where they will carry the eggs until they hatch. As such, Darwin's theory that males always compete does not hold up with these more recent observations where females compete for mates.

What dictates which sex competes? In the case of the jacana and pipefish, females produce eggs faster than males can care for them. Thus, males are tied up with reproduction while more females are ready to mate at any given time and must compete with one another for mating opportunities. In mammals, females are responsible for offspring after birth[10] because they provide milk for infants. This time commitment for them means that more males are available to mate, and males must compete with one another for mating opportunities. As such, the ratio of time it takes to reproduce between males and females in a given species largely determines who competes for mates.[11]

Expanding the theory

Not only are sex and reproduction important in mating, but also (non-sexual) social interactions between members of the same species. In some songbird species, when a parent returns to the nest with food, the offspring open their mouths wide and stretch up to solicit food. The color inside their mouth, called a gape, indicates immune function, where in barn swallow nestlings, red correlates to a better immune system.[12] As such, parents are more likely to invest in deep red, healthy chicks because they have a stronger chance of survival. This would be an example of a non-sexual signal between parent and offspring. In 1983, evolutionary biologist Mary West-Eberhard expanded the use of weaponry and ornamentation traits in non-sexual interactions between parents and offspring or among siblings. Her theory of social selection[13] suggests that interactions between individuals of the same species are chosen, both in sexual and non-sexual contexts, based on the ability to attain limited resources. Thus, sexual selection exists as a subset of social selection as a part of a species' means of survival.

Catherine Redmond

Darwin's original theory of sexual selection has been challenged and altered over time, reflecting the impact of society's shifting views on sex and reproduction, along with more evidence collected from species Darwin did not survey. A unique human trait, as far as we know, is to justify, validate, or approve behaviors in human society. Humans often make the misguided assumption that because something exists in nature, it is morally "good".[14] A behavior exists in wild animals because it either improves reproductive success or increases the chance of survival.

Stepping back from our perceptions and moral structures, scientific exploration should strive to identify an objective framework to discover explanations for the things we observe in the natural world. This provides a significant challenge since our experimentation is conducted under a social and cultural context, much like Darwin. Nevertheless, we should be aware of how our views impact the science conducted that our views can limit our perspective; we must remember the goal of science is to understand the natural world.

PD

Biol. 78, 1647-1661.

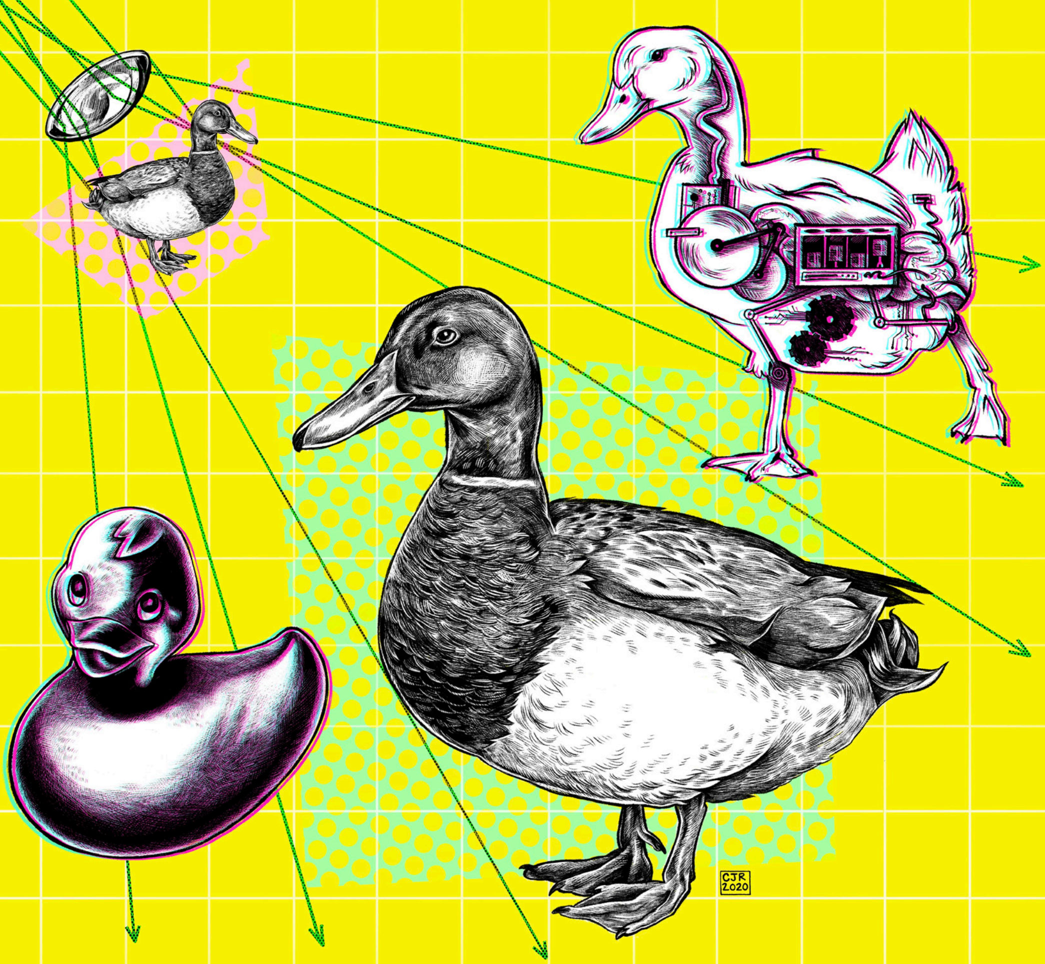
10 Some mammals like the california mouse practice biparental care where both parents raise the offspring; Gubernick D J & Teferi T (2000). *Proc. Biol. Soc.* 267(1439): 147-150.

11 Of course, the distribution of food, predation risk, environmental harshness, population density, and the required level of paternal care also impact these structures: it's never a simple rule of males compete and females decide.

12 Saino N *et al.* (2003). *Behav. Ecol.* 14(1), 16-22.

13 West-Eberhard M J (1983). *Q. Rev. Biol.* 58(2), 155-183.

14 This is formally known as the naturalistic fallacy



A Different Perspective, on the Light of Reason

Sarah Kearns

Scientific ideas are always changing, updated by new observations and models. Tools and instruments are invented and perfected to push the boundaries of the observable world. Better telescopes allow us to see farther out into deep space and image black holes, while improved microscopes zoom into the atomic structures of proteins and inorganic compounds. These instruments augment and expand our five senses and let us 'see' what would otherwise be impossible. Using research equipment in this way not only changes science but also impacts how scientists wrap their heads around data and, in turn, form models and hypotheses that drive future research. Scientific findings impact not just thoughts and feelings but also actions and narratives about the world; for example, climate research permeates conversations about lifestyle, politics, and how individuals evaluate and face crises.

In the earlier days of science, the questions researched were much more basic: of what were objects made? How does light work? Without the instrumentation and knowledge that we have now, the models and philosophy of the time had a bigger impact on scholars' understanding of the world, yet even today scientific practice and ideas play a large role in epistemology, or the nature of knowledge itself. Scientists and philosophers alike would probe, either via observation or thought, how humans understood the world. Rene Descartes certainly wasn't the first person to posit answers to these questions, but as the so-called 'father of modern philosophy' his ideas still echo in philosophy classes and discourse alike. Descartes's work with lenses offers a metaphor, paralleling how he imagined humans interpret visual perceptions to understand and rationalize the world around us. Even hundreds of years later, scientific theories and philosophical models continue to be entangled.

Focus

During Descartes's time, light was thought to travel as an outward push, bouncing off intervening air and objects. By analogy, Descartes described that sight is like a blind man tapping out a path between obstacles with a cane or a walking stick. Vision lets us 'feel' our way visually, as a bat uses air pressure for echolocation. Forces from other objects create air pressure, allowing light to accept and transmit this energy through and against other media. Since light radiation is like a projectile, he postulated, it can reflect and refract when it encounters substances other than air particles. We are able to see when this light enters our eye - through the lens and into the humor.

Through medical procedures and operations, it was known that neither the eye nor the lens are perfectly spherical and instead are more like ovals. This oval (or hyperbolic) lens can focus parallel rays into a single point (Fig. 1). Rays of light originating from a full-size object are focused on the back of the eye (where the optic nerve transmits the resulting image to the brain for identification). For

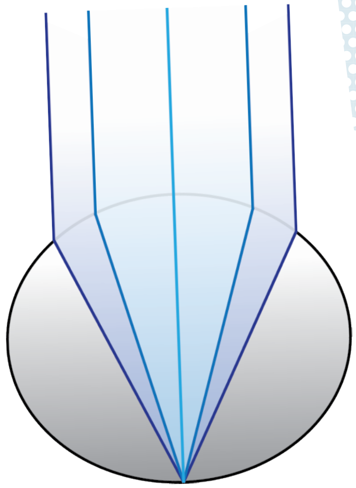


Figure 1: Descartes' single-axis model of lenses

Descartes, "[nature] wished to gather all the radiation of any visible object entering the opening of the [pupil] into a single point of the retina in order both that the point of the picture might be all the more evident, and the rest of the points of the picture might not be confused by extraneous rays whether stray or gathered together." This means that the main object is brought down to a point, such that other parts in view aren't distracting. From this observation, Descartes uses vision as an analogy for the formation of ideas.

Even though Descartes was first and foremost a rationalist, requiring that everything, however seemingly obvious from firsthand experience, be derived from first principles rather than observation, he concedes that "whatever I have up 'til now accepted as most true, I have acquired from the senses or through the senses."[1] Perhaps not everything needs to be proven through a series of mathematical proofs if there is a way to focus our attention and thoughts towards what's true.

That's exactly what lenses do with light: they bring a particular object into focus. "If one tries to look at many objects at one glance, one sees none of them distinctly. Likewise, if one is inclined to attend to many things at the same time in a single act of thought, one does so with a confused mind."[2] Looking around a room, our eyes focus on particular objects, near or far, and everything else becomes a bit more blurry. Our eyes cannot see everything, yet our mind desires to know what is going on at all scales and places, even beyond our peripheral vision. Using lenses as an instrument, whether in a telescope like Kepler or a microscope like Hooke,[3] we can see more of our world, but these distant objects are still brought down to a single point.

To obtain knowledge about the world our minds must similarly focus concepts and ideas to a 'single point,' or an integrated framework. If we don't have a clear mental model, then as we collect more data the concept we are investigating is harder to put into focus because there is no grounding center. By finding perspective to make our vision clear and distinct, we remove the confusion, increasing the signal amongst the noise.

1 Descartes, *Meditations on First Philosophy*, Med 7.
2 Descartes, *Regulae*, Rule 9
3 Both contemporaries to Descartes

Perspective

Descartes's single-axis theory of concept formation certainly does not describe epistemology in its entirety and has been criticized throughout philosophical discourse, even by his contemporaries. As an experienced lens grinder,[4] Baruch Spinoza had a different perspective on the theory of light, and a different theory of the soul and epistemology. Following in the rationalist tradition around 30 years after Descartes, Spinoza posited that there are two types of knowledge: random experience and reason. The former comes from raw observations of nature and our surroundings, but does not give us any ideas, because our five senses are not enough to obtain understanding. Reason, on the other hand, synthesizes the impressions derived from the senses and connects them to other objects. For Spinoza, the resulting ideas are attributable to God and the laws of nature. Information obtained through our five senses would never be enough to know or understand nature, but Spinoza still postulated that the mind can have an "adequate knowledge of God's eternal and infinite essence."[5]

4 Descartes noted "specialists like hunters and sailors train themselves to look at very distant objects and engravers or other artisans who do very subtle work to look at very close ones," suggesting that experience and training, we can alter our own lenses to identify particular details that are critical in constructing our world views. *Discourse on Method*, Discourse seven.
5 Spinoza, *Ethics*, 2p29. No other philosopher in history has been willing to make this claim, but no other philosopher has really identified God with Nature in the way Spinoza did. We may well appreciate this delineation today in an era of separation between Church and State, but during Spinoza's time this was blasphemous and got him excommunicated from his very traditional Amsterdam Portuguese-Jewish congregation for "his wicked ways," "abominable heresies" and "monstrous deeds" despite not having published his ideas. Since he never referred to this period of his life in letters or journals, it's difficult for us to fully understand why he received this harsh punishment from his community.

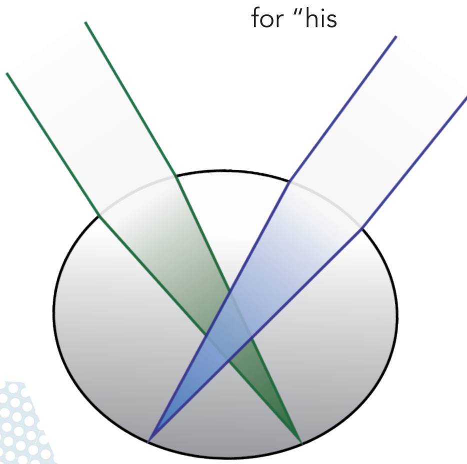


Figure 2: Spinoza's multi-axis model of lenses

Spinoza's paradigm-shifting notions did not stop at religion and theology but extended into how he considered the interplay between vision and the mind. Instead of parallel rays focusing to one ideal point (like Descartes), for Spinoza, the eye was able to focus light to a variety of axes. Where Descartes' single-axis lens represented his belief in clarity for clarity's sake, Spinoza thought that vision represented many perspectives being focused within the eye (Fig. 2). In rejecting the single-axis model and its analogy of center-focused human vision, instead Spinoza suggests that with vision occurring across a field of foci, the periphery has no less truth than the center. "It is certain that, in order to see an entire object, we need not only rays coming from a single point, but also all the other rays that come from all other points. And therefore it is also necessary that on passing through the glass, they should come together in as many other foci."[6]

Descartes' theory is closer to how actual light is bent and focused in a lens (perhaps ironic given Spinoza's practical familiarity with delicate glass lenses). But here Spinoza's describing an *ideal eye*: that window into the soul, where focused light is an analogy for synthesized concepts. Spinoza thought that a single-axis lens would limit how much information is gathered and focused. Rather than being the combination of many clear and distinct ideas, truth for Spinoza is the combination of everything in one's field of view. Because he knew that his panoptical or multi-axis lens was not realistic physically, Spinoza considered the human eye and its perceptions inexact, bolstering his rationalistic philosophy. In order to maximize understanding, the mind must utilize tools and work to bring concepts and observations together:

> The most perfect method [for understanding] will be one which shows how the mind should be directed… As [the mind] understands more things, at the same time [it] acquires other tools which facilitates its further understanding… The more the mind understands Nature, the better it understands itself… and will become then most perfect when the mind attends to or reflects upon the knowledge of the most perfect Being [God or Nature].

According to Spinoza, the only way to have a clear model of the world around us is to continue to see with multiple perspectives and to continue to update and expand what we see and how we see it. This conception of how to contextualize the world is what we might nowadays call 'intersectional' for its similarity to viewing topics through the lens of different interest groups or cultures.

6 Spinoza, *Letter 40 to Jelles*, Trans. Samuel Shirley.

Refracted Ducks

Catherine Redmond

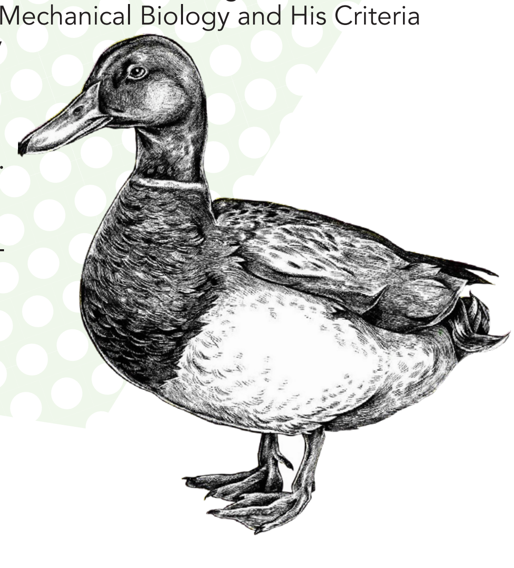
All the light we see first travels through a lens. The lenses in our eyes refract the light from our world, distorting it for our brains to reconstruct. Our visual reality is virtual, containing a degree of separation between reality's undistorted, true form, and ultimately our perception. The true nature of reality has been the discussion of philosophers for generations, from Plato's allegory of the cave to René Descartes' reductionist theory of life. Descartes argued that a sufficiently complex machine, or automata, would be indistinguishable from a living animal. That is, Descartes perceived life to be a collection of parts that could be disassembled and reassembled. A century after Descartes published his theories on natural reductionism, his ideas on the mechanical reality of life were practically tested. In 1739, the French inventor Jacques de Vaucanson unveiled his *Digesting Duck* — a duck-shaped machine that appeared to be able to eat and defecate. The Digesting Duck in actuality was incapable of digestion but could be perceived to be without disassembly to reveal its internal workings.

What is the true nature and reality of a duck that we see refracted through a lens? *Refracted Ducks* playfully presents three virtual images of a refracted duck, with various degrees of separation from its original form, from a reductionist machine to a simple rubber toy.

1. Caelli, T. (1981). Light and Introductory Optics. In Visual Perception: Theory and Practice.

2. Ablondi, F. (1998). Automata, Living and Non-Living: Descartes' Mechanical Biology and His Criteria for Life. Biology and Philosophy, 13, 179–186.

3. Riskin, J. (2003). The Defecating Duck, or, the Ambiguous Origins of Artificial Life. Critical Inquiry, 599–633.



Illuminated

While Descartes' theory of light through a lens was more correct than Spinoza's, their models of the lens parallel their respective philosophies. Both of these models for epistemology have some validity: we gather information about the world through our senses and, depending on whether we are trying to deeply understand it and focus down to a point or put that point within a bigger context, we use Descartes' or Spinoza's "lenses," respectively.

New ideas continue to challenge the validity of older models, more starkly in scientific contexts where old models can become outdated by new discoveries,[7] but in philosophical inquiry, scholars are more often finding and recontextualizing past ideas. In terms of Cartesian concept formation, it's mostly accepted that we form concepts through observation followed by focusing down to essential characteristics of the particular object or idea.[8] Similarly, the "single-axis" lens model of epistemology finds a new home in reductionism, where an idea or phenomenon is dissected and broken down into its distinct components. The "poly-axial" theory, perhaps, has more of a contemporary footing with perspectivism, which states that people's perspectives will keep them from obtaining objective facts,[9] or relativism, which takes each individual's perspective as its own truth within the cultural context in which it was formed. Until recently, epistemology has focused on how individuals form beliefs and knowledge structures - both Descartes and Spinoza described the process of a single person. In contrast, social epistemology takes into consideration that our ideas and values can be acquired from or inspired by others. At the very least, sharing ideas, results, and models with others allows for the ideas to take hold within a community. Sometimes it takes a lot of effort for ideas to be adopted within a scientific or cultural framework. For example, astronomers like Nicolaus Copernicus and Galileo Galilei, despite their observations and careful measurements, had to argue with their communities in order to switch the accepted model of an Earth-centered solar system to a sun-centered one. These shifts within particular fields of research only impact future research if their idea is adopted into the larger social contexts.[10] Perhaps without the Copernican Revolution, Kepler would not have had the right knowledge and mindset to calculate the laws of planetary motion with his telescopes. Perhaps without Kepler's careful mathematics of telescope lenses, Descartes might have had a very different theory of lenses, and a very different model for epistemology.

In an increasingly interdisciplinary world, our goals, projects, and research can combine knowledge that individuals, groups, and cultures have obtained through experience and link them together in a common and accessible explanation. This idea of consilience is to synthesize reductionist ideas and combine them into something more, integrating aesthetics with science and culture with technology. This is analogous to physicists' goal of a unified field theory,[11] but on a much larger scale, including nonscientific fields. Scientific models, especially theories of light and lenses, have drastically changed since the times of Descartes and Spinoza, largely due to inventions and technology that let us answer questions on new scales and dimensions.[12] We don't have to look much farther than The Internet to see how a technological tool profoundly influences our culture and societal values. As new tools are invented and implemented, we must be mindful of how they change our perspectives, and in turn how they influence our research and knowledge-gathering.

SK

7 Kuhn, The Structure of Scientific Revolutions & Lakatos, Falsification and the Methodology of Scientific Research Programmes (1970)
8 For example, we learn "tree" by seeing many types and species of trees and then coming to the definition of 'woody perennial plant, typically having a single stem or trunk bearing lateral branches at some distance from the ground' such that height or leaf shape has nothing to do with tree-ness. Aristotle's *Categories*
9 Nietzsche, Will to Power

10 Kuhn, The Structure of Scientific Revolutions (1962)
11 A so-called "Theory of Everything" to unite quantum mechanics and relativity.
12 Now physicists know about electrons, photons, and the Heisenberg uncertainty principle. See Feynman, QED (1985) for an accessible explanation of quantum mechanics and light.

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