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# NU SCI

# COLOR

## Letter from the Editor

As Northeastern huskies, we proudly sport our red and black gear any day of the week. As scientists, we don pristine white lab coats and blue gloves to observe vibrant yellow and green bacteria, transparent C. elegans, or red-eyed Drosophila. From colors produced through chemical interactions to the genes that determine the color of our skin and hair, color is everywhere.

So, in our second issue of the Fall 2017 semester, we are breaking down the science of the colors in your everyday life.

Our writers take you through a history of how early thinkers like Aristotle and Galileo explained color, and bring you up to speed on the great discoveries and hard work of LGBT scientists. From the different types of animal camouflage to the way that color impacts taste to the use of the color pink in jails to increase calm energy, Issue 34 has it all.

I've been thinking a lot lately about the importance of science communication. At NU Sci, our primary goal has always been to share as much as we can about diverse and current topics in science around the world. Having "color" as our theme this issue gave us the opportunity to do that. Everything we do and see has some sort of science behind it. Current topics of debate, new technology, the changing climate - everything is based in science and discovery. Within our color issue, you'll learn how climate change affects annual foliage and the importance of the carbon cycle. You'll also be able to explore new technologies for color-blindness, atomic force microscopy, and more. We can only improve as citizens if we become more aware of what that science is. If you learn something new today as you browse through the many pages of articles, share it with a friend and help us spread science as far and wide as possible.

Since this issue is one of our most colorful yet it seems appropriate to give a special shout out to our design team. Head Designers Annie Lee and Kristi Bui supervise a team whose job is to bring our writing to life. Our abstract themes and complex topics don't always lend themselves to simple design work, but the designers are always up for the challenge.

And as always, I want to thank our constantly growing team of writers, marketers, editors, and more that help us to create a great product and further science communication across the university.

Sage Wesenberg
Editor-in-Chief

P.S. If you can't get enough of NU Sci, now you don't have to wait for Issue 35 in the spring. Subscribe to our newsletter (bit.ly/nusci) to get monthly updates on new articles, events around campus, and other science club features!


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NU SCI EXPLAINS

# Synesthesia: an experience without an explanation

BY CICELY KREBILL, BIOLOGY, 2019

DESIGN BY ANNA LI, BEHAVIORAL NEUROSCIENCE, 2018

**Previously considered to be a mere curiosity,** synesthesia is an unusual condition, continuing to both interest and puzzle scientists. Individuals with synesthesia experience an atypical sensory input paired with a normal perception. For example, grapheme-color synesthesia is a type of synesthesia in which numbers and letters elicit the experience of colors. When asked what color a particular number feels like or represents, synesthetes are able to describe their experience and it frequently stays consistent, even when asked again five years later. Although grapheme-color synesthesia is the most prevalent form of synesthesia, many different sensory experiences can be linked, including feeling tactile shapes while tasting a specific food or music evoking specific colors. This condition is believed to be relatively rare. Recent research suggests that it affects about 1 in 2000 individuals, however many predict this to be an underestimate. Because these cases are considered to be both rare and under reported, researchers lack a complete picture on the mechanisms that influence and create it.

Genetic components influence the development of synesthesia. The condition runs in families and has been suggested to be more common in women than men. Early researchers believed that it was possibly X-linked dominant, passing through the X chromosome from the mother or father to their offspring. This theory has since been reconciled with recent studies, including one where monozygotic twins were found to be discordant for synesthesia. Current researchers believe that the answer is not as straightforward as dominant inheritance, rather quite complex.

Besides the genetic mode of transmission, cognitive and psychosocial models fail to reveal a full explanation of this condition as well; a multitude of theories exist in this field. One theory discusses that synesthesia could result as a failure of neural pruning, with individuals who have a greater conscious awareness of their synesthesia having more neural connections as compared to others. Another hypothesis is built on the fact that the two regions of the brain that processes visual word and color lie adjacent to each other. The theory suggests that there is a reorganization within the brain that creates a sensory stimulation following a perceived experience, similar to that of a phantom limb patient. In this realm, researchers have made some progress in narrowing down the mechanism of action in grapheme-color synesthesia. Currently, they are looking closely at three competing theories, however they are still unable to describe its mechanism definitively. Although there are still a lot of open questions in this field, one thing is clear: the rarity and its individuality of this condition makes it particularly difficult to study.

# The myth of the disappearing redhead

BY GWENDOLYN SCHANKER, JOURNALISM AND BIOLOGY, 2018

**One of the first topics** that's introduced in genetics class is the difference between dominant and recessive genes. Of the recessive genes, the gene for red hair is a primary example. For red hair to be physically expressed in a person, that person needs to have two copies of the gene for red hair in their genotype. According to *The Washington Post*, red hair is caused by a mutation of the MC1R gene, which causes pale skin and freckles in addition to red hair, reducing a person's protection from the sun. Two parents who carry the MC1R gene have a 25 percent chance of having a redheaded child.

Like many recessive traits, red hair is rare. In the U.S., between two and six percent of people have red hair, while that number is closer to 10 percent in Ireland and Scotland. Globally, *The Guardian* estimates that four to five percent of people have red hair.

Knowledge of the rarity of red hair has led to unfounded rumors that eventually, it may disappear from the population altogether. These rumors had a surge in 2005 and again in 2007, with multiple news organizations touting the impending extinction of redheads and citing questionable sources like the *Oxford Hair Foundation*. The rumor of the disappearing redhead was revisited in 2014 when Alistair Moffat, managing director of a DNA testing company called Scotlands*DNA*, mentioned casually in an interview with the British publication *The Independent* that, "The reason for light skin and red hair is that we do not get enough sun" and as climate change increases the amount of sunshine people are exposed to, "there would be fewer people carrying the gene."

Despite the unsourced nature of Moffat's comments, this statement led to a series of news articles exacerbating the rumor that the loss of the red hair gene was a potential side effect of climate change. British news magazine The Week proclaimed in one article that "Redheads could become extinct, thanks to climate change," drawing plenty of clicks but citing no reliable sources. Coverage like this fortunately sparked a number of saner responses. David Rutherford, writing for *The Guardian*, explained that red hair would not disappear from the population unless every redhead and carrier stopped producing offspring. Gail Sullivan, of The Washington Post, outlined the many assumptions that were made in Moffat's claim, including the unconfirmed statement that climate change will reduce cloud formation.

"Genetics is complex, and anyone who tells you different is selling something," stated Rutherford. The myth of the disappearing redhead is an important reminder of the oversimplified way that science can be represented in the news. Journalists and newsreaders should be wary of claims that are compelling but have minimal supporting evidence, especially when they pertain to genetics.

And to quote Rutherford once more: "Relax, redheads. You're not about to die out."



# Eat the rainbow:

## *How color preference influences food choice*

BY CHRISTINA MCCONNEY, BIOLOGY, 2021

DESIGN BY ANNIE LEE, DESIGN, 2019

**It is not uncommon** to hear the age old spiel from nutritionists to "eat the rainbow": making sure to get a proper mix of colorful veggies at breakfast, lunch, and dinner. While it has been proven that by essentially "eating the rainbow" people can have better overall health by acquiring essential vitamins and nutrients, there is another way to interpret this saying -- with Skittles.

The popular "Taste the Rainbow" campaign employs a literal interpretation of this saying, using it as a marketing strategy for the sale of the popular Skittles candy. However, the real question lies in how such words can be taken so literally. Humans, as both marketers and consumers, have assigned physical attributes (tastes) to inanimate objects purely for marketing purposes. Green is almost universally accepted as sour (whether that be green apple or watermelon), yellow is lemon, red is cherry or strawberry, and blue is almost always blue raspberry -- a flavor based off of a food that does not exist. Not only have the marketing companies managed to convince the consumer population that colors have tastes -- and have exploited this in their advertising campaigns -- but they have also managed to make consumers taste things that are not really there.

> "Human minds are so powerful that they are capable of attaching nonexistent features such as taste to otherwise flavorless foods."

In 2014, TIME magazine resurfaced a report with some devastating news: The popular loops in the Kellogg's Froot Loops cereal all taste the same. Subjects of a blind taste test conducted by Food Beast reported that each loop tasted "like mildly sweetened cardboard, with negligible or no differences between them." For years, the idea that the green, orange, purple, yellow, and red Froot Loops equated to "lime, orange, grape, lemon and cherry and/or strawberry flavored" was held as a universal truth, sparking debate over the best-tasting color. With the information that all the different loops have no individually discernable tastes, how is it that people are so quick to pick a favorite flavor Froot Loop when there is no flavor there to begin with? And since Froot Loops aren't the only culprits of these misleading color-taste associations, what makes one color food preferable over another?

A study published in the Journal of Psychology in 1990 by L. M. Walsh and a team of scientists focused on the link between color preference and food choice among children. The study suggests that color impacts food preference when there are no known expectations or associations of flavor, reasoning that "preference for color in food items coincides with color preferences in nonfood items." So while consumers are imagining different flavors in their beloved flavorless Froot Loops, the "best flavor Froot Loop" is based entirely upon personal color preference. The known flavor associations and expectations that are available to us are based on the commercial linking of certain color-flavor combinations, such as lime-green or cherry-red, and show the power of top-down processing in relation to what people experience -- in this case, taste. However, this study dove deeper into the mystery of color preference and food choice: discovering that favorite colors change in semi-predictable patterns as people begin to age. This ultimately dictates a pattern of food preference among children based on color, which has been used in the food marketing industry. In children ages two to four, red ranks first, followed by green then blue. Color preference shifts to blue, followed by red then green in school children between kindergarten and eighth grade.

In the end, what you see isn't always what you get: Human minds are so powerful that they are capable of attaching nonexistent features such as taste to otherwise flavorless foods. Using known color-flavor combinations, humans can conclude that the yellow Froot Loop actually tastes like lemon, and the orange like orange, when all the different colored loops essentially taste the same. Furthermore, the ongoing debate about the best Froot Loop "flavor" finally has an answer: there isn't one. Humans are inclined towards foods of certain colors based purely upon personal color preference rather than actual taste.

# ATOMIC WORLD OF COLOR

BY STEVE DRESEL, CHEMISTRY, 2021

**Until recently,** the primary relationship between atoms and color was the reaction of different atoms and molecules to light allowing humans to perceive different colors. This year, French and Japanese scientists collaborating in a research group at the University of Tokyo have reversed these roles by using color to visualize surfaces at the atomic level. They used an atomic force microscope to scan a surface and then converted the data into color images, allowing for many new visual applications in science and technology.

Atomic force microscopy is not a new method. Invented by Gerd Binnig and Heinrich Rohrer in 1982, it involves a cantilever, a laser, and a light detector. The extremely small tip of the cantilever moves along a surface while the laser deflects off the cantilever and onto the detector. This measures the position of the cantilever with high spatial and temporal precision. In one version of this method, the equilibrium position of the tip is kept at a fixed height and the changes in the frequency of the cantilever vibrations on the surface are measured. Another version keeps the frequency of the vibrations constant by moving the cantilever tip up and down.

When the laser beam hits the detector, it is converted into an electrical signal whose strength is determined by the displacement of the cantilever from its equilibrium position. These electrical signals are used to create a topographical image of the surface, much like a map that shows mountains and valleys. This technique can also be used to measure other properties of the surface, such as conductivity and adhesion strength.

Unfortunately, atomic force microscopy is far from perfect. While it has the potential to provide a wide variety of information, including the position of atoms on the surface, the chemical properties of the atoms, and the behavior of the surface, much of this information is usually discarded as the signal from the laser is processed by the detector.

In the new method developed by French and Japanese scientists, the tip of the cantilever is held at a height where the frequency of the vibrations is strongly impacted by reactions with the surface. All information received by the detector is used to create an image with different data points correlating to different colors. This makes it much easier for scientists to visualize chemical and physical information about a surface because each image contains multiple variables.

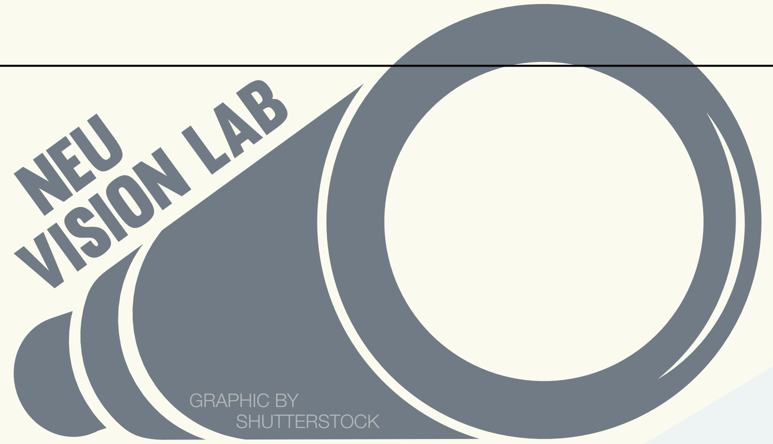
> “Atomic force microscopy is far from perfect. While it has the potential to provide a wide variety of information, much of this information is usually discarded.”

While the topographical map represents the only surface geography, the colors could represent any of the measurable properties of the surface. This makes each data point collected by the detector more unique and impactful.

The advantages of having a highly efficient and successful method for conducting atomic force microscopy are endless. From biologists analyzing cells and tissues to physicists determining which atoms comprise a material, every branch of science will benefit from having the ability to gather accurate information about surfaces at the atomic level.



*Applied Physics Letters* (2017). DOI: 10.1063/1.4991790.




GRAPHIC BY SHUTTERSTOCK

# COLORS AS STIMULI

BY ADANYA LUSTIG, LINGUISTICS, 2018

**For Rhea Eskew,** color is not just a beautiful or fantastic concept, it's a tool for understanding how vision works. Eskew, a Northeastern professor and principal investigator for Northeastern's Vision Lab, has been using color to study vision for more than 30 years. NU Sci sat down with Eskew to hear a little bit about his background and current work.

***Q: How did you get into this field?***

A: I was in graduate school in industrial psychology, at Georgia Tech. Industrial psychology is psychology applied to business problems, not clinical and counseling problems. I had thought as an undergraduate that I was interested in that, and it took me about a year to realize that I really wasn't interested in it. I moved my interests to a faculty member there who was doing work on vision.

When I was completing my PhD, I wrote to a range of vision scientists around the world trying to get a postdoctoral fellowship, and it happened that the one that came through was with the senior person in the color vision field. From there, I took a research associate position in biomedical physics at Harvard. After four years of that, I was looking to move into a regular faculty position. Northeastern has had a very strong history in studying vision and visual perception. One of the founders of [the psychology] department was a prominent vision scientist. I was quite happy to get a job offer here, and I've been here since 1990.

**Q: Why did you stick with color vision?**

A: There are some people who study color and color vision because they're fascinated by the phenomenology of color. They love to talk and think about the way things look. And that's not me. What I love about color is that manipulation of color allows for elegant studies of the function of the visual system. I'm interested in using color as a tool to understand something else.

We can manipulate color stimuli so that they only stimulate one of the three types of photoreceptors that line the back of the human eye. A very common thing to do in my lab is to present stimuli that are only visible to one of these classes of photoreceptors, see if somebody can see that at all, see if they can make certain kinds of judgements about it, and then add another photoreceptor and see if it gets easier to see, harder to see, which it does in some cases. We manipulate the way the system works in order to see how things are wired up.

The visual system is extremely complicated. About 60 percent of the human brain cortex is devoted to vision, in one way or another. The retina has something like 70 different types of cells in it, that are wired up in an extremely regular way, but it's very hard to get in there and study what they are because it's quite complex. It's also important to study the function of the system, and ultimately you'd like to relate them together.

If the systems fed by the photoreceptors were all the same, then this wouldn't be quite so interesting, but it turns out they're quite different. We're particularly interested in the short wavelength sensitive cones, the ones that respond to light that most people call blue or purple. They are evolutionarily different from the other, they are genetically different from the others, they don't support vision in the same way that the others do. So if you see the world just with your s-cones, you don't see much movement, you don't see shadows appropriately, you don't see a variation in intensity, and your spatial acuity is very low. You can't read with your s-cones, you can't recognize objects very well.

***Q: What's your favorite class to teach?***

A: At the undergraduate level, it's sensation and perception. At the graduate level, it's a statistics class. No matter what my students go off to do, having knowledge of basic statistics is important, whether they're going into industry or government or just being an informed citizen.

# A Beautiful Difference:
## How a person can have a different color in each eye

BY FAYEZ GHAZI, BIOLOGY, 2019

DESIGN BY ANNIE LEE, DESIGN, 2019

**Heterochromia iridium** is a rare condition characterized by a difference in the coloration of each eye. Heterochromia is not a well-known condition, with only around 200,000 cases reported in the United States per year. The condition is both self-diagnosed and usually harmless. It is truly a previously unexplored, fascinating phenomenon that modern science is just starting to unravel.

Eye color refers to the pigmentation of the iris, which is the structure around the black pupil at the center of the eye. The iris controls how much light can enter the eye, with the color reflecting the intensity of light, or the amplitude of the light wavelength that the eye can absorb. That pigmentation is known as melanin. The amount of melanin produced by a person is controlled and expressed by genes at birth. The more melanin that exists in the iris, the darker it appears to be. Therefore, people with darker eye color are more capable of looking at bright sources of light.

In humans, there are 23 pairs of different chromosomes that contribute to our uniqueness. However, not all genetic material inherited will be expressed, as proteins, enzymes, and mutation actively adjust and turn on the DNA. Melanin amount is controlled by genetic variations occurring at multiple DNA strains located in chromosome 15. Usually, the melanin-controlled genes will express equally for both eyes. However, in a person with heterochromia iridium, the two eyes receive different amounts of melanin due to mutations or blockage of gene expression. This difference in melanin distribution is caused by various conditions that can be inherited or acquired. Inherited causes include various genetic syndromes, such as Waardenburg's syndrome - genetic clusters that cause hearing and pigmentation deviation, and Horner's syndrome - a disrupted nerve pathway to the face and the eyes. Acquired causes include injury or trauma to the eye, eye surgery, and are sometimes even the result of glaucoma medication.

Usually, heterochromia iridium is a benign condition. However, an eye test by an ophthalmologist is recommended to rule out any harmful underlying causes. If these are ruled out, no treatment is required, and the individual is left with one of the most mesmerizing phenomena in life.



# Melanin:
## Your personal sunscreen

BY DENNY TRUONG, CHEMICAL ENGINEERING, 2020

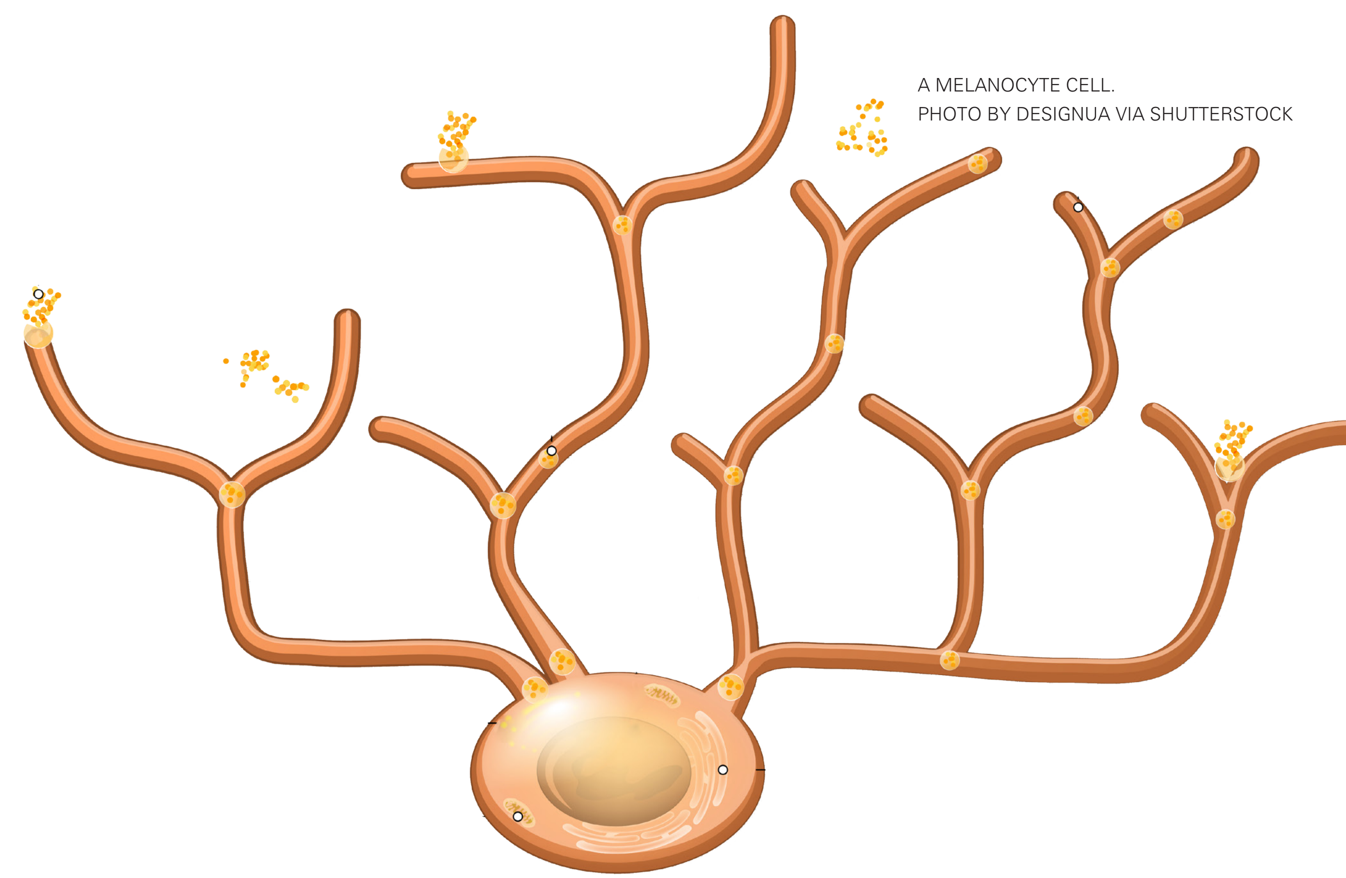
DESIGN BY ANNIE LEE, DESIGN, 2019

**Like snowflakes,** every individual is, well, an individual. One of the defining characteristics of human beings is their uniqueness. From personality to physical appearance, no two people are exactly alike. Arguably the most noticeable characteristic of a person's individuality is their pigmentation, which is regulated by their melanin composition. Without melanin, everyone would have extremely fair skin, white hair, and no pigmentation in the iris. Not only that, but humans would be extremely susceptible to damage from the sun, skin cancer, and vision problems like reduced eye sharpness, involuntary eye spasms, and heightened light sensitivity.

Within the skin, melanocytes produce two different types of melanin: black-brown eumelanins and yellow-red pheomelanins. These types of melanin not only differ in color, but also in their solubility and sulfur content. The eumelanins are a homogenous group of polymeric pigments, larger pigment molecules composed of repeating smaller subunits, and can undergo reversible reduction, the gaining of electrons. Meanwhile the pheomelanins are polymers that are soluble in alkali and contain both nitrogen and sulfur.

Given the physiochemical properties of melanin, one can expect that it possesses photoprotective traits. Both types of melanin can absorb UV light from the sun continuously, but not visible light. That is why people with oculocutaneous albinism, a genetic condition that affects skin melanin, possess an increased risk of skin cancer when exposed to sunlight. It should also be noted that the more melanin in a person's skin, the better they are able to absorb UV photons.

The mechanism by which melanin is able to perform such a feat is a fascinating yet complex one. In simple terms, melanin transforms one form of energy into another. Typically, melanin demonstrates photoprotective ability by turning harmful forms of energy into heat, which then dissipates. That being said, your melanin can easily be overwhelmed, which results in the production of carcinogenic free radicals in the skin. This means that no matter how much melanin an individual possesses, they should always be cautious of too much sunlight exposure.



A MELANOCYTE CELL.
PHOTO BY DESIGNUA VIA SHUTTERSTOCK

# Coloring away disease

*Scientists at the Lewis Lab research the connection between bacterial pigments and diseases*

BY CATRIONA HONG, BIOLOGY AND ENGLISH, 2021

DESIGN BY KRISTI BUI, COMPUTER SCIENCE, 2021

**Your clothes, the food you eat, the paint on the wall** – all these things have color, and all the color comes from pigments. Hundreds of years ago, pigments were derived from plants and used to dye garments and cloth. However, the pigments were later able to be mass produced with the advancements in organic chemistry. Pigments are derived from ores, insects, plants and microbes, and can have antibiotic, anticancer, and antifungal properties. In the context of modern day medicine and drug discovery, pigments are a valuable tool in furthering the production and discovery of new antibiotics.

Pharmaceutical industries and research labs alike are constantly looking for new compounds that will inhibit the growth of a pathogenic bacteria, among other things. These compounds are usually isolated from either bacteria or plants. Different species of bacteria produce a variety of compounds, and these compounds can have an inhibitory or bactericidal effect on other species of bacteria. Some of these bacteria also produce brightly colored pigments; blues, greens, reds, yellows, oranges, and so on. For example, the bacterial genus, Streptomyces or Serratia, produces a red pigmented compound called prodigiosin. This compound has antibiotic and antimalarial properties, and was shown to inhibit the proliferation of cancer cells in vivo.

Occasionally, bacteria that produce antimicrobial compounds also produce pigments with the same mechanism. This co-production allows for a visible marker to track the output of the antimicrobial compound from the bacteria. However, it is difficult to extract these compounds in a pure, concentrated form from the media or the bacteria in which they were produced. For a compound to be useful and have potential scientific applications, it needs to be able to be synthesized in an efficient manner. Sometimes the pigmented compound itself has antimicrobial properties, and sometimes another compound produced by the same bacteria has the antimicrobial properties.

With these important characteristics, comes the question - how can scientists make bacteria produce more of a desired compound? This is one of the many problems the Lewis Lab at Northeastern University is trying to tackle.

With over 35 members, the Lewis Lab has groups focusing on solving the mystery of lyme disease, investigating the microbiome, discovering new antimicrobial compounds, and searching for ways to overcome antibiotic resistant bacteria. Often, these fields of interest intersect. An example of one such project is investigating the potential inhibitory effects of thousands of natural products on E. coli in a mixed population of bacteria. Thus, the project will examine both potential new drugs as well as interactions between bacteria, as seen in the microbiome. Ryan Miller, a graduate student in the Lewis Lab, is working with underexplored producers of antibiotics which also make pigments. He is aiming to find

> "Sometimes the pigmented compound itself has antimicrobial properties, and sometimes another compound produced by the same bacteria has the antimicrobial properties."

the optimal growth conditions for the antibiotic producing bacteria in order to increase the output. Miller explains how at the center of the project he is designing are pigments, which are being used as "a tool to let us identify what growth conditions have an effect on secondary metabolism. Pigments are great, visible markers that indicate to us when 'secondary metabolism' is active." While some bacteria produce pigments naturally, other times they can be elicited with the combination of several chemicals. Pigments are sometimes called "secondary metabolites", meaning that they are not essential to the life and health of the bacteria, but can function as a signaling messenger for example. Within these organisms, certain mechanisms can be turned on by a combination of different factors to enhance the rate of production of specific compounds. By using bacteria that produce pigmented compounds, the rate of production can be directly monitored by the saturation of the pigment. As the number of antibiotic resistant bacteria continues to rise, the need for new drugs to combat them is higher than ever, and these pigments provide a useful tool to expedite the process.

*Process Biochemistry* (2013). DOI: 10.1016 jprocbio.2013.06.006.

PHOTOS BY GREBCHA VIA SHUTTERSTOCK



# Brighten your day: specialized glasses to correct color blindness

BY KATIE MCCREEDY, HEALTH SCIENCES, 2021

DESIGN BY VICTORIA PAJAK, BEHAVIORAL NEUROSCIENCE, 2021

**Sunsets are rich and colorful moments** that shock us into silent stares. When red, orange, and purple shades saturate the sky before fading quietly into the night, we can't help but admire that beauty. However, not everyone can enjoy this. Colorblind individuals often don't see sunsets as deeply as everyone else, because they can't discern the differences in shades a normal eye can. This may become a problem of the past with the latest innovation in technology. EnChroma Inc. has designed specialized glasses that may offer the solution to the thousands affected by colorblindness.

EnChroma Inc. created the EnChroma filter, a specialized glass in the lens of their glasses that corrects color vision disparities. These glasses cannot cure color blindness, but similar to prescription glasses, they can correct vision. They increase the color saturation of red and green light, allowing red-green colorblind individuals to see color more clearly. There are many forms of colorblindness, but the most common form is red-green color vision deficiency: a condition where it is difficult to discern the difference between red and green shades.

At $365 a pair, the glasses are expensive for many, but not unattainable. According to AARP the average pair of prescription glasses cost $200, not a distant price from the color vision glasses. Across social media, families are pooling funds to purchase the glasses for their loved ones and are surprising them on camera. Many are overjoyed by their first experience using the glasses and being able to see colors they previously couldn't. These videos garner thousands, sometimes millions of views.

Researchers at Pacific University in Forest Grove, Oregon, wanted to examine the EnChroma filter to determine its effectiveness on red-green color vision deficiency. The researchers, whose study was published in July 2017, recruited nine males and one female. Seven of the participants had deuteranomaly and the two others had protanomaly, two common color vision deficiencies. Deuteranomaly is a condition in which green cones in the eyes do not detect green light well, while protanomaly is a condition in which red cones in the eyes do not detect red light well.

The researchers used ColorDx, an online program that uses pseudoisochromatic tests, to measure the effectiveness of the EnChroma filter. Pseudoisochromatic tests are a series of images commonly used to identify colorblindness, where dots in one color form a circle with a number embedded inside in dots of a different color. The contrast between the two colors is specifically chosen to highlight deficiencies in people who are unable to recognize the difference between colors. A control group took the test using placebo glasses with no filter, while another group took the test using the EnChroma glasses. Only two of the participants succeeded on the test using the EnChroma glasses, and neither of those participants had their color vision entirely restored.

The researchers concluded that "the EnChroma filters had no significant effect on the performance of any of the [color vision deficiency] subjects" (Almutairi). Color vision deficiency (CVD) patients, regardless of whether they had protanomaly or deuteranomaly, did not experience improvement by using the glasses. The EnChroma website also admits that only "30 percent of people with strong protanomaly experienced improved color vision with EnChroma glasses."

While the EnChroma glasses are currently unable to help those with severe color blindness, the waves of online videos and positive reviews show that they are helping many people with less severe color blindness. EnChroma Inc. is currently developing a contact lens that may improve their technology and provide more clarity to those with color blindness. Beyond their company, Maureen Neitz, a researcher at the University of Washington, successfully cured colorblindness in monkeys in 2009 through gene therapy. Their lab is continuing to research how to translate their cure from the animal model to humans. Between gene therapy and corrective lenses, the future is colorful for those with color blindness and fully saturated sunsets are on their horizon.

# Coloring in the Blanks: LGBTQIA Accomplishments in STEM

BY ADRIANNA GRAZIANO, BIOLOGY, 2019

DESIGN BY LILLIE HOFFART, ENVIRONMENTAL SCIENCE, 2022

**Diversity within the STEM** fields in the United States is significantly unrepresentative of the country's general population that the fields aim to educate and influence. In 2010, white males accounted for 51 percent of workers in science and engineering fields, but only 32 percent of the general population. This overrepresentation creates less space for racial minorities in STEM. For example, while Latinos and African Americans make up about 16 and 12 percent of the general population, they are only six and five percent of STEM workers respectively. Disparities also exist between the binary genders provided by census polls, with males representing 70 percent of the STEM workforce.

Although federal and local programs to increase gender and racial diversity in STEM are on the rise, initiatives to increase the diversity and inclusion of LGBTQIA people within these fields are lacking both attention and resources. This is because queer citizens are unaccounted for at a national level in the United States. The US Census has never contained questions about sexual orientation or gender identity, making it essentially impossible to assess the needs of and address the challenges these communities face. Furthermore, the use of binary gender categories in the current census completely erases trans and nonbinary identities. Thus, the lack of encompassing statistics leads to invisible and unrecognized communities.

However, informal surveys of LGBTQIA people in the United States and in STEM have been performed. The 2015 Queer in STEM survey reported that about 40 percent of queer scientists have not disclosed their identity to their coworkers. This number is even greater in traditionally male dominated and racially homogenous fields, like engineering and computer science, and suggests that less overall diversity creates less space and acceptance for queer identities. Furthermore, when marginalized identities, like race and class intersect with queer identities, invisibility and lack of recognition is heightened. In researching for this article, queer people of color were entirely absent from lists of LGBTQIA scientific achievements. In STEM, the privilege of whiteness creates less space for queer people of color, which is a significant limitation of this article.

Representation and equal opportunity are essential for diversifying any field because they provide resources and a visible framework that encourages marginalized groups to pursue and succeed in these areas. Representation is essential for the progression of science, providing different points of views, alternate ways of thinking and solving problems, and offering inclusionary goals and visions for different communities.

For these reasons, this article highlights the accomplishments of LGBTQIA people in STEM to emphasize the importance of striving towards inclusion and visibility.

## Sara Josephine Baker
(1873-1945)

Based in New York City, Baker was a physician who centrally focused on children's health and aimed to reduce infant mortality rates, specifically in impoverished and immigrant communities. She helped train mothers in proper infant care, distributed clean milk and baby formula, and offered solutions to prevent infant blindness that was caused by the transmission of gonorrhea at birth. After retirement, she became the first female representative to the League of Nations and was president of the American Medical Women's Association. Most interestingly, Baker helped catch Typhoid Mary, the first known healthy carrier of typhoid, twice.

## Louise Pearce
(1885-1959)

A dedicated physician and pathologist, Pearce researched African Sleeping sickness (trypanosomiasis), syphilis, and cancer over the course of her career. Her research led to an effective drug against African Sleeping Sickness which she used to treat patients during an outbreak in the Democratic Republic of the Congo. Afterwards, Pearce researched the course of syphilis in rabbits as well as studied the transmission and growth of malignant epithelial tumors. She received many honors for her work and was also the first elected woman member of the American Society of Pharmacology and Experimental Therapeutics.

## Alan L Hart
(1890-1962)

Hart was a trans American physician and researcher who dedicated his career to the treatment of tuberculosis. He most notably influenced tuberculosis detection by pioneering the use of the X-ray, and he also implemented TB screening programs that aided in the prevention and isolation of this disease. This combination saved many lives because it preemptively detected TB before it began to show symptoms, and it also allowed for early intervention and isolation to prevent the spread and limit the amount of deaths it caused.

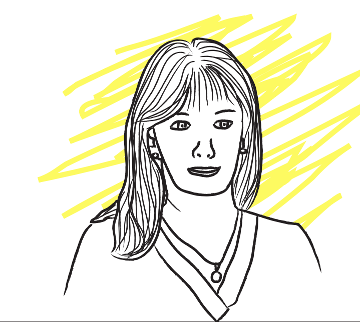
Learn more at nuscimag.com

## Alan Turing
(1912-1954)

An incredibly intelligent English computer scientist, mathematician, and cryptographer, Turing is widely accredited as the father of theoretical computer science and artificial intelligence. His computation framework provided grounds for the first computer, as it theorized that a machine could simulate all mathematical deduction using binary symbols. During World War II, he cracked the code on a machine made by the Germans ("Enigma") and deciphered German traffic signals. Despite his contributions, Turing was arrested on accounts of his sexuality in the 1950s, when homosexuality was illegal in the United Kingdom. Unfortunately, he was barred from working in cryptography up until his suspicious death by poison a few years later.

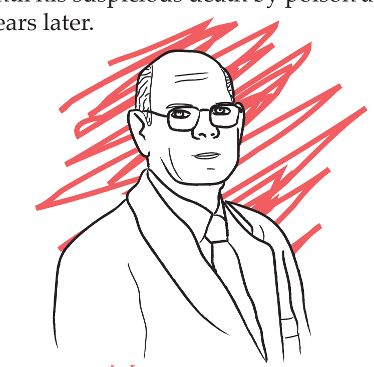
## Neena Betty Schwartz
(b. 1926)

Known for her work on the regulation of hormone signaling pathways in reproductive biology, Schwartz and her lab studied the feedback mechanisms that govern these signaling pathways in the menstrual cycle and discovered the hormone inhibin. Inhibin is a hormonal secretion in both the testes and ovaries and plays a central role in signaling and controlling hormone fluctuations. Schwartz is also known as a founding member of the Association for Women in Science. Later in her life, she revealed her lesbian identity in her autobiography "A Lab of My Own" in the hopes of "providing young gay scientists and other professionals with a lesson of possibilities for success and happiness without such splits in their lives."



## Lynn Conway
(b. 1938)

A computer scientist and electrical engineer, Conway's research in microelectronics contributed to the "Mead and Conway revolution" of very-large-scale integration (VLSI) structural design in the 1970s. This discovery simplified chip design while also increasing its electronic power, and it has impacted the design of microelectronics worldwide by minimizing the semiconductor materials of electric design, like capacitors. Conway is a prominent and successful transgender woman and she continues to advocate for the employment opportunities and rights of transgender people in technology during her retirement.



## Uzi Even
(b. 1940)

Even is an Israeli professor of physical chemistry at Tel Aviv University who specializes in the spectroscopy of super-cold helium clusters and cluster impact chemistry. He has theoretically and experimentally explored the fragmentation patterns of heated molecular clusters and how their transition into fragments is in accordance with entropy. After his PhD, Even worked for the Israeli army's Nuclear Research Center until his sexuality was discovered – a fireable offense in the Israeli military at the time. After his termination, he contributed to the changing that law so openly gay citizens could serve in their armed forces, and then became the first openly gay Israeli parliament member.

## Ben A. Barres
(b. 1955)

Barres is a neurobiologist at Stanford University who studies the interactions between neurons and glial cells in the mammalian central nervous system. His lab's most recent publications identify microglial subsets that promote myelination, which is an axon insulator on nerve cells essential for a functional nervous system. He's also a founding member of two organizations involved in the search for drug therapies that block neurodegeneration in Alzheimer's and in multiple sclerosis research investments. Barres was the first openly transgender scientist in the US National Academy of Sciences and is a proponent of reducing gender and racial bias within the science community.


## Sally Ride
(1951-2012)

At the age of 32, Ride became the first American woman and the youngest American astronaut to have traveled to space, as well as the first known LGBTQIA astronaut. Of her many accomplishments, Ride flew twice on the Challenger before its disaster and spent more than 343 hours in space. After NASA, she dedicated her life to the education and encouragement of American youth to pursue STEM by becoming a college physics professor and the head of two STEM public-outreach programs for children. Her legacy continues in her name as she was the founder of the company Sally Ride Science that brought science programs to schools, and as the co-author of science children's books she wrote with her wife.

# Study tells a new story about how human skin color evolved

ARTICLE AND DESIGN BY GWENDOLYN SCHANKER, JOURNALISM AND BIOLOGY, 2018

**Historically, skin color** has been a fundamental dividing human characteristic. According to geneticist Sarah Tishkoff, however, skin color is “a terrible classifier of race.” Tishkoff, quoted in a podcast for Science, is a coauthor on a study published in October 2017 that reveals new information about how pigmentation genes evolved in humans and the extent to which they are responsible for human skin color.

Tishkoff, professor of genetics at the University of Pennsylvania, worked with fellow colleagues, as well as Harvard University and the National Institutes of Health, to survey more than 2,000 volunteers across 10 different ethnic groups in Ethiopia, Tanzania, and Botswana. The researchers used a color measurement device to quantify pigmentation levels on the volunteers’ inner arms – a part of the body unlikely to be affected by environmental factors. They also collected blood samples from 1,570 of their study subjects. The results of the study, many of which directly contradict current perceptions of the notion of skin color, help contribute to a better understanding of the geographic distribution of and the genes responsible for skin color.

> “ The new study makes a significant contribution to the world of pigmentation genetics in several ways.”

Up until today, research of skin color has supported the belief that after our ancestors shed body hair, humans developed dark skin to avoid sun damage. Once humans began to migrate out of Africa and into more Northern areas, they adapted to less sunlight by developing lighter skin. The work done by Tishkoff and her colleagues reveals a more nuanced picture: Measurements of skin reflectance showed that the lightest pigments were present in the San population in southern Africa, while the darkest pigments were found in the Mursi and Surma populations in eastern Africa. The multitude of pigments in between dispels the long-held notion that skin color in Africa is in any way homogenous.

The results of the genetic component of the study revealed four key regions of the genotype containing variants that are collectively responsible for 29 percent of skin color variation in the studied populations. This is a large percentage, suggesting that the genetic makeup of skin pigmentation is less complex than that of other human traits, like height or genetic disease. Furthermore, by comparing the DNA of the African populations studied to that of European populations surveyed in previous research, Tishkoff and her colleagues determined that some of the variants responsible for light skin likely arose in Africa nearly one million years ago and were later spread to Asian, Austro-Melanesian, and European populations. Their presence in both light- and dark-skinned populations today suggests a common pattern of descent.

These commonly inherited variants were found on regions of the Solute Carrier Family 24 Member 5 (SLC24A5) gene, which has the strongest correlation with skin color of the variants studied, as well as in the Damage-Specific DNA Binding Protein (DDB1) gene. DDB1, as its name suggests, also has a number of other important functions in the human body: it helps to regulate follicle maintenance as well as female fertility. The researchers’ discovery that it also plays a role in skin pigmentation provides an exciting clue as to why this gene is highly conserved (continually present) in populations all over the world.

Another variant of particular interest to the researchers was found on the Major Facilitator Superfamily Domain Containing 12 (MFSD12) gene. Analyzing the genotypes of the populations studied showed that African ancestry is correlated with decreased expression of the MFSD12 gene. Further study in mice and zebrafish showed that MFSD12 has a suppressing effect on dark pigmentation.

The new study makes a significant contribution to the world of pigmentation genetics in several ways. One is the discovery of genetic variants that are significantly responsible for skin color. Another is the fact that that many of these variants are conserved across human populations, regardless of the color of their skin. Previous studies of skin color have been focused largely on European populations, making the new findings from African populations even more valuable.

“The study really discredits the idea of a biological construct of race,” said Tishkoff in an interview for The Atlantic in October. Not only do the results highlight the enormous diversity in skin color being overlooked in African populations, they also drive home the fact that people with different colored skin are really not that biologically different from one another. It also supports an argument made in a paper Tishkoff helped coauthor in early 2016: that racial terminology should be phased out of biological research. “Historical racial categories that are treated as natural and infused with notions of superiority and inferiority have no place in biology,” the paper states. The most recent study is an important step towards cementing that fact.

*Science* (2017). DOI: 10.1126/science.aan8433.
*Science* (2016). DOI: 10.1126/science.aac4951.

# Lefty no longer

## The short story of Jeremy the snail

BY JAMESON O’REILLY, PHYSICS AND MATH, 2019

DESIGN BY JULIE MURMANN, BEHAVIORAL NEUROSCIENCE, 2021

**In a dextral world,** Jeremy the snail lived sinistral (left-handed) and proud. When viewed from behind, his shell coiled to the left rather than to the right. The latter is the overwhelmingly more common direction for garden snails. Sadly, he was found dead in his hibernation fridge on October 11th, but not before having children whose genome could shed light on the reasons for Jeremy’s strange mutation.

Jeremy was originally discovered in a compost heap and brought to the attention of Angus Davison, a professor at the University of Nottingham. Davison, an evolutionary geneticist, wanted to find out if Jeremy’s handedness was caused by a genetic mutation or environmental factors, so he began a quest to find another lefty snail for Jeremy to mate with. They had to be sinistral because Jeremy’s organs, including his genitals, turn counter-clockwise. This is different than the vast majority of common garden snails, and it made mating with dextral snails impossible. On the other hand, all members of his species are hermaphrodites, so they can produce both eggs and spermatozoa. This made the search a bit easier, as sinistrality was the only criterion.

After a viral internet campaign, six potential mates were found. Some of these were found near each other, which may suggest that they are related and thus that their shell orientation is caused by a common mutation. Last November, Lefty from England and Tomeu from Spain were brought to Nottingham in the hopes of finding love for Jeremy. In a bittersweet turn of events, they were much more interested in each other than they were in Jeremy. Eventually, however, Tomeu gave birth to over four dozen babies, some of which Jeremy likely fathered.

Surprisingly, all of the offspring were born with right-handed shells. This may mean that the recessive left-handed trait will not show up for another generation or it may point towards some other factor for explaining shell handedness. Either way, genetic analysis of Jeremy and these offspring should be able to provide more concrete answers in the short term. Sadly, Jeremy died only a few days after his offspring were born, but his legacy will live on through them and in our hearts.

# HIDING IN PLAIN SIGHT

BY GWENDOLYN MCMANUS, MARINE BIOLOGY, 2021

DESIGN BY JAMES GOULART, CHEMISTRY, 2021

**In the wild**, conserving energy is crucial. Many organisms will spend a significant portion of their waking hours in search of food, and lost foraging time can be the difference between life and death. This poses a problem for animals that face predation: how do you leave your shelter for long enough to find food without getting eaten? Over time, natural selection and the constant cycle of predator-prey interactions have shaped the evolution of a wide range of camouflage tactics. Some of these solutions are so elegant that humans have adapted them for their own use.

> "The patterns may look random, but studies suggest their effectiveness depends on a lot of factors."

One of the most classic examples of camouflage in the animal kingdom is known as disruptive patterning, an adaptation that relies heavily on the use of color and is seen commonly in both predators and prey. This strategy relies on the fact that sight-dependent animals like humans naturally perceive objects by detecting their outline. Disruptive patterning hinders this by 'breaking up' the outline of the organism with spots, stripes, or patches of another color. The patterns may look random, but studies suggest that their effectiveness depends on a lot of factors. Regularity, for example, must be avoided. One study showed that it's much easier for the eye to take in an object with geometrically symmetrical patterning than one without rhyme or reason. Another study, performed with marine isopods, indicates that patterning may occur at the outline of the body more frequently than predicted—another indication that this is a highly developed evolutionary tactic.

Disruptive patterning is commonly seen in animals that travel in large groups, like zebras or schooling fish. The presence of irregular spots or stripes across a group of individuals serves to dissolve their individual outlines, making a hundred organisms seem more like a shifting, singular mass. Predators are less able to single out specific targets, and thus the chance of survival is increased for all individuals in the group. That doesn't mean this adaptation is seen only in schooling animals; the stripes and spots of many big cats are a good example of the way solitary creatures use disruptive coloration to 'melt' into the background and avoid detection.

The theory of disruptive patterning was alluded to in the late 1800s, but it was only expanded upon by G. H. Thayer in 1909. The U.S. government, seeing its military potential, was able to adopt this knowledge in time for World War I. The mottled gray-green pattern still used for military uniforms and equipment today relies on the same set of rules that govern natural disruptive patterning: the colors match the environment, and randomized patches break up the outline of soldiers or vehicles so they are difficult to spot from far away.

There's more than one way to avoid predation. Certain animals, like the Dendrobatoidea family of frogs, have evolved to use color in a way that at first seems counterintuitive: instead of blending into their environment, they adopt bright hues that are practically fluorescent against the dull backdrop of the rainforests where they live. For these amphibians, which are more commonly known as poison dart frogs, color is a warning: a single individual can contain enough toxins to kill 10 grown men. Why hide when you can ensure that nothing would want to eat you in the first place? This use of flashy colors and patterns to deter predators is so effective that it caused the evolution of another type of camouflage, known as Batesian mimicry. Many non-toxic species of frogs, reptiles, and insects have evolved to imitate their less palatable neighbors, providing a deceptive and unique way to hide from their predators.

While humans aren't exactly capable of replicating this method of camouflage, we are still skilled imitators in our own way. Rather than looking like another species, mimicry among humans is intraspecific and often behavioral. A study performed in 1999 placed people in a room with a stranger who would exhibit a specific, repetitive movement, like tapping their foot, while performing an unrelated task. The subjects would usually mimic that behavior in the moment, but be unable to recall it afterwards. This subconscious tendency is likely a remnant of our long history as a social species, but it continues to be relevant in our interactions with each other. Next time you interact with someone, watch their body language—if they mimic yours, it's often a sign of friendship or agreement.

# AN ELECTRIC FLOWER POWER

BY TAYLOR MANNES, MARINE BIOLOGY, 2020

DESIGN BY JAMES GOULART, CHEMISTRY, 2021

**Our world is filled with color,** yet these colors look different to almost every organism on earth. Bees in particular have a knack for discerning color, and have evolved alongside flowers to use this to their advantage. A bee's eyes can process patterns and colors invisible to human eyes. On top of that, bees recognize color three times faster than humans. When we're running or driving past a field, we generally have a hard time telling individual flowers apart. Bees, however, see each flower easily, even when they're flying at fifteen miles per hour. This comes in handy when they're looking for an individual with a hefty store of nectar, which they use to make honey. Finding flowers isn't as simple as picking brightly colored flowers, though. It would be too easy for flowers to evolve colors to trick bees into stopping by. To avoid this, bees have developed sensory skills that allow them to detect a flower's electrical field. They use these fields to determine whether or not a flower has enough nectar to suit their needs. They also associate a negative charge with nectar, and a positive one with an empty flower.

Pollen is released by the male part of a flower and contains sex cells that are transferred to female flowers by pollinators like bees. Flowers produce nectar to lure bees in; the bees incidentally pick up the pollen in the process. It's an important relationship because many flowers wouldn't be able to reproduce without bees. Flowers give off negatively charged particles (like dust or other small molecules) that fly through the air, sticking to the bee. The bee is attracted to these particles and heads toward the flower producing them. This not only helps guide bees to the flower's pollen, but can actually make the pollen stick better to the bees. The air around us is generally positively charged, and bees produce a positive charge by flapping their wings. So, when a positive bee touches down on a negative flower, the pollen acts magnetically; the difference in charge causes the pollen to be attracted to the bee. And unlike color or smell, electric signals can change in a moment. Because bees and flowers are oppositely charged, the flower will automatically become more positive after an interaction.

Bees communicate with their hive-mates to let them know which patches to frequent and which to avoid. Repeated encounters with an empty flower mean the bees will learn to stay away. So, flowers have evolved to keep their electrical fields more positive until they can produce more nectar.

There are, of course, cheaters. One species of flower may be pollinated by a single bee, while a different species requires multiple visitors. The flower who only needs one pollinator will spend extra energy making sure their electrical field is maintained when the bee lands on it, and will invest extra time to keep their signals negative. This then tells each passing bee that they have nectar to share, even when that's not true. The flowers who require multiple pollinators will not lie, because they can't afford to lose an entire hive of pollinators. They'll let their electrical field remain more positive until they're able to produce more nectar. This creates a trusting relationship between the bees and flowers.

Color also plays an important role in a bee's decision making. Just like humans, a bee's eyes have rods and cones responsible for perceiving color. Bees are also trichromatic, which means their cones generally process three colors. Whereas our cones see red, green, and blue, theirs see blue, green, and a totally different spectrum- ultraviolet. Color helps them determine whether they want to spend their time looking for nectar, or whether they should move on to another flower, seeing the colors and wavelengths we cannot. Flowers have ultraviolet patterns that lead the bee to the nectar. We can't see them, but to bees they are a map that makes finding nectar easier. Bees can also pick up on patterns quickly. This may lead to a bee having a "favorite color." If a certain bee finds that violet flowers tend to produce more nectar than blue, the bee will almost always end up visiting the violet flower.

The cooperative flower-bee relationship has been perfected over a many million-year timescale. Complex compound eyes and intricate sensory capabilities have made bees a master of their environment. There's still much to discover about how they're able to detect electric fields, and how that may affect other areas of their life. We do know, however, that bees live a life filled with ultraviolet colors, smells, and electrical fields. Flowers have evolved to take advantage of this, and in turn humans reap the benefits of beautiful bouquets and perfectly pollinated crops.

# UnbeLEAFable!

## *The wonder of autumn foliage*

BY SAGE WESENBERG, BIOLOGY AND JOURNALISM, 2019

DESIGN BY JULIE MURMANN, BEHAVIORAL NEUROSCIENCE, 2021

**An aerial rainbow of red, gold, purple, and green;** brisk wind reddening cheeks, and leaves crunching with each step: fall is a robust season marked by bright foliage, jack-o-lanterns, and apple pie.

But have you ever wondered how trees morph into their bright array of colors?

Deciduous trees lose their leaves each year, growing new buds for the spring. Common deciduous trees of New England include hemlock, red maple, and white cedar. These trees all experience a short period of annual growth that finishes by June, in which each tree grows its leaves and becomes prepared with a set of buds for the next year. After the growth period is complete, trees spend the rest of the year working to produce and store carbohydrates that will help them grow in years to come. Leaves are vital parts of the process of producing carbohydrates.

Chlorophyll is the green pigment found in leaves whose job is to capture light energy from the sun through photosynthesis. This light energy can be used to combine carbon dioxide and water to produce the necessary carbohydrates. As chlorophyll is exposed to light, it gradually breaks down, and so always needs to be replaced. During this growth, constant chlorophyll production blocks orange and yellow pigments, carotenoids and xanthophylls.

> “Soon, the chlorophyll production is completely stopped, allowing for the reveal of the hidden orange and yellow pigments.”

As the growth season progresses further and the days begin to get shorter, deciduous trees respond to less light each day. When a certain threshold of day length is reached, the cells located at the base of the leaf begin to rapidly divide, which forms the abscission layer. This layer acts as a large wall, slowing chlorophyll production and blocking carbohydrate transportation from the leaf to its branch. Soon, the chlorophyll production is completely stopped, allowing for the reveal of the hidden orange and yellow pigments. Red and purple colors often appear as well, from anthocyanins - pigments produced from extra sugar trapped in the leaf.

As the autumn months move forward, the abscission layer grows drier, eventually causing the leaf to break off from the tree and float down to the ground. As they lie on the ground at the mercy of leaf blowers and rakes, they eventually lose all their pigment except the tannins that show a brown color.

Seasonal temperatures and other environmental factors play an important part in determining the colors and intensities of them that we see each season.

The most ideal conditions for colorful trees are a dry, cool, sunny autumn. Lots of sunlight and lower temperatures (but above freezing) help chlorophylls get destructed more quickly, exposing the radiant colors underneath. Additionally, if temperatures are cool at night and the days are sunny, more anthocyanins are produced, giving more range of color.

An early frost can quickly end a season of foliage, since the freezing temperatures ruin any chance to produce anthocyanins. Heavy wind and rain also cause leaves to prematurely fall to the ground before they're able to reach their full potential. On the contrary, drought conditions during the spring growing season causes the abscission layer to form much earlier and leaves may drop before they change color.

New England is not the only part of the world to see colorful leaves. Northeast Asia has similar deciduous species to new England and show a brief, intense display each fall. Since Europe spends most of its autumn under cloudy skies, their foliage responds with dull colors. In mixed forests of evergreens and deciduous trees seen at higher elevations, trees go from bright yellows to almost bare in about two weeks.

While New England isn't the only place to see vivid fall color in the trees and swirling through in the wind, Bostonians are pretty lucky. When you look back on that scenic drive up north, or your walk through Harvard University's Arnold Arboretum, remember all the xanthophylls, carotenoids, tannins, and anthocyanins.



# How many carrots is too many?

BY PAULA HORNSTEIN, BIOLOGY, 2020

DESIGN BY ANNIE LEE, DESIGN, 2019

**Believe it or not**, the classic anecdote in which a man who eats too many carrots becomes an orange color is actually a plausible reality.

The condition is called carotenemia, and it is characterized by a yellow-orange tint of the skin that can easily be clinically confused with jaundice, which also causes a yellowish pigmentation. While jaundice is often a symptom of a serious infection or blood disease, carotenemia is virtually harmless; in fact, it could be said that carotenemia means that you are too healthy.

Carotenemia is credited to elevated levels of beta-carotene in the blood. Carotene is found in all fruits and vegetables as they ripen, but the lipochrome is most prevalent in carrots, squash, and sweet potatoes. The amount of carotene consumed that causes carotenemia varies from person to person, but the condition is most commonly diagnosed in infants and small children for a few different reasons. For one, the ratio of body-mass-to-food of infants and small children promotes comparably heightened carotene proportions, making it easier for them to turn a yellowish color. Also, pureeing and mashing vegetables—as they exist in baby foods—causes the cell membranes to rupture, releasing higher amounts of carotene from the cells and promoting carotene absorption in the digestive system. Lastly, breast milk contains large concentrations of beta-carotene, so infants who are breastfeeding tend to have a predisposition for carotenemia when they consume large amounts of carotene-containing baby food.

While most cases of carotenemia occur in infants, the condition is also slightly more prevalent in people with diabetes and anorexia nervosa due to dietary restrictions and conditions. It is also prevalent in individuals with hypothyroidism, as a symptom of hypothyroidism is decreased conversion of carotene in to vitamin A. Carotenemia is also common in vegetarians and vegans.

Although carotenemia is unharmful, orange skin is not usually desirable unless you have some misconceptions about fake tans. If one does experience a carotene-induced yellow pigmentation, elimination of carrots, sweet potatoes, and squash from their diet will usually cause skin coloration to return to normal in a few weeks, although carotene levels in the blood will drop to normal levels (50 to 300 micrograms per deciliter) within a week of the change in diet. Carotenemia is extremely rare, however, and most people do not get enough vitamin A as it is—so feel free to eat those extra carrots.

# THE CARBON CYCLE FROM SPACE

BY HANNAH BERNSTEIN, JOURNALISM AND ENVIRONMENTAL SCIENCE, 2021

**For the last three years**, scientists around the world have watched the Earth move steadily through the carbon cycle. This is possible through the use of a NASA spacecraft, the Orbiting Carbon Observatory, whose sole purpose is to record carbon dioxide levels in the atmosphere. Now, three years after its launch, research papers have just begun to surface, appearing in a special October issue of Science. This story really begins in the 1950s, when scientist Charles Keeling hiked into the California mountains and took air sample after air sample, measuring carbon dioxide in the atmosphere. His colleagues were skeptical: No one had ever been able to record consistent data, and most researchers assumed carbon was simply too unpredictable to measure.

"His numbers were steady at first, and then they went down and he thought something was wrong with the instruments," said Tim Lueker, a veteran researcher in the Keeling group at the Scripps Institution of Oceanography. "After a year of pulling his hair out, he saw a seasonal cycle. He figured he was seeing the whole planet breathing."Lueker has been working with the Keelings for more than 30 years and worked with Charles himself while he was alive. He now works with Ralph Keeling, Charles' son, doing the exact same measurements Ralph's father conducted 60 years ago. Those measurements form the Keeling curve, a tool used to look at the average amount of carbon dioxide in the atmosphere.

Now, 60 years later, air samples come to Scripps from around the world, from places such as Christmas Island in the Indian Ocean; Point Barrow, Alaska; and the South Pole. Air analyzers at both Scripps and the Mauna Loa Observatory in Hawaii conduct continuous measurements as well.

Lueker said the measurements from the curve have shown scientists how much carbon the planet can remove from the atmosphere through its natural cycle, and how large the human impact is on that process.

"The Keeling curve tells us that a little more than half of (the CO2) stays in the atmosphere, and the rest of it gets taken up by the ocean or the plants on land," Lueker explained. "That's the global carbon cycle. A lot of the research over the years has gone into, how does that work?"

Lueker said NASA's OCO-2 satellite represents the best chance scientists have ever had to answer questions that Keeling never could.

"When the Keeling curve started, there weren't any satellites — the only thing in space was Sputnik," Lueker said, referring to the first orbiting spacecraft launched by the Soviet Union in 1957. "There were no big eyes in the sky. Now, the amount of information they've gathered with the satellite is just mind-boggling."

## Research expands into space

In 2000, a group of scientists at NASA's Jet Propulsion Laboratory (JPL) thought of another way to measure the carbon cycle: They asked NASA to send a satellite into orbit to measure atmospheric carbon dioxide from above. "We felt that in order to make these global measurements, space is a natural vantage point," said Michael Gunson, a project scientist at JPL. "So, we conceived the Orbiting Carbon Observatory, which has essentially just one instrument on it, to make these measurements."

The first prototype of the observatory launched in 2009 but failed to make orbit. The second attempt, named OCO-2, was successful in 2014 and has been collecting enormous amounts of data ever since.

What makes OCO-2 special has to do with its design — its function is to sense wavelengths of light. Florian Schwandner, a volcanologist and project scientist at JPL, explained exactly how it works.

"[The sensors] look at sunlight. They don't take in air and pass it over detectors, they detect sunlight itself," Schwandner said. "The sunlight goes through the atmosphere, interacts with the [carbon dioxide] gas, and the gas absorbs some energy in certain wavelengths."

As Schwandner said, when sunlight passes through carbon dioxide gas, the gas absorbs some wavelengths of light and ignores others in a very predictable pattern. Instead of measuring the actual contents of the air, it measures the wavelengths in the entire space between the observatory and the ground.

Gunson said the Keeling curve data was like little pinpricks of information based on where the air sample came from. Without taking a step back the way OCO did, it was impossible to draw global conclusions.

"If you measure carbon dioxide in an air sample, and if I took that air sample out of the tailpipe of a car, it doesn't tell me much more than what that car's doing," Gunson said. "If you want to understand what's happening in the bigger picture, you're caught between a rock and a hard place."

## Scientists reach many disciplines

Abhishek Chatterjee, a scientist with the Universities Space Research Association working at NASA's Goddard Space Flight Center, focused on watching El Niño, a weather cycle characterized by drought in Australia and Asia and increased rainfall in Africa.

Chatterjee said it was lucky that an El Niño event occurred while OCO-2 was in the air, given that such events are hard to predict. On top of that, the 2015-16 El Niño was the largest recorded since 1997 and released a huge amount of $CO_2$ into the atmosphere.

Chatterjee said because OCO-2 returns to the same location 16 days after it left, it has an enormous ability to collect data. He used an analogy to explain the difference: If someone sprays perfume in a room, it will take some time until it reaches the farthest corner. But if someone were to walk through the spray, they would smell it immediately. The same concept applies to a ground station versus a satellite in space.

"On a 16-day basis, we have a snapshot of the changes that are happening over the tropical Pacific Ocean, whereas previously, we had a surface site at Mauna Loa," Chatterjee said. "You have to wait for any changes that happen in the carbon cycle to reach that surface."

Schwandner, the JPL scientist, is using the data in a much different way, hoping to pinpoint early warning signs of volcanic eruptions. He co-authored a paper in Science on localized CO2, where the satellite was able to detect specific areas of heightened gas with incredible precision.

Volcanoes also emit CO2 into atmospheric plumes, which are small but measurable by OCO-2. Schwandner said this data is important when creating future policy around volcanic hazards.

"Volcanic eruptions are predictable, but they're only predictable if we look for the signals," Schwandner said. "If we learn better how to read these signals and observe them globally, then we can make better decisions or recommend better decisions to authorities to get people out of harm's way."

Jeffrey Woods, an assistant research professor at the University of Missouri, said another thing OCO-2 can do is measure the fluorescence, or glow, of photosynthesis.

"Any time that plants are photosynthesizing, they are essentially glowing," Woods said. "We can't see it because it's not in the visible range, but it's there, and we can now measure it."

Woods said this type of data is useful to understand the complexity of the global carbon cycle, but also has potential in the farming industry on a smaller scale. Less photosynthesis is a common sign that plants aren't doing well.

"Being able to use it for monitoring crop stress during the growing season is something that eventually will be possible," Woods said. "There's more operational uses for it in that way in the future."

Gunson, the JPL project scientist, said he thinks the fluorescence of photosynthesis is one of the most promising new findings coming out of the observatory.

"The idea that you can see byproducts of photosynthesis, that little bit of light that plants give off, in space, blows me away," Gunson said. "I think that is one of the most exciting new observations I've seen in a long time."

> "When the Keeling curve started, there weren't any satellites — the only thing in space was Sputnik. There were no big eyes in the sky. Now, the amount of information they've gathered with the satellite is just mind-boggling."
>
> - **Tim Lueker,** *Scripps Institution of Oceanography*

NASA missions operate for three years before evaluation, which is why much of the OCO-2 data was released this October. Gunson said now that NASA has extended the project another three years, the groundbreaking research can continue.

"We've actually formally passed our baseline mission of operation, but we've been cleared to continue operating," Gunson said. "Everything looks physically healthy on the observatory. Hopefully we'll go for a lot longer."

DESIGN BY ANNA LI, BEHAVIORAL NEUROSCIENCE, 2018

# The Doppler Effect at light speed:
## *Red shift and why it is important*

BY DREW BODMER, BIOLOGY, 2022

DESIGN BY KYRA PERZ, CHEMISTRY, 2020

**Most people know of the Doppler effect,** where sounds from an object moving towards you are higher-pitched than the same sounds made while an object is moving away from you. It can be heard when an ambulance passes us on the street or in the sound from a race car as it drives past. This effect happens because sound waves can be compressed or stretched slightly based on the movement of their source. For example, when an ambulance is racing towards you, it emits sound that travels to your ear at about 343 meters per second. As the sound travels towards you, the ambulance is also moving towards you, albeit at a much slower pace. By the time you hear the beginning of the sound, the ambulance has moved a little closer, and so you hear the rest of the sound from it a little bit sooner than you would if the ambulance had been standing still. The faster the source is going, the greater the distortion, which is why race cars have such a distinctive sound when they drive past.

> "Scientists often use the redshift effect to figure out how fast distant galaxies are moving away from us."

Redshift is the Doppler effect, but with light. This effect is called redshift because light waves become redder as they get stretched out. Red light has the longest wavelength of all visible light, which is also why it is the outer ring of a rainbow. When light gets compressed, it turns bluish-purple, which is not coincidently the inside color of a rainbow. Red light is like the lower-pitched sound when the ambulance is driving away, while blue light is like the higher-pitched sound when the ambulance is driving towards you. We cannot see redshift the same way we see the Doppler effect because light is so much faster than sound. It travels almost 900 thousand times faster than sound, so the only way to see redshift is with objects moving much, much faster than an ambulance or a race car. Scientists often use the redshift effect to figure out how fast distant galaxies are moving away from us because the speed with which they are moving is directly proportional to how stretched out (red-tinted) the light waves get. They do this by looking at the spectral lines of hydrogen. Hydrogen, just like every other element, emits only very specific wavelengths of light. Because hydrogen makes up a majority of the universe, its specific spectral signature is much brighter than that of any other element. These wavelengths have already been measured and recorded on Earth. If the galaxy is moving away from us, the distinctive wavelengths given off by hydrogen are stretched, showing a longer (redder) wavelength on a spectrometer. Astronomers can find the speed of a galaxy by finding the difference in wavelength of the hydrogen spectral lines that were already recorded and the lines that are seen from a distant galaxy.

The Doppler effect was first applied to light in 1848 by a French scientist, Hippolyte Fizeau, who noticed that there was a shift in spectral lines from stars and concluded that it must be a similar effect to the one that occurs with sound. Twenty years later, British astronomer William Huggins calculated the velocity of a star using this theory. Calculating the velocities of stars and distant galaxies ultimately led to Hubble's Law, which says that the farther something is away from Earth, the faster it is moving away from us. These observations ultimately helped motivate the Big Bang theory.

PHOTO BY WIKIMEDIA COMMONS



# The light at the end of the collision:
## The Northern Lights explained

BY SAGE WESENBERG, BIOLOGY AND JOURNALISM, 2019

DESIGN BY KYRA PERZ, CHEMISTRY, 2020

**If you're lucky enough** to live near or visit places like Alaska, northwestern Canada, the northern coast of Norway, or Iceland, you may have seen the colorful dancing lights in the sky - a beautiful array of colors and patterns that brings awe and wonder to those who experience them. These are known as the Aurora Borealis.

More commonly, this phenomenon is referred to as the Northern Lights. But in fact, it's not a phenomenon at all. The light display is caused by charged particles from the sun that interact with the Earth's magnetic field.

> "The light display is caused by charged particles from the sun that interact with the Earth's magnetic field."

That magnetic field acts as an invisible shield over our planet, with lines extending from north to south poles. It protects us from the many particles that come from the sun, especially those that can be released by occasional large flares of the sun. On the sun, 93 million miles away, the temperature is so incredibly hot that gas molecule collisions happen quite frequently. These collisions result in free protons and electrons being shot out of the sun's atmosphere and pushed towards the Earth on solar winds.

Many of these particles are deflected by the magnetic field, but at the poles, the field is weaker. As a particle approaches the poles, it moves along the magnetic field lines in a spiral and eventually breaks into the atmosphere, where it will collide with gaseous particles like oxygen and nitrogen. This collision creates photons of light, which are what we see in the aurora.

The Northern Lights are most often a pale green or pink, but they're able to take on many colors based on what gases they collide with. A collision with an oxygen molecule at a lower altitude of about 60 miles above the earth leads to pale yellow-green colors, while a collision with that same molecule at a much higher altitude of 200 miles will bring about rare red colors. Collisions with nitrogen cause blue and purple-red colors.

The light displays that these particle collisions create extend between 50 and 400 miles above the earth's surface and present themselves in many forms - from patches to streamers, scattered clouds of light, and light curtains. While they are more often seen around the northern pole, the Aurora Australis (Southern Lights) occurs at the south pole, under the same principles. The auroras across the world from each other mirror each other, occurring at the same time and showing the same colors. Unfortunately, the Southern Lights present in a ring around Antarctica and over the Indian ocean and are therefore harder to see.

If you're looking to find yourself some ripples of color across the night sky, your best opportunities will be to travel up north over the winter in areas without light pollution. Around midnight, take a look up at the sky and you may be able to see, and even sometimes hear, tiny particles colliding and colorful photons. Auroras work cyclically, peaking every 11 years, so your best chance to see the brightest display won't be coming until 2024.

PHOTO BY FLICKR, DESIGN BY IMAGE EDITOR

# The blackest black
# The pinkest pink

*A colorful rivalry*

BY KATELYN LI, BIOLOGY, 2021
DESIGN BY YU CHENG, GRAPHIC DESIGN, 2018

**It is a commonly known fact** that the colors humans perceive are the wavelengths of light being reflected off an object. Blue things are blue because they absorb all wavelengths across the visible spectrum except the ones that correspond with blue. White things are white because they reflect all wavelengths. And black things are black because they absorb all wavelengths.

Developed by Surrey NanoSystems in 2014, Vantablack—recognized by Guinness World Records as the darkest man-made substance on Earth—is one of the blackest blacks on Earth. Absorbing 99.96 percent of the light that strikes its surface, the material is lightweight and versatile, promising the potential to apply to anything from space travel to high-end luxury products.

Its name, which stands for Vertically Aligned Nanotube Array black, explains it all: Vantablack is comprised of what Surrey NanoSystems describes as a "forest" of carbon nanotubes (CNTs) one-fiftieth of one-millionth of a meter in diameter. When photons enter the CNT array, they are bounced from nanotube to nanotube until finally being absorbed and converted to heat. The array is mostly free space, allowing for very minimal light to be reflected, so that only a small proportion of photons might hit the top of a CNT and bounce back. Additionally, the length of the tubes in proportion to their diameter makes it difficult for photons to escape.

Although Vantablack can be employed in a variety of fields, its use in art has been licensed exclusively to Kapoor Studios UK. As such, Anish Kapoor is the only artist in the world who can include it in his works. The news of this monopoly, announced in February 2016, outraged many artists, among them Stuart Semple. Semple retaliated in November 2016 by developing the self-proclaimed "World's Pinkest Pink," a high pigment powder paint, and releasing it for £3.99 to everybody but Kapoor. In response, Kapoor took to Instagram in December 2016 with a photo of his middle finger dipped in a jar of Pinkest Pink.

Semple, however, has remained undeterred. He has continued to develop materials such as "The World's Most Glittery Glitter" and a four-pack of "The World's Colouriest Powder Paints," all of which are available on his website to everybody but Kapoor. Although Semple originally created Pinkest Pink to make a point, one could argue that his line of colors have since become an artistic statement. Regardless of where this rivalry goes, however, science continues to expand and push the limits of what we once thought was possible.

# How are planets colored?

BY KEVIN WU, PHYSICS & ELECTRICAL ENGINEERING, 2018
DESIGN BY YU CHENG, GRAPHIC DESIGN, 2018

**The cosmos is full of colors,** and the clumps of rock and gas we call planets are some of the most interesting examples. In the night sky, the planets of the Solar System are stunning sights thanks to the light they reflect. In fact, most planets are not sources of light but instead rely on a nearby star to be visible to the naked eye. What paints the portrait of a planet partly depends on its particular atmosphere.

For example, Neptune's blue comes from methane, which makes up about 1.5 percent of its atmosphere. A relatively small amount, it nonetheless is the most abundant after molecular hydrogen and helium, which appear colorless. Why does the methane appear blue? Simple - it reflects blue. As light from the Sun reaches Neptune, the methane in the atmosphere absorbs the redder parts but sends back the bluer light. When we look at Neptune, the light hitting our eyes is exactly what was reflected – blue!

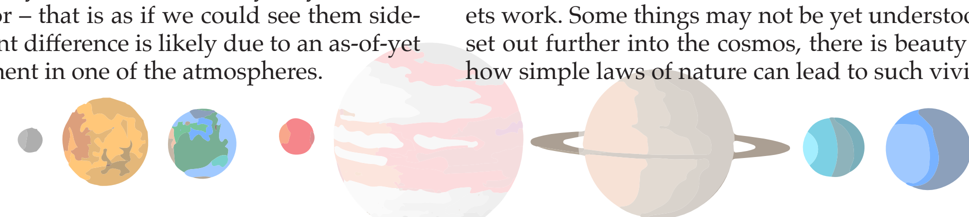
Uranus's bluish-green comes from methane as well. Why Uranus appears slightly different is still a mystery, but both are close in true color – that is as if we could see them side-by-side. Any apparent difference is likely due to an as-of-yet unidentified component in one of the atmospheres.

Not all the planets are these bluish colors. Saturn has trace amounts of ammonia, water vapor, and hydrocarbons that lend a yellowish-brown color instead. Meanwhile, Jupiter has remarkably contrasting stripes of orange-brown and white. The exact mechanisms behind what make Jupiter's stripes so colorful are unknown, but we do know that the lightly-colored zones have dense clouds of ammonia ice at higher altitudes, while the darker belts are at lower altitudes with thinner clouds.

Mars is the first planet we come to with no atmosphere, and for the inner planets, the palettes depend more on the compositions of the surfaces. The fine dust coating Mars is iron oxide, also known as rust, which gives off a reddish-orange color. Earth has its oceans of blue and lands of green and brown, interspersed with white clouds. Venus's yellowish color comes from a thick carbon dioxide atmosphere and clouds of sulfuric acid. Finally, the dark gray surface of Mercury is thought to be from igneous silicate rocks and dust.

Just from their colors, we can learn so much about how planets work. Some things may not be yet understood, but as we set out further into the cosmos, there is beauty to behold in how simple laws of nature can lead to such vivid pictures.

PHOTO BY PIXABAY





# True Colors

*Seeing is believing. But should it be?*

BY DENNY TRUONG, CHEMICAL ENGINEERING, 2020
DESIGN BY LAUREN KOURAFAS, GRAPHIC DESIGN, 2021

**Vision is the most relied upon sensation** in the human brain. It is so important that the brain devotes an entire lobe, the occipital lobe, that takes up nearly a quarter of its total area solely to process visual information. With such a level of dedication, one would assume that seeing must be believing, and everyone should see any specific object identically. However, this assumption was put to the test with a simple picture of a dress that first appeared on Facebook a few years ago.

Two separate arguments were instantly formed by opposing sides of the internet regarding the colors of the dress. For some, the dress appeared blue and black. For others, it was white and gold. While the internet still cannot seem to settle this debate, science offers an explanation for this phenomenon all thanks to the Theory of Afterimage Effects. All of the important processing power in the occipital lobe cannot account for the receptive limits in the human eye. Afterimage effects involve pushing these limits. When light comes into the eye, it gets absorbed by two different types of special cells in the back of the eye known as rods and cones. Rods process brightness, and cones process colors. According to Ewalk Hering, who developed process theory, there are three types of photoreceptors in these cones that encode the incoming light into antagonistic pairs of colors. These pairs are red/green, yellow/blue, and black/white. Different wavelengths of light result in the activation of different receptive tolerances of each photoreceptor. If a stimulus overloads one kind of photoreceptor, the photoreceptor will stop responding to that specific wavelength, or will get "tired". This is known as retina fatigue, or adaptation. When the overloading stimulus disappears and another stimulus comes into focus, the fatigued receptors lose their readiness to respond to the similar, specific, non-overloading wavelengths.

Thus, the brain perceives this absence of one wavelength as the presence of another, usually the wavelength of the complimentary color. For instance, if you were forced to look at a red rectangle for a long time, the red-green photoreceptors would lose their sensitivity to the red wavelengths. So, if you were then immediately forced to look at a white rectangle, these photoreceptors' ability to activate perception of the red wavelength would be hindered. This absence of red leads the brain to believe that there is a presence of its antagonistic color, green. Thus, the white rectangle would appear green.

As for the solution for the color of the dress, there is no wrong answer. The perceived colors that each individual argues for are likely dependent on which color he or she last sees before looking at the dress. This phenomenon happens because gold and blue complement each other perfectly in our photoreceptors, and similarly do black and white. If the last color seen is a bright color, it is more likely that blue and black colors are perceived on the dress, and vice versa. However, for the curious minds who must know the answer - the dress is in fact black and blue.

Afterimage effect is used to explain more than just the colors of the dress, however. It is also used to explain numerous illusions and phenomena around the world. One of the most impactful explanations and subsequent applications that afterimage effect theories provide regards surgeries. Because surgeons are forced to look at blood and bright lamps extensively, this can lead to various visual errors, for instance, leaving a knife inside the body due to the inability to differentiate the knife color from the blood. Mistakes in the surgery room due to these errors can be fatal. Due to the explanation that the afterimage theory provides, more and more surgeons can prevent these errors by having their assistants wear green or light blue scrubs. These colors are complementary with red and yellow, so the chance of visual errors is minimize by helping the photoreceptors relax slightly before focusing back on the recurring red and yellow of the blood and light again.

Afterimage effect theories have already settled a fierce debate as well as prevented life loss from medical mistakes. However, their most important impact has been providing further evidence that even with a complex system of sensation and perception, our brain can still be fooled. There are hundreds of illusions that can be accounted for using afterimage theories, but there also are hundreds of illusions and phenomena that are still without explanation. So, the question still remains: Is seeing believing?

PHOTO BY JUSTIN BROACKES


# IF THEIR COLORS WERE DIFFERENT?

## Exploring the psychology of color in branding

BY BRYNN VESSEY, BEHAVIORAL NEUROSCIENCE, 2019
DESIGN BY LILLIE HOFFART, ENVIRONMENTAL SCIENCE, 2022

**Do donuts have an innate color?** With so many flavors and toppings related to them, it's hard to narrow down the entire entity of donuts to one or two colors- but somehow, when the name Dunkin Donuts is added to the equation, orange and pink become inseparable from that doughy goodness. So what makes orange and pink the go-to colors of donut branding? Is there something special about these two colors that inherently links them to sugary snacks, or did the colors become tied through a strategic decision to market the brand in one specific way?

Dunkin Donuts' orange and pink pairing is an example of brand personality. Brand personality, the set of human characteristics tied to a brand, helps to personify a brand in order to differentiate it from its competitors and create a sense of brand loyalty. Brand personality is as multifaceted as human personality, with a scale based on the "Big Five" of human personality traits. Different traits like sophistication, ruggedness, excitement, and sincerity are measured using this scale, giving a brand a distinct identity.

"Brand personality, the set of human characteristics tied to a brand, helps to personify a brand in order to differentiate it from its competitors."

Despite criticism of this scale, it's been largely embraced and has even been validated in a number of different cultures; the personality scale is the golden standard for research on brand personality. One of the most easily identifiable aspects of a brand's identity is the color used in their marketing scheme… Starbucks is green, and Dunkin Donuts is orange and pink. The importance of color has been studied in regards to consumer perceptions of advertising, brand recognition, purchasing intentions, and brand appropriation, but some of the underlying concepts of color psychology have yet to be explained.

Associative learning and its links to the importance of color in marketing have been studied in recent work conducted by Schlack and Albright (2007). From this research, it has been concluded that color associations make use of semantic memory for their formation and activation. The understanding of semantic memory has increased dramatically in the past ten years, with an evidence of modality specific activation. In conjunction with sound and motion, color processing has been demonstrated to show activation in sensory, action, and emotion systems of the brain. The modality specific representations that encode color develop through experience with both internal and external environmental stimuli. As we experience the world in color, memories and associations are created and stored that pair specific things with a color. While conventional schemas for color include red with aggression and yellow with cheerfulness, through the creation of a brand personality, colors can also be tied with these traits as they pertain to a brand.

"Color processing has been demonstrated to show activation in sensory, action, and emotion systems of the brain."

Color associations can influence cognition, affect, and behavior, and can do so without conscious knowledge or intent. Tying colors to brands allows brands to have a subliminal impact on desire, with color choice often being intentional to cause an association. For example, orange has been shown to be arousing, exciting, energetic, sociable, and extroverted. Pink, on the other hand, has been linked to sophistication, softness, and femininity. For a brand hoping to draw in consumers for a morning coffee or donut, the idea of arousal, energy, extroversion, and sophistication makes for a convincing reason to stop in on the way to a long day of work and meetings. Dunkin Donuts' logo was initially all black until a woman in the 1980s suggested that the colors weren't fun and energetic, and didn't accurately represent the brand.

"Color associations can influence cognition, affect, and behavior, and can do so without conscious knowledge or intent."

If nothing else persuades you that color psychology may have some basis in cognitive sciences, ask yourself if you would stop for coffee and donuts at a shop with sterile black and white colors while running to class exhausted, with three feet of snow underfoot. America may run on Dunkin's, but perhaps some of our willingness to drink an iced coffee in 30°F weather is at least partially due to the fact that that cold coffee will make us feel energized, alive, orange, sophisticated, and pink.

# What came first:

## The color or its name?

BY NATALIE MCGOWAN, BEHAVIORAL NEUROSCIENCE, 2021

DESIGN BY LILLIE HOFFART, ENVIRONMENTAL SCIENCE, 2022

**Children grow up** learning that there are several basic categories for different colors, and that each color fits neatly into one of these boxes. Thus, as adults, we think of our ability to discern color as innate, so the language that we use to describe different color categories directly follows our perceptions. If it's a chicken/egg scenario, then the color categories came first, and the ways in which we named them followed. However, cultural differences may actually influence the way we classify color, which changes the perception of colors between different groups of people.

Although we tend to think of the categories that classify different colors as categorical, speakers of different languages can define them in different ways. Specifically, the boundaries between different colors may be broader for one language than they are for another. Furthermore, certain colors may be more universal in terms of how precisely they are perceived between cultures.

A study led by Edward Gibson at MIT focused on the differences in color naming for the Tsimané, a tribe of hunter-gatherers located in Bolivia. Compared to American English or Bolivian Spanish speakers, the Tsimané had fewer categories for color. The researchers conducted a color-naming test, in which participants were given 80 chips and were asked to identify the color of each one. Their results showed that the boundaries between different colors were not as well defined for the Tsimané speakers, and they only had eight basic color terms.

The researchers also found that there was greater variability of color naming among the Tsimané speakers, meaning that each person described slightly different colors with each color term. However, there was almost no variability between red, white, and black among each lingual group. Red is the color of blood, which is an important stimulus to recognize no matter the culture. Similarly, black and white are indicators of light and dark, which are important to identify in a variety of environments. Another example of this is that people all over the world have more words for warm colors because they tend to be the focal points of in the environment, whereas cool colors tend to be in the background, like the sky and the trees. This suggests that we are better at characterizing colors with higher salience.

The dominant theory for these differences is that cultures develop more distinct categories for different colors depending on how useful those colors are to them. In industrialized nations, color may be the primary way to distinguish man-made objects, which may not be as necessary for those living in less industrialized places. These highly defined categories haven't developed simply because the communicative need for them is simply not there. Thus, color naming is generally universal, but is nuanced depending on how useful the color is for that culture.

Furthermore, the language we use to classify colors may change the way we perceive them. We have different words for pink and red because we perceive them as separate colors, even though pink is actually a form of light red. Similarly, Russian speakers have two different words for light blue and dark blue, and generally see the two as separate colors in the same way that we regard pink and red. To study this, Jonathan Winawer from Stanford conducted an experiment that presented participants with three blue squares. One of the three was a lighter shade than the other two, and participants were asked to identify this square in a timed test. Russian speakers could identify this square faster than English speakers could, suggesting that the way we use language to classify different colors affects our perception of them.

This research not only defines the nuances of color naming for people who speak different languages, but also provides a framework for understanding the reasons for these differences. By understanding more of the sociocultural factors that affect color naming, we can better understand the way in which language shapes our perception of the world around us.

# All's fair in love and war, except when wearing red

BY ERICA YEE, INFORMATION SCIENCE & JOURNALISM, 2020

DESIGN BY LAUREN KOURAFAS, GRAPHIC DESIGN, 2021

**Though love and aggression** may seem opposite, their associations with the color red make sense from an evolutionary perspective. Researchers have found that in some non-human species, a male's dominance -- and thus ability to mate successfully -- can be increased by attaching red stimuli. This was demonstrated in a 1987 experiment in which male zebra finches assigned to wear red leg bands exhibited more behavioral dominance than those wearing light green.

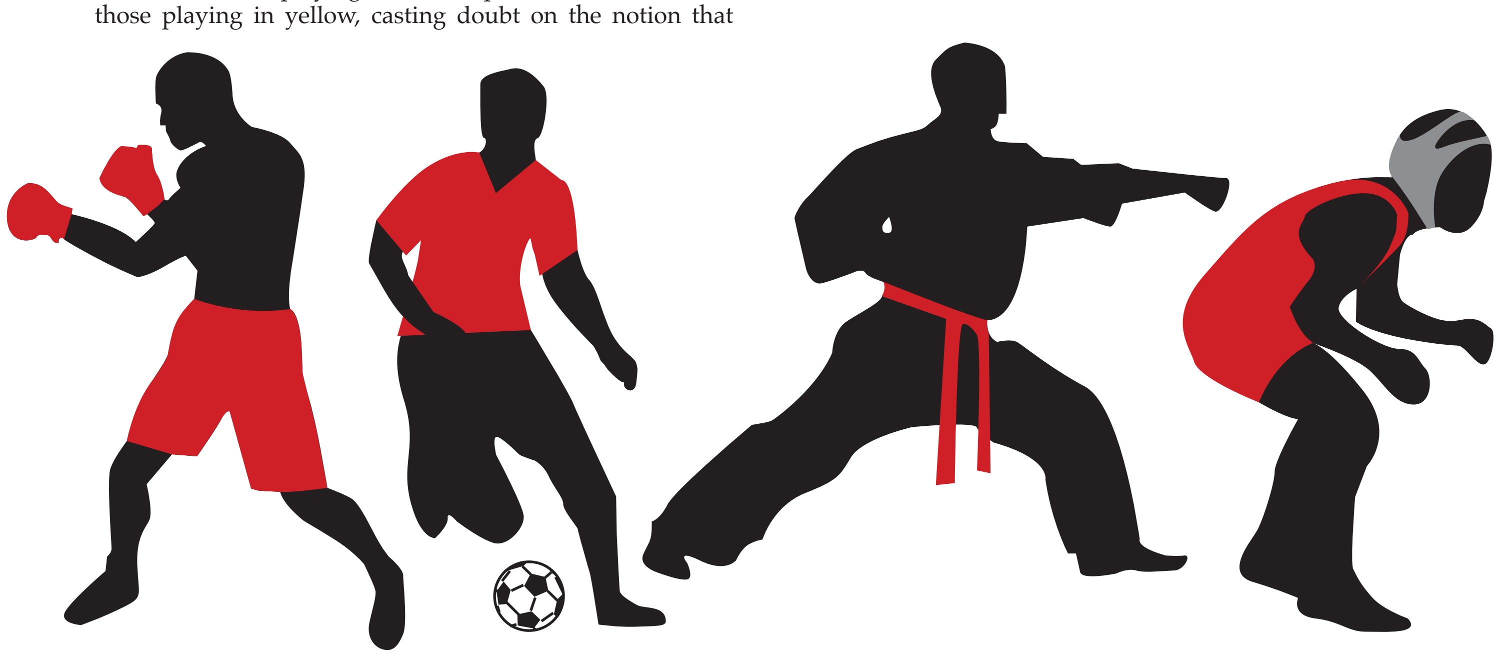
As color is thought to influence not just animal mood but human mood as well, University of Durham researchers Russell Hill and Robert Barton set out to see if this effect translated into a common display of human dominance: sports.

The 2004 Olympics proved to be ripe for studying, with competitors in boxing, taekwondo, Graeco-Roman wrestling, and freestyle wrestling all randomly assigned either red or blue outfits. In all four combat sports and across all weight divisions, Hill and Barton found a consistent and statistically significant pattern, in which contestants wearing red won more fights. Red seemed to only give an edge in closely matched competitions, indicating that "artificial colours may influence the outcome of physical contests in humans," they wrote in Nature.

There have since been several follow-up studies trying to replicate these results in different contexts. Hill and Barton performed another study, published in the Journal of Sports Sciences in 2007, analyzing long-term performance of red-wearing Englishsoccer teams. They found red teams had the best home record across all league divisions over several decades. Teams playing in white performed better than those playing in yellow, casting doubt on the notion that red's winning effects manifest merely in teams that wear a color. This study seemed to support the findings of Hill and Barton's Olympics study, but this time for team sports.

Researchers from Romania and Denmark chose to study the effects of wearing red in virtual competition. By analyzing data from a 2004 multiplayer first-person- shooter tournament, they found that teams playing characters wearing red won more than teams in blue. These findings also seemed to confirm the wearing red effect in team sports, though this time with virtual uniforms.
Another group of researchers wanted to see if Hill and Barton's findings were due to the color red distracting men in competition. Both men and women underwent Stroop tests and were told they would be ranked for this experiment. In a Stroop test, the subject must name the color of a word while disregarding its meaning. The researchers found men had longer response times for the red stimuli, such as "BLUE" in red ink, but that this distractor effect was not apparent in women. This finding suggests that "seeing red" can distract men through a "psychological rather than a perceptual mechanism," by associating red with dominance in competition, the researchers wrote in Evolution and Human Behavior.

While the corroboration of Hill and Barton's findings over various types of competition provides a compelling case for red's winning effect, these results are not necessarily consistent across the actual sports world. As Barton acknowledged to The New York Times when his study was published, "All scientific results are a bit provisional." As sports history has shown, individuals or teams in red do not always hold the upper hand.





# THE HEALING HUES

BY HEATHER OFFERMANN, BEHAVIORAL NEUROSCINCE, 2019

**Are you green with envy?** Has something occurred out of the blue? Have you been caught red-handed? As a society we create idioms that relate color to an emotion, a powerful bond between visual stimulations and responsive feelings. This connection gets tossed around in everyday conversations, but colors can provide therapeutic and healing effects on the person observing them. Color therapy can help people with emotional disorders and physical pain, but it can also simply relax or decrease present negative emotions such as temporary stress or anger.

The theory that colors have healing properties is no new idea. The ancient cultures of Greece, Persia, and China believed that colors can be related to temperatures of the body, just as we relate red to "hot" and blue to "cold." Color is a form of visible light, which has both frequencies and vibrations specific to where the color falls on the visible spectrum. It is thought that these specific frequencies can affect the energies in our bodies, thus ultimately producing emotional or even physical feelings when viewing a certain color. This is this idea behind Pantone's annual "Color of the Year," which is a color carefully chosen based on the prediction of a mood and attitude for the upcoming year. The color for 2017 was "Greenery," which is a yellow-green shade associated with vitality and increasing closeness to nature.

The "Color of the Year" is just a small example of how color reflects emotions, but many researchers and psychologists have taken color therapy to a larger scale to benefit those who are hurting both emotionally and physically. Baker-Miller Pink is a particular shade of bubblegum pink that has proven to suppress appetite and increase weakness, thus decreasing intended acts of violence. A researcher by the name of Alexander Schauss conducted studies in the late 1960s to see both the physiological and psychological changes in people after viewing Baker-Miller Pink, and observed decreased heart rates and slower breathing. This shade has been painted in numerous correction facilities, prisons, and psychiatric hospitals to decrease incidences of violence and to improve the overall environment for the prisoners and patients. The effects can be seen after just 15 minutes of viewing this pink, and trendy fashion items such as sweatshirts and sunglasses have been tinted to Baker-Miller Pink to help spread calmness and relaxation.

In hospitals, it is especially important to create an environment that is welcoming for patients undergoing stressful procedures. By carefully choosing colors for walls, carpets, and curtains, interior designers can play a part in the healing processes of medical care. Pediatric environments tend to have bright colors such as oranges or yellows to promote warmth and positive energy. Calming colors like blues and purples are common in critical care or emergency units to maximize stress-reduction for patients going through a trauma. We are all familiar with the nerves induced when waiting for a doctor in a small examination room. Soft, light colors such as pale yellows are used in these areas to counteract any feelings of claustrophobia.

Colors have been shown to hold physical healing properties as well. Blue light has been found to reduce the pain of rheumatoid arthritis,



and with longer exposure to the light, the more pain relief was felt by the patient. Another more specific type of color healing is photodynamic therapy, which uses a photosensitizing agent with light of a particular wavelength to directly kill cancer cells and surrounding cells. Many people view color therapy as pseudoscience, but it can subliminally change the mood of a person in a way that impacts their future attitudes of medicinal treatment. Color therapy can be as simple as painting an office a particular color to increase productivity, or even wearing a colored shirt that reflects your mood of the day. More people are starting to realize the effects that colors can have to improve their everyday lives in schools, the workplace, and hospitals - highlighting the connection between what we visualize in the outside world and the psychophysiological responses of our bodies.

DESIGN BY YECHAN YANG, PSYCHOLOGY AND CHEMISTRY, 2022

# Visionaries

BY LUCAS PRINCIPE, ENVIRONMENTAL SCIENCE AND PHILOSOPHY, 2021

ILLUSTRATIONS BY IRINA PYATAEVA, BIOENGINEERING, 2020

**It is sometime** in the mid-3rd century BCE. Aristotle, the most famous philosopher of his day, is strolling through the sunlight grove of the school he established, The Lyceum, discussing his ideas on a sensation we all experience everyday: color. From your frosty seat on the shaded white-marble stairs you can see him approaching, cloak whisking in the Mediterranean summer breeze, speaking with a friend. Luckily, you're able to make out the poetry he's weaving.

"My dear Herpyllis, it's quite like this: as you know, the four basic elements are earth, water, fire, and air. And these elements don't only exist in isolation, but as varying mixtures of each that make up all the matter in the world, including humans. The objects we see every day consist of varying proportions of these elements, which in turn produce the colors we perceive them to wear. All colors are, however, a mixture of light and darkness, black and white. Light and darkness then enter the eye at such a rapid speed that they aren't perceived as just black and white, but as colors. This is because they are superimposed inside the eye. This creates the five fundamental colors: violet, green, blue, red, and yellow."

Suddenly, the olive trees and wine-dark Aegean sea of Ancient Greece have disappeared. You find yourself in a quiet, candlelit study furnished with dusty leather seats and a broad wooden desk. A primitive telescope sits in the corner. The year is now 1622 in a villa near Florence, Italy. Two men walk in, already so engaged in a discussion they don't even notice you sitting in the corner. Closing the door for absolute privacy, they continue on with their conversation.

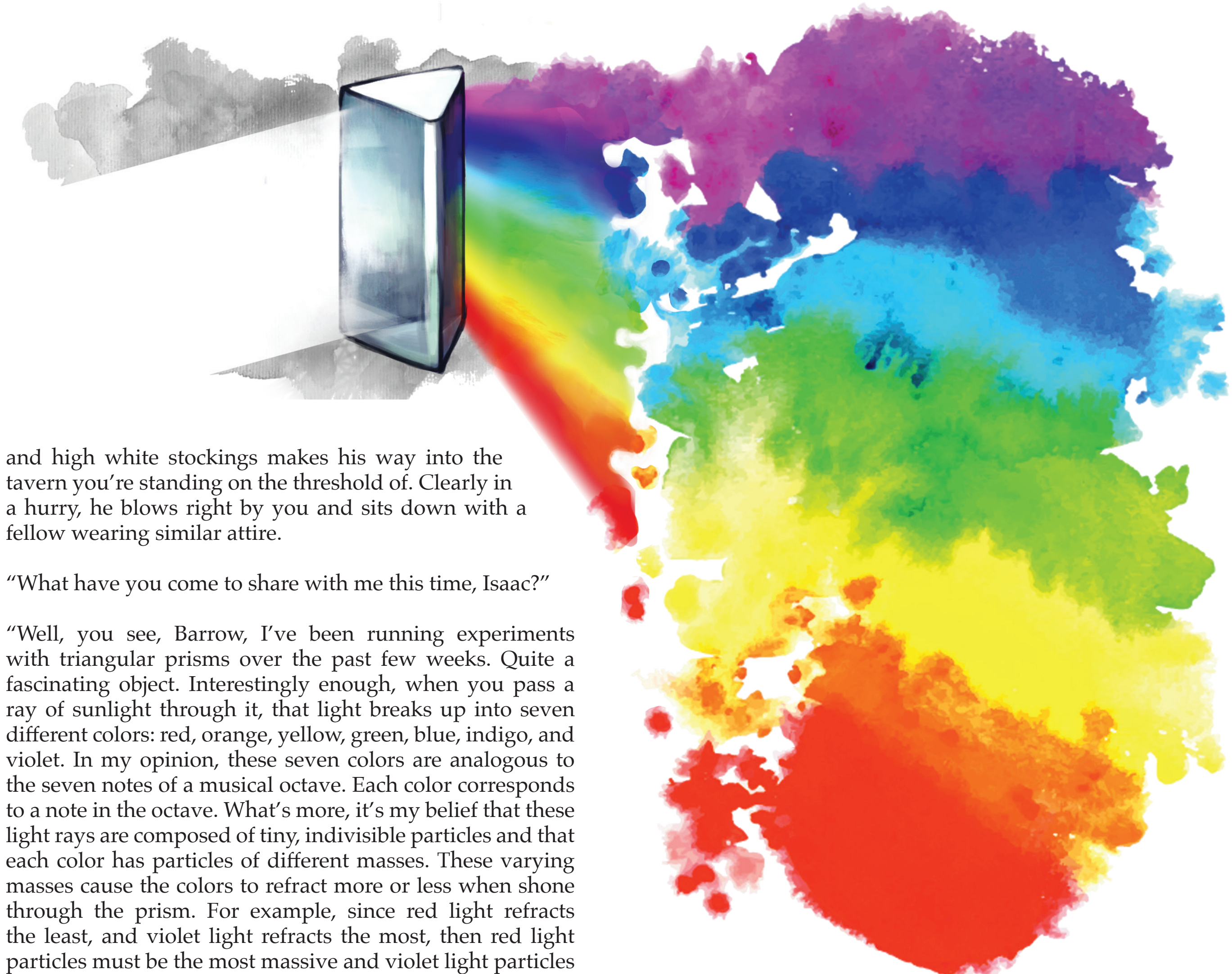
"You've already been condemned by the Church, Galileo. Must you publish another scientific work? You're playing with fire each time you do."

"This time it's different, Virginio. I haven't been thinking about the motion of celestial bodies lately, only the fundamental particles of life. You see, everything in this world is made up of tiny, indivisible particles, corpuscles I call them. The interactions of these corpuscles with our sensory perceivers create the five sensations we experience every day. Moreover, each corpuscle contains primary qualities, such as motion, size, shape, and location, which in turn give rise to secondary qualities in objects, like odor, sound, and color. Color, the most interesting of all, is nothing more than the tiny particles of light of varying number, shape, and size, coming from an object, which interact with our eyes in different manners, producing different shades. What's more, I can then conclude that if we, the men who perceive these colors, were banished from existence, then colors wouldn't exist at all."

"So you're saying that color only exists within the mind? and isn't a property of the object itself?"

"Exactly."

Once again, you find yourself lifted out of the engaging discussion you were comfortably eavesdropping on, only to be whisked away somewhere else. Wherever you are now, it's dreary and cold. The sun is veiled by a thin layer of metallic clouds. It's a rainy, wind-laden day on a busy street filled with pedestrians. Horses and carriages are dodging here and there to avoid colliding with each other on the rough cobblestones. It's the mid-1660's, in Cambridge, England. A young man in a long wool coat



and high white stockings makes his way into the tavern you're standing on the threshold of. Clearly in a hurry, he blows right by you and sits down with a fellow wearing similar attire.

"What have you come to share with me this time, Isaac?"

"Well, you see, Barrow, I've been running experiments with triangular prisms over the past few weeks. Quite a fascinating object. Interestingly enough, when you pass a ray of sunlight through it, that light breaks up into seven different colors: red, orange, yellow, green, blue, indigo, and violet. In my opinion, these seven colors are analogous to the seven notes of a musical octave. Each color corresponds to a note in the octave. What's more, it's my belief that these light rays are composed of tiny, indivisible particles and that each color has particles of different masses. These varying masses cause the colors to refract more or less when shone through the prism. For example, since red light refracts the least, and violet light refracts the most, then red light particles must be the most massive and violet light particles the least."

You were captive on the edge of your seat listening to the great Isaac Newton, but now you unexpectedly find yourself lifted out of Stuart period England, back into your current time, reading the latest issue of NU Sci. More than two thousand years have just passed you by, yet only relatively recently have we started to understand the true, minute mechanics of color theory and the wave-particle duality of light.

You may find their beliefs archaic, but these are just a few of the philosophers and scientists who laid the groundwork for our modern color theories, along with so much more. Without their contributions, our contemporary understanding of color may have never come about. It's no secret that each visionary was flawed in his own regard. For Aristotle, we know now that there are far more than four basic elements; and that color isn't produced by the superimposition of dark and light in our eyes, but by the perception of different wavelengths of light by cone cells in the back of the eye. In regards to Galileo, it's now clear that the world isn't made up of tiny block-like, solid corpuscles ranging in shape and size, but by atoms composed of standardized protons, neutrons, and electrons. Likewise, Newton made the same mistake assuming light to be composed of particles. Not the conception of the particle-wave duality we hold today. However, what's remarkable is the degree to which they were right. Each in their own regard developed a very competent color mechanism for their time. By applying their theories to ours, we realize that while the terminology may be different, the structure is somewhat similar. All three developed a mechanism for color that involves the eye absorbing and analyzing light. Furthermore, each of these theories provide that the microscopic properties of an object determine the color it displays. By looking at our modern understanding of color, it's clear to see the influence these theories carry. The phrase "ahead of their time" is an understatement.

So, as we plunge forward into our bright future in this scientific golden age, we should always be cognizant of the past achievements that have brought us to this point. We must recognize that science is ultimately the process of building new ideas on a bedrock of timeworn ones, a gift each generation has granted to posterity.

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