CABINET OF CURIOSITIES
ESSAYS AND ARTICLES ON TOPICS OF INTEREST

by
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Abstract

I have always found my attention easily captured and my interests ever-changing. This collection of essays and articles displays my ever-shifting focus and natural curiosity. I invite you to dive into my curiosities with me.

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My attention and curiosity have always been easily captured. Throughout middle school, high school, and college, I constantly changed my career outlook to match my current fascination. Everything from science fiction author to forensic anthropologist made my list of dream careers at some point. It was only during my time in the Master of Arts in Science Writing program at Johns Hopkins University that I realized I could use this shifting focus to my advantage.

Science writing is one of those all-encompassing terms that is just a little fuzzy around the edges. I think this is part of what draws me to the field: the infinite possibilities of things to pursue. Science writing is an outlet that allows me to explore whatever my current curiosity is—to whatever depth I want to dive.

My thesis, composed of essays and articles on all sorts of topics, showcases the curiosities I chose to pursue during my time in the science writing program. Everything from nutrient deficiencies to robots has captured my attention, and those are just what made it into my thesis.

All of this work was completed during my time at Johns Hopkins University, starting in August 2022 and ending in May 2024. I wish to thank all the teachers, mentors, and peers who helped me along the way, my friends and family for supporting me through my journey,
and my thesis adviser for working with me to develop my best work. I will always appreciate the friends I made and the opportunities I had along the way.

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Smoke on the Mountains: Science of the Smoky Mountains

On any given day, a drive through the Great Smoky Mountains National Park could yield views of mountains painted brilliant hues—the palette changing by the season—and decorated with puffs of “smoke” rising from the ranges. The glowing summer sun lights up countless shades of green, then returns in the fall to highlight the autumn colors as they pop out from behind their chlorophyll coverings. After melancholy winter days, spring announces its arrival with the return of color to the mountains in the form of wildflowers and budding leaves. Regardless of the season, the Smoky Mountains always have sights and colors to be seen.

These mountains, part of the Blue Ridge Mountain range family, which are, in turn, part of the Appalachian Mountain range, span the border of Tennessee and North Carolina. The longer chain of the Blue Ridge stretches from Georgia north to Pennsylvania. Western North Carolina boasts the highest peaks along the chain, with Mount Mitchell—just outside Asheville—the tallest mountain east of the Mississippi. The Smoky Mountains, nestled amongst the Blue Ridge, are home to many beautiful views and scientific marvels, some of which provide the mountains with their names. However, the region’s beauty does not protect it from the problems plaguing the rest of the world.

The Smoky Mountains earned their name from the characteristic “smoke” often seen curling among the peaks. But as anyone who has spent time in the region can tell you, this smoke isn’t from fires. Instead, these wisps are a fog created by volatile organic compounds,
or VOCs—natural byproducts of photosynthesis released by the region’s numerous trees. Although plant-based VOCs share a chemical pedigree with those released by vehicles (major contributors to air pollution), they are harmless. The smells associated with many plants, like grass or pine trees, result from these flora releasing their VOCs into the air. These compounds have a very high vapor pressure, forming a thick fog-like mist on a nice, temperate day. These cottony wisps often appear to be caught in the trees as they rise, giving the feeling you could reach out and touch them.

You might be wondering why the Smoky Mountains are known for this phenomenon if plants cause it—surely other regions can produce this fog. And they can, but the Smoky Mountains have an abundance of it on any given day because of this area's unique topography and ecology. The Southern Appalachians are considered a temperate deciduous rainforest, known as the Appalachian Rainforest. Large amounts of yearly rainfall (an average of 60 inches per year) result in high humidity that combines with cool temperatures to create numerous clouds. These clouds often sit low on the mountains — contributing to the appearance of smoke—and create an ideal environment for the plants to maintain moisture. Then the plants undergo photosynthesis, and the rest is history. Well, kind of—we didn’t always know this was the cause of our mountain smoke.

Plants and their photosynthesis are also responsible for the name behind the Blue Ridge Mountains. This range is one of a select few in the world known for their blueish cast when viewed from a distance. VOCs called terpenes, produced only by conifers, scatter blue light as it rises into the atmosphere, casting a blue haze across the valleys and peaks. Again,
these are not dangerous, pollution-causing VOCs—plus, these smell of fragrant pine, not car exhaust. Some people believe that the Japanese art of forest bathing—simply spending time in the forest and smelling its scents (the VOCs)—can have health benefits, such as stress relief and the associated physiological impacts.

Before the 1960s, no one was quite sure what the source of the smoke in the mountains was, though the phenomenon was well documented before that. Theories included everything from dust to water vapor collecting in the sky. In July 1964, the New York Times published an article outlining the journey from speculation to experimentation on the cause of the smoke in the Smoky Mountains. Earlier that year, scientist F.W. Went and his colleague, Reinhold A. Rasmussen, published their findings on the topic: VOCs were the cause of this phenomenon. Went had previously published a theory on the blue haze being caused by plants releasing vapor. In hopes of proving the hypothesis, Rasmussen spent considerable time and effort testing the air of the Smokies and other locations to compare VOC concentrations. He used a chromatograph, which allowed him to separate the atmospheric gas components to test their quantities. Rasmussen not only proved Went’s theory correct but also learned that these vapors’ concentrations depended on environmental conditions like rainfall and sunshine.

Each year, the Great Smoky Mountains National Park hosts millions of visitors, consistently ranking as the most visited park in the country. In recent years, the popularity of visiting the Smokies has grown, with the park experiencing a record-breaking year for visitors in 2022. October—the peak of leaf season in this region—was responsible for 1.6
million of the year’s 13 million visitors. Locals are familiar with the influx of traffic to the area during autumn, often planning large fall festivals to coincide with leaf season and the last of the year’s tourists.

The United States has plenty of places to view fall foliage and mountain views, including the rest of the Appalachian Mountains. Still, nestled in the heart of the Blue Ridge, the Smoky Mountains have a unique appeal. The blue haze tends to disappear during the colder months of fall and winter, but smoky wisps still rise from the trees. Paired with the vibrant oranges, reds, and yellows of the deciduous trees in fall, the blankets of smoky mist create an ethereal sight. On a drive through the Great Smoky Mountains National Park or a tunnel of trees on the Blue Ridge Parkway, rediscovering a sense of wonder for the natural world is not hard. Pull off at any overlook along these routes, and you’ll meet fellow admirers and nature photographers soaking in the beauty. Fortunately, people of the past thought to protect these fascinating forests, even before they understood the magic behind them.

The Cherokee of the area called this region Shaconage (Sha-Kon-O-Hey), meaning “Land of Blue Smoke.” The first appearance of the colloquial name was in the North Carolina legislature, noting a region as the “great Iron or Smoaky Mountain.” The modernized spelling came later. Efforts to create a national or state park in the area began as early as the 1890s but with little success. Finally, in May 1926, Calvin Coolidge passed a federal bill to create the Great Smoky Mountains National Park and its Virginian cousin Shenandoah National Park. (These parks are now linked by the Blue Ridge Parkway, America’s longest linear park).
Tennessee and North Carolina donated hundreds of thousands of acres to create the destination, and Franklin D. Roosevelt officially dedicated the park in 1940.

People of the past saw these lands as worthy of protection, but sadly, even a national park designation cannot protect them from everything. The naturally occurring VOCs in the Smoky Mountains are in no danger of going away, but they have some competition for air space. The Great Smoky Mountains National Park regularly measures some of the highest air pollution in any of the national parks, according to the National Parks Service. Air pollution, caused mainly by burning fossil fuels, originates outside the park and is carried into the boundaries by the customary high winds of the region. The mountainous terrain and weather patterns trap pollutants, causing them to concentrate over the park. Since the park's dedication, the air quality and associated visibility have decreased drastically, with visibility in the park now roughly 80% lower in summer and 40% lower in winter than in the 1940s. Unfortunately for the natural beauty of this area and its visitors, the pollution washes out colors and decreases the distance and quality of what can be seen.

In addition to obscuring views, pollutants can pose health risks to tourists, flora, and fauna in various ways. Poor air quality can be hazardous to anyone if it is bad enough, but people at higher risk—like those with asthma or other health conditions—should be cautious during times of higher pollution. Acid rain is also a concern within the park, with the average rainfall measuring five to ten times more acidic than typical rainfall in other places. Acid rain is caused by high deposits of sulfur and nitrogen within the park, which can also
harm plants in other ways, like triggering the release of aluminum concentrations from the soil.

Great Smoky Mountains National Park has most of its pollution blown in from other areas—shown through testing of the pollutants by the National Parks Service—but visitors are also notable contributors. Visitors release emissions directly into the park through the high volume of vehicles passing through. Quantifying the amount of pollution emitted from vehicles passing through the park is difficult, if not impossible. However, vehicles are a major cause of pollution within the United States, so they undoubtedly contribute to air quality in the Smokies.

Since the 1980s, the NPS has taken several steps to limit or eliminate pollution sources within 120 miles of the park. The park system continues to take steps to stop the pollution in the park through joint efforts with the Environmental Protection Agency, state agencies, and the relevant parties releasing concerning pollutants. While the Smoky Mountains have not fully returned to their former glory and are still several decades away, improvements are slowly occurring. Improvements in the pollutant levels can be seen in the regular monitoring reports from the park. As for now, we can enjoy the park's beauty while being mindful of our potential impacts on the natural environment.
Caught Red-Legged
Elusive Salamanders Spotted in the North Georgia Mountains

We had found it.

Well, my research partner, Trey, had found it. His ecstatic cry had come from further down the slope of the rocky mountain trail. A headlamp bounced toward me as the yelling continued; Trey came to a stumbling stop beside me, breathing heavily. It had been him calling for everyone's attention. Boots squelched through mud, and rocks tumbled together as everyone on the research trip hastened to form a group around the discovery.

There, huddled in Trey's cupped hands, was the small black body of a gray-cheeked salamander. Specifically, a gray-cheeked salamander with one partially red leg—easily identifiable and exactly what we had been looking for. The little creature became a celebrity as we tried to show off our new friend: Cameras flashed, lighting was adjusted, and new backgrounds were tested.

This gray-cheeked salamander was a groundbreaking discovery, and one of the members of our expedition—Thomas Floyd, a Georgia Department of Natural Resources (Georgia DNR) biologist—was there to verify it. Previously, experts believed this salamander did not exist in the north Georgia mountains. Its now-proven presence in this area could allow us to make important inferences about climate change and its impact on these colorful amphibians.
Our research aimed to prove the gray-cheeked salamander had changed its natural range to include mountainous areas where it hadn’t previously been found. We thought it was doubtful these salamanders had just been overlooked before, so proving they were here meant we were also proving they were new to the area. If we paired this discovery with other climate data, like increasing temperatures, we could show that this species was moving further north and higher in elevation in response to a changing climate and warming temperatures. We proved the gray-cheeked salamander was in our area in a relatively short time, but it will take many more years of careful data collection to confirm the species’ range is shifting in response to climate change.

The research team I worked with, composed of several other biology majors and myself, had gathered data for months under Jonathan Micancin, Ph.D., assistant professor of biology at Young Harris College. Our research began as the leaves left the trees during our fall semester and culminated as branches welcomed spring with new buds. This research hike was our last hurrah before some of us graduated and moved on.

The school is nestled in the north Georgia mountains at the southern end of the Appalachian Mountain range. The college campus has many acres of pristine forest and shares a border with the Chattahoochee-Ocoee National Forest. This position put us in a prime location to study salamanders and the changes they might be undergoing in response to climate change. The southeastern United States is considered a biodiversity hot spot for amphibians, meaning many species have chosen to call this area home—giving us lots of potential samples. Our chosen subject, though, was fascinating to many of us.
The gray-cheeked salamander is a terrestrial species in the family Plethodontidae or the Plethodons. The gray-cheeked salamander was a single species until several years ago when genetic testing told us we were looking at several distinct but very similar species. These species now form the gray-cheeked salamander complex and are almost impossible to differentiate without genetic testing. The recent change means the classifications are still murky and somewhat in flux. Some experts, like Micancin, believe seven species belong in this complex, while others think there are only four. Currently, there is no consensus, and some scientific literature contradicts itself even within the same article.

All species in this complex share a trait of light gray cheeks, the reason for their name. These cheeks contrast beautifully with their dark bluish-black bodies. These black beauties can grow to five inches long, but we rarely saw them this size during our explorations. Some gray-cheeked species sport red legs or red cheek patches, but these colorations can vary widely, even between individuals of the same species. The red designs can present uniquely, sometimes only covering part of one leg. We hoped to find the red-legged salamander of the gray-cheeked complex, sometimes known as Jordan’s salamander, because it was easily identifiable. We could petition to extend range maps to include our area of north Georgia once we had enough verifiable observations. Unfortunately, our observations of true gray-cheeked salamanders were few and far between. So, we had to get a little creative.

Micancin believed the gray-cheeked salamanders may have started to hybridize or crossbreed with their cousins, the slimy salamander. He thought this for several reasons, but
one was our repeated finding of strange-looking slimy salamanders. Micancin had plans for future research teams to prove this hybridization was happening and add further evidence to our climate change theory. However, before that research could be done, we had to prove the gray-cheeked salamander was present in our area. Though we weren’t trying to prove hybridization was happening (yet), we used it as a working theory to help us collect data.

The slimy salamander is also part of the Plethodon family of terrestrial salamanders but is grouped with a different species complex. They are named for a sticky, glue-like slime they emit when under stress—like being picked up by a researcher. We’d often drag back onto campus after a night of hiking with our hands covered in layers of dried slime caked in dirt. This slime was notoriously hard to scrub off and could frequently still be found on our hands in class the next day. “Slimys” can grow up to seven inches long (though we usually found them much smaller) and have a black back fading into a light stomach. They are known for a rash of spots running along their dark sides; the speckles often glowed slightly green in the light of our headlamps but can appear white or yellow depending on the individual salamander.

We frequently found slimy salamanders that seemed just a little “off”: significantly fewer spots than usual, an uncharacteristic gray tint to their cheeks, or a lighter body color. Micancin and Trey created a scoring system that, very simply, ranked these possible hybrids as “more or less like a slimy” and allowed us to include them in our research.

Our research team carefully collected data from forests in our area in the months leading up to our hike with DNR biologist Floyd. We used Micancin’s office as a home base,
meeting there before hikes to discuss route plans and pack bags. After each prep session, we hiked into the woods, armed with waterproof notebooks, headlamps, and research packs stuffed with other essentials. (In my case, this was always at least one peanut butter sandwich). The campus served as our base camp and primary research location for these late-night adventures, but given the nature of a salamander, we had to stray far from any of the buildings.

All salamanders prefer a cool, damp environment, but they find these in different places. Gray-cheeked salamanders are usually found in forested areas and only emerge from their tiny underground homes when the weather is right. Some of their cousins prefer streambanks to have desirable moisture all season—I’d imagine this is the salamander equivalent of living in a vacation destination. Terrestrial salamanders will appear on the surface when the weather is cool and damp, and after a fall or spring rain shower is the perfect time for a salamander hunt. Don’t bother heading out during the day, though; salamanders are nocturnal. We conducted most of our research using the light of headlamps, sweeping the beams back and forth across our path to watch for movement among the forest debris. We found dozens of salamanders scampering across the tops of leaves along the trail on good nights. On bad nights, we sometimes resorted to digging through the leaf scatter on our hands and knees, but usually not for long before giving up.

We caught and temporarily held any salamander we thought could be a gray-cheeked or hybrid while we made notes. Sometimes, the captor held the salamander in their hands while we did this. Other times, we placed them in plastic sandwich bags blown full of air,
allowing for easy observation in a way that theoretically minimized stress. The carbon
dioxide in our breath supposedly calmed them down without causing any harm. We always
returned the salamanders to the place we had found them.

We collected data on size, age, sex, and location, all carefully written down. Sex and
location were the most important factors in our research, but it didn’t hurt to have the others
despite them not being very accurate. Size and age were both best-guess scenarios: We didn’t
follow any rules for determining these factors. Size was small, medium, or large, and age was
juvenile or adult. This worked well enough for our purposes. Determining the sex of the
Plethodon salamanders equated to flipping them over and checking for a “disc” on the
bottom of their chin. Males had the disc, a raised patch of skin used to release pheromones.
We marked salamander locations on our GPS systems, but Trey also wrote down the
coordinates for where we found each salamander. Later, we turned these data points into a
map for visualization.

As the temperatures started to warm again and became friendly to amphibians and
their undergraduate researchers, we finally felt ready to share our work. Micancin contacted
Floyd and scheduled the fateful hike that would make or break our research. Floyd was the
expert on the gray-cheeked salamander. Not only did he study amphibians and wildlife, but
he also wrote the gray-cheeked salamander entry in Amphibians and Reptiles of Georgia, the
field guide Micancin and all his students relied on. Unfortunately, the range maps—
depictions of where a species is naturally found—were no longer accurate.
Floyd agreed to hike with us along the Wagon Train Trail, a historical trail connecting our campus to Brasstown Bald, the highest peak in Georgia. We were worried Floyd did not believe our research was accurate and might be coming to gloat if we were wrong. None of the students spoke to Floyd before the hike, so these feelings came from nerves. However, a personal investment in disproving our theory was understandable. If our research was correct it threatened to displace him as the primary expert on the gray-cheeked salamander and make his entry in Amphibians and Reptiles of Georgia out of date.

We set out from the top of Brasstown Bald as dusk began to settle around us. Floyd had gotten a head start to give him time to explore and planned to meet us on the trail. Our large group split into several smaller clusters and spread out as we started hiking. Volunteers had joined our research team, including a large section of the women’s softball team (tagging along with one biology major friend) and a few lower-level biology students, hoping for extra credit.

As the darkness fully cocooned us, headlamps flipped on one by one. With eyes peeled, we watched the ground in front of our feet—partly for safety, so we didn’t twist our ankles on the uneven ground and loose rocks, but also to watch for skittering salamanders to cross our path. We had settled into a comfortable silence when the call for the first salamander came in. Unfortunately, it wasn’t a gray-cheeked salamander, but it was still a sign that our weather predictions were correct.

Excited calls joined chirping crickets as the number of salamanders increased the later it got. Everyone was finding salamanders soon, and the captures became less exciting.
Multiple species were found, admired, and replaced as we descended the mountain. We had caught several dozen salamanders when we saw Floyd’s headlamp approaching from down the trail, but none of the kind we wanted. The research students had fallen silent, knowing the importance of finding at least one gray-cheeked salamander. More hours passed, with many people searching the trail and surrounding bushes for the precious prize we all wanted. We just needed one.

Finally, Trey’s call floated up to me as midnight approached. The yells had grown less excited as the night went on, but this one was different. Trey joined me on the side of the trail, sheltered from the slight drizzle by the thick rhododendron bushes. Micancin and Floyd appeared beside us out of the darkness. Students crowded in on all sides, pushing to see the star of the night. Floyd studied the creature silently while everyone else held their breath. Even the crickets seemed to be waiting for the answer.

I had seen the prize and knew there was no way Floyd could deny that the salamander sported a red leg. Regardless, I couldn’t stop my grin when his headlamp bobbed up and down in a nod, flashing the light across our faces. Trey moved to jump up and down, then remembered he was still holding our precious cargo and contained himself, making it look like he’d shrugged aggressively instead. Micancin’s arms flew out to punch the air in victory, accidentally catching the side of my face. The cold mountain air had numbed my face, and the hit didn’t hurt, but Micancin pulled me in for a hug and a quick “sorry” while he continued celebrating. Floyd maintained his silence while he pulled out a camera to document the salamander.
Floyd’s face was obscured by the bright light of his headlamp, making it hard to decipher his reaction. He stayed silent, but maybe he was the strong, silent type. Floyd certainly hadn’t talked much before the find. Micancin handled all communications with Floyd until the hike, and I had no previous in-person experience.

After we finished documenting the salamander and had adequately patted each other on the back, we started the long hike back to the top of the mountain. The softball players took the lead as the students again spread out; the athletes’ laughter disappeared into the darkness of the trail ahead of us. The research students put space between us, Micancin, and Floyd. We could hear the men talking in low voices behind us as we ascended.

We knew before the hike this was just the first step in a long process. With Floyd on board, it will be much easier to make progress in changing the range maps and drawing more attention to the range shifts happening in our mountains. However, we students weren’t sure what the next steps would be. With our impending graduation, we had only been looking as far into the future as this hike. Now that it was over, we knew the research was in the hands of Floyd, Micancin, and future students. It was a huge step forward to find a gray-cheeked salamander in the presence of an expert, but the critters’ presence will have to be documented more than once on this mountain and its neighbors before the range maps can officially be changed. Hopefully, Floyd is working on the project now, too, from a different angle and with different resources than Micancin. We only needed to find one gray-cheeked salamander while he hiked with us.

And we had found it.
I slung my backpack over the back of a bar stool in a Dublin Burger King. It was my first morning in Ireland, and the fast-food chain was the only place open at 4:30 in the morning. I was sure they served breakfast. They didn’t. So, instead, I ordered chicken nuggets for breakfast and let them grow cold while I dug through my backpack for maps and bus routes. I planned to explore the southern coast for the afternoon before catching the last bus to Killarney in the west. I would be crossing the entire country in one day, with plenty of time for detours and stops. This was a novel concept as an American, where many hours of driving might not even allow you to escape a state.

I stayed in the Burger King until the stares of the employees started to make me feel uncomfortable. The daylight was beginning to peep through the clouds, and I was ready to explore anyway. And if I didn’t start moving soon, I might fall asleep on the table. I had withstood the embarrassment when one of the employees had to help me count the coins for my meal, but passing out from exhaustion was not something I could come back from.

My plane had landed in the Dublin airport earlier that morning after an overnight flight from Boston. I had been held up in customs when the acceptance letter for my study abroad program was insufficient proof that I was supposed to be in the country. Eventually, the customs official was satisfied that I planned to leave after my two-week stay and stamped my passport. I’m sure arriving early for my program did not help my case for being in the
country. I had planned to arrive three days early and explore the country on my own before meeting the rest of my group for our ancient architecture course.

After many hours confined in a plane, I was eager to explore and caught the first bus into the city center. I felt alone in the typically bustling city; no one else had ventured outside. Unfortunately, no one else being awake meant there wasn’t much to do in the wee hours of the Irish morning. However, the mysticism of the empty streets and morning fog captured my imagination. A thick fog drifted up from the river running through the city, and colorful flowers hung from doorways and lamp posts, scattering their petals onto the sidewalks below. I carried my cold chicken nuggets as I wandered the sleeping city.

By 6:30 a.m. I was on a bus to Cork, a lively city on Ireland's southern coast. I joined the rows of passengers who had ridden directly from the airport, recognizing some of the same travelers who had deboarded my plane with me. County Cork is known for its coastal real estate and rolling farmland, but my destination—Cork City—is a metropolis of historical and cultural sites. I wedged myself and my carry-on suitcase into a seat halfway toward the back of the bus and settled in for an uncomfortable ride.

My first glimpses of Cork looked very similar to most cities I’ve experienced—full of construction. Detours forced the bus driver to let us off on a side street rather than the planned stop. As I climbed off the bus, I was disappointed. Cork was one of my bucket list cities, but it stank—literally. The day had grown hot since I boarded the bus in Dublin, and I felt like I’d stepped into an oven. I had half a mind to get back on the bus and head directly
to Killarney rather than spend the afternoon in this seaside cityscape. The sounds of construction echoed off the buildings around me, mingling with the smells of fish, bus exhaust, and sea air to overwhelm my senses. My extensive travel from Atlanta to Boston to Ireland in less than twenty-four hours had left me exhausted and nauseous, the feelings exacerbated by my heavy luggage and the smells of the city. The city steamed with humidity, making the day even more miserable than heat alone could.

Instead of boarding the bus, I followed my original plan and mapped out my afternoon on my phone. A few blocks later, I checked my suitcase into the storage room of a tour company, trashed my chicken nuggets, and started the hike to the historic Cork County Jail. The jail—or gaol, as it is also known—was why this seaside town had been on my Irish bucket list. Earlier in the year, I had worked for a travel agent specializing in Ireland and the U.K. Every day, I booked other people’s trips to the places I hoped to visit someday and slowly added them to my bucket list. The gaol was a popular destination for the travel agent’s clientele, and I had been looking forward to visiting it since the first time I added it to someone’s itinerary.

I began my uphill hike to the gaol, stopping for pictures as buildings sprawled below me. Dark river water snaked through the city, lined on both sides by cobbled sidewalks and colorful buildings. I could see the English Market—another popular destination—on the opposite river bank. I quickly regretted not checking my backpack into storage also. It was on the small side, intended for traveling, but was storing some of my heavier items like electronics. The straps dug into my shoulders, and its padded surface—designed for
comfort—trapped the July heat against my back. I watched tour buses and taxis breeze by me on the way to the same destination, but they made much quicker work of the San Francisco-esque climb.

The lobby of the stone jail offered a cool reprieve from the summer heat. I paid for my tour and retreated into the courtyard at the center of the prison, where I could rest in the shade of the stone walls. The employees had gifted me water, and I settled on a picnic table to enjoy it.

Cork City Gaol was built in the 19th century and served the area for just over 100 years. The walls that shaded me during the steamy July weather had been built in 1818, more than 200 years before I walked into the courtyard. The jail closed in the early 20th century due to deterioration of the facility, then reopened in the late 90s as a historical tourist attraction for the region. Now, visitors can take pictures in a jail cell, walk the inmates’ exercise circle, and learn the jail’s history through a guided tour. The venue is also available for weddings—a popular destination, I’m sure.

A young tour guide herded a small group of tourists and me around the grounds and the jail, spouting facts about its history and occupants. Metal staircases wound between floors, opening onto landings lined with the low-framed wooden doors of cells. Wax figures of jailers and inmates stood frozen in time throughout the jail, adding to the eerie feeling the building might be haunted. I stayed behind in every room to capture tourist-free pictures of the old stones and low-hanging ceilings. These would be part of a collection of more than 3,000 pictures I took during my three weeks in Ireland.
After the tour, I started the winding walk back into the city. Most people would have learned from their earlier mistakes and taken a taxi, but I decided downhill was more manageable than uphill. The jail satisfied my curiosity about Cork, but the city’s famous English Market also intrigued me.

The market, established in 1788, features a variety of goods from a plethora of vendors. I pushed my way through crowds into the vaulted atrium of the market. Stalls filled with cheeses, meats, and clothing lined the walkway, but the throngs of people formed a buffer between me and the ability to purchase easily. Like the rest of Cork, the sounds, sights, and smells overwhelmed me. I found my way back into the daylight through a side door. I enjoyed the rest of my afternoon by purchasing lunch and a pot of tea in a café, then parking myself on a bench by the river.

The river itself wasn’t particularly charming. The smell of fish and brackish water drifted up on the breeze. The water slid through the city, carrying trash and green slime toward the sea. My bench of choice was framed by flowering trees and hanging baskets, dropping petals that floated to the ground like July snow. Colorful foot bridges arched across the canal, connecting the cobbled pathways and shops on opposite banks. Across the river, buildings stood in a line, decorated with flowers and signs announcing tourist shops. The English Market proudly overlooked the river with its stoic brick and window front. The occasional waterfowl floated by, allowing the river to carry it to open water.

When I decided I’d had enough of the signature Cork smell, I boarded another bus to my final destination for the day. I arrived in Killarney, on the west coast of Ireland, by late
afternoon. Killarney, nestled in County Kerry, lies adjacent to Killarney National Park, home to many beautiful landscapes and attractions. Killarney’s bus terminal was within walking distance of downtown and my hotel. My boss, the travel agent, had booked me into one of her company’s luxury partners: The Ross Hotel. I would have been happy to crawl into my suite’s plush bedding, but I decided I wasn’t done exploring for the day.

I ventured down the country road toward the park’s entrance, greeting cows and horses in the fields I passed. Low stone walls lined the road for much of my journey toward the park, with the occasional farmhouse breaking up the pastures on the other side. Rhododendron and azalea bushes sprouted in front yards—giant pompoms of vibrant pinks and stunning whites—broke up the countryside’s green. I was walking through proof that Ireland deserved its nickname, “The Emerald Isle.”

Killarney National Park, adopted in 1932, was Ireland’s first national park. In more recent years, the park was designated a Biosphere Reserve by the United Nations Educational, Scientific, and Cultural Organization. Several heritage sites were encompassed within the park’s bounds, including Ross Castle, Copper Mines, and Killarney House and Gardens.

Ross Castle had closed before I arrived in Killarney, but the nature trails that formed a spider web around it remained open. I wandered one of the shorter trails as dusk began to loom. I was fascinated by the sights and sounds of the forest within the park. I’d grown up in a heavily wooded, rural area, but these forests felt different. In many ways, they felt magical; I understood why these areas birthed so many myths and legends. The delicate petals of the
flowers and carpet of clovers made it easy to picture fairies and leprechauns weaving among the flora. My surroundings reminded me of my home in the Appalachian Mountains, once a popular area for settlement among Irish immigrants. I could see why my home appealed to them: It reminded them of theirs.

Stopping every few feet to add to my photography collection, I filled my phone with dozens of pictures of the flowers and trees I’d never seen before. Delicate, pink petal cups hung in clusters, waiting for forest elves to pluck them for their dinner table. Fallen trees lay overtaken by prolific ferns and curling vines. I spent a particularly long time picking my way around the cottages that English ivy and flowering vines had overtaken. Their sleeping forms made me wonder who built them centuries before. These shelters reminded me of one of my favorite concepts: everything returns to nature.

The next morning, I packed a daypack with the essentials for a day out and started my walk back into the national park. I had accidentally slept almost fourteen hours, missing breakfast and most of the morning. The previous night, I had booked tickets for a boat tour of Lough Leane, the lake at the park’s center. Sleeping late meant I had to jog the last quarter mile to reach the dock on time. Our tour boat launched from the dock of Ross Castle, the park’s centerpiece. Its stone walls loomed over me as I descended the short ramp to the boat.

I chose a spot on the boat’s rear deck, behind the glass-enclosed seating. The weather was excellent, and I wanted to enjoy the sunshine and the breeze rippling the lake’s surface. I watched Ross Castle grow smaller as we drifted away; its magnificent stone walls basked in
the sunlight. The castle was built in the fifteenth century; legend claims its builder, an Irish chieftain, rises from Lough Leane every seven years on the first day of May. Unfortunately, I was there in the wrong month, and possibly the wrong year, to see that happen.

This tour focused on the scenery surrounding the lake, and I was intrigued by the islands and inlets we floated past. One island sparked thoughts of home when I recognized the shiny leaves of rhododendron bushes decorating the slopes. The shrubs became less beautiful when I learned they were highly invasive to Ireland. The guide told us that rhododendrons were brought into Ireland for their beautiful flowers but prospered a little too well, and the bushes have taken over several islands in Lough Leane entirely. The history of bringing exotic plants into natural areas isn’t unique to the United States.

I didn’t have as many hours of daylight left as I would have liked after my boat tour ended. I decided to explore the trails that wound along the shores of the lake within the park. New sights greeted me with every bend in the path: old copper mines tunneling into the ground, ponds full of lily pads, and fields of waving grasses. I lost myself in exploring the park, amazed at its beauty. I returned to my room, exhausted again and sore from miles of walking. In hindsight, I should have stretched or taken advantage of the room’s soaker tub before bed to help relax my muscles, but I didn’t consider it then.

On my second morning in Killarney, I woke up late again, my joints and muscles stiff from the previous day’s exertions. I stayed closer to my hotel, worried my limbs would give out and I wouldn’t make it back from the depths of the park. I shifted my focus to the more
developed areas of the park immediately bordering the town, which included Killarney House and Gardens.

Killarney House and Gardens are some of the park’s more modern attractions and have a rich but sad history. The original Killarney House was lost to fire in the early 20th century; the house of today was named after the original when an investor bought the property. Killarney House was allowed to fall into disrepair after it was gifted to the park, left mostly ignored by visitors and staff. Fortunately, it was restored to its former glory and reopened only two years before I visited.

I didn’t bother with the house tour, but I was fascinated by the surrounding grasslands. Here, the carefully manicured lawns of Killarney House contrasted against the untamed beauty of the natural grasses. The manicured gardens showed me the beauty of controlled nature, the art that could be created with plants. But the wild, native grasses appealed to the part of me that admired unbridled nature. The paths that snaked through the fields let me lose myself in the acres of waist-high gold and carefully trimmed bushes. I walked through the fields for several hours, enjoying the whisper of the wind through the tall grass stalks. I retreated from the sunny field to eat my picnic lunch in the shade of the old-growth trees.

I went to bed that night, knowing it would be my last time exploring the Killarney area. My heart ached to say goodbye to the natural beauty that surrounded me there, as well as the man-made wonders that coexisted with it. I spent my last morning exploring the town, charmed by the small shops and cafes lining the streets. Souvenir stores and bakeries
stood side by side, displaying their goods in sunlit windows. Irish folk music drifted out of open doors, reminding me of Appalachian folk songs and their origins. Quilts and bright scarves hung on racks, completing the feeling I was walking through a festival at home. I was ultimately disappointed with the town compared to the vast expanses of nature on the other side of the stone walls of the park. I took a picture of the blooming rhododendrons and azaleas in the city circle as I waited for the bus to take me to join my study abroad program in Galway. They were the same varieties growing everywhere at home, but these felt significantly more special.

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When I arrived home a few weeks later, I was greeted by the rhododendron bushes bordering my front yard. These are native to the Appalachian Mountains where I live and are the same variety carried back to Ireland decades ago. It’s a loose tie, but the bountiful blooms remind me of my home's ties to my ancestral roots in the Emerald Isle. These similarities might be what made Ireland feel like home to me, or maybe it was my ancestors’ blood coming to the surface.

Growing up, I’d always loved rhododendrons, but now they reminded me of my time in Ireland rather than my parents’ front yard. I still held wonder for the nature I had grown up with, but I longed to return to Ireland and continue my exploration there. Far from where I grew up in Appalachia, I had found a place that felt inexplicably like home.

I’ve seen many parallels drawn between the Appalachian Mountains and Ireland. The culture of the mountains has a lot of Irish roots; it can be heard in the folk songs played at
local festivals each summer. Even the plants are similar, with the rhododendron and azalea bushes present on each side of the trail also found on the islands of Killarney National Park. I’m reminded how similar these places can be each summer, especially after a rain. The grass glows bright green, and my memories of the Emerald Isle flood back to me.
Would You Let a Robot Draw Your Blood?

The year is 2050. You are waiting in the doctor’s office to have your blood drawn as part of a routine check-up. As the nurse left, she assured you someone would be in soon to take your sample. Just as you are starting to wonder how much longer you will be here, in rolls a robot, equipped with needles and collection tubes, ready to sample your blood. This is the “someone” you’ve been waiting for. Suddenly, you aren’t so sure about this; needles are bad enough, but needles controlled by a robot are even worse. The ceiling lights flicker as the robot inches closer, brandishing a syringe and repeating “blood” in a grating, digitalized voice. There’s no way this could end well.

Except maybe it could. While a self-propelled robot phlebotomist—the person who draws your blood—may seem like science fiction, it might not be as unbelievable as it seems. Research teams are using robotics and computers to create automated blood–draw technology to help medical professionals sample blood. The current projects look much different than this futuristic, out-for-blood robot, but we could see them popping up in doctor’s offices, hospitals, and other settings within the next decade. Fortunately, a human will still control them.

Taking a blood sample is a normal part of health exams. It helps doctors and nurses determine if something is wrong by checking the levels of specific blood components. But drawing blood from a vein is sometimes challenging, especially when a patient is sick. These challenges arise for several reasons, such as dehydration caused by not having enough water or just being sick, making veins smaller and harder to prick with a needle. Automated blood draw technology decreases the risk of missing or going through a vein by using ultrasound technology,
allowing the person drawing your blood to see inside your arm and visualize exactly where the needle needs to go.

“Essentially, this [device] would sit on a desk, you would place your arm underneath it, and using its cameras and infrared cameras, it would identify where the vessels are, then position this ultrasound probe and needle insertion device,” Josh Leipheimer explained about a tabletop device for drawing blood, called the Venous Pro. Leipheimer earned his doctorate in biomedical engineering, which combines medicine, biology, and engineering. As part of his degree, Leipheimer developed the VeniBot, a blood-draw device based on his mentor’s earlier design—the Venous Pro.

The VeniBot and similar devices would allow nurses and other medical professionals to draw blood quickly, safely, and efficiently wherever the patient is. The tabletop version, Venous Pro, would require the patient to be brought to the lab, which might be difficult or impossible if a patient is in critical condition or a lot of pain. Leipheimer’s VeniBot is a portable version that would allow the hospital staff to bring the blood draw device to the patient. Drawing blood in the patient’s room is considered normal, but it must be done by hand by either a nurse or a trained phlebotomist.

Leipheimer explained that the current method for drawing blood sometimes requires several tries by different people. Even experienced nurses and phlebotomists can sometimes have trouble drawing blood, especially when a patient is sick, meaning the patient might get poked more than once before blood is drawn—likely leaving them feeling a little like a pincushion. Nurses are also at risk for potentially hurting themselves, with almost 1,000 people getting accidentally stuck by needles during work daily. The VeniBot would allow blood to be drawn on the first try without the risk of accidental pokes.
Having your blood drawn by a robot might seem scary, but a person will still operate these devices—at least for now. The robot might be even better than a human in some ways because it can learn immediately from its mistakes. The VeniBot and its table-top parent Venous Pro use artificial intelligence based on machine learning.

“[Machine learning] lets you train a model to get really good at finding blood vessels, which is very important when you’re also using that information to send a needle to that target,” Leipheimer explained. Machine learning means the robot learns as it goes, almost like a human does. A nurse would know immediately if they hurt the patient, and machine learning allows these robots to understand something similar. The VeniBot and Venous Pro might not know they hurt their patient, but they could recognize they missed their target or went too far when pricking the vein. Leipheimer says the Venibot feels no different than getting your blood taken by a person; he’s tried it himself.

As a tabletop model, the Venous Pro has some features the VeniBot does not. The most important of these is a microcentrifuge—a circular device that spins very quickly to separate components of a blood sample. In a centrifuge, the heavier parts of the blood, like the red blood cells, sink to the bottom of the tube. The other pieces, like white blood cells and plasma, arrange themselves by weight, too. Using this centrifuge, the Venous Pro can start testing blood samples as soon as they are drawn instead of waiting for a lab employee to run the tests. This can speed up sample processing time and let doctors diagnose their patients much faster. Right now, the Venous Pro can only do basic tests, like counting white blood cells to look for signs of infection. The VeniBot cannot do any of this yet, but Leipheimer hopes to see both models improve to add more testing options.
Leipheimer expects to see these devices in places where blood is drawn frequently, like blood drives. Something like VeniBot could speed up the process of drawing blood, especially in facilities that draw a lot of blood every day. He also notes that automated blood draw technology would require less training than current blood draw options. Leipheimer estimates these devices might appear in healthcare settings like the Red Cross within the next ten years.

Would you let a robot draw your blood? Someday, you might not have a choice.
“Why do we need school when one day we’ll just have computers in our brains telling us everything anyway?” My fifth-grade tutoring student, Riley, asked me during a debate (read: argument) over his math homework.

“Because that’s not going to happen in our lifetimes,” I told him. I didn’t voice the “I hope” I mentally added to the end of that sentence. Honestly, a computer in my brain telling me everything I could need in a split second is an overwhelming and mildly unnerving thought. I also didn’t tell Riley what I’d recently learned about brain-computer interfaces, the technology that could do precisely what he’d just asked about.

Brain-computer interfaces, also known as brain-machine interfaces (BCI or BMI for short), allow the human brain to work in tandem with a computer to accomplish a task. In recent years, this technology has made huge strides. BCI-related research has shown us that everything from giving sight to the blind and voice to the mute could be possible, and researchers are already using technologies to perform such seemingly miraculous feats. If Riley knew what BCIs are capable of, he might think we’re close to creating the mental encyclopedia he wants. In reality, we’re probably much farther than anyone even realizes.

BCIs have many associated challenges, explained Mike Wolmetz, PhD, the program manager for Human and Machine Intelligence at Johns Hopkins University’s Applied Physics Laboratory (APL) in Laurel, Maryland. During a tour of the facility, Wolmetz shared some of
the challenges the BCI-focused teams at APL face in conducting their research. One of the biggest speedbumps is the limits and dangers of the available technology. Not to mention, researchers are still learning how the brain works.

Currently, there are two types of BCIs: noninvasive and invasive. Both forms rely on electrodes picking up signals from the brain and relaying them to a computer capable of decoding them. This computer turns the brain signals into instructions to complete the intended action, like speaking or moving a robotic arm. The possibilities of these actions depend on whether the BCI is noninvasive or invasive.

Noninvasive BCIs are electrodes placed on the outside of the participant’s head. These often appear in the media as skullcaps or futuristic-looking headbands with many wires connected to them, sharing data from the brain to the attached computer—picture Professor X from X-Men with his smart computer, Cerebro. Noninvasive BCIs are restricted in their uses because of the limited data they can collect. Being placed on the outside of the skull means the sensors cannot directly interact with the brain and may be blocked from receiving weaker signals.

“Can we use this to look through the skull and scalp to see tiny innervations in the tissue?” Wolmetz asked. The answer is maybe, or in many cases, probably not. “Noninvasive mostly sucks; all current noninvasive projects are bad,” Wolmetz shared his opinion on the technology. He explained these signals can even be affected by hair color and thickness. Because current noninvasive BCI technology is very limited in its abilities and uses, the
future of BCIs lies in advancing invasive technology, which unfortunately also has its share of problems.

Invasive BCIs require brain surgery to implant electrodes directly onto the surface of the brain or into the outer layers. Compared to noninvasive options, invasive technology offers many more possibilities. The sensors can detect more of the brain’s activity, expanding the possibilities of what the brain could control. However, the implants come with some risks.

Invasive BCIs must be removed after a relatively short period, usually either in response to or for the prevention of infection or rejection by the participant’s body. Like all technology, there also comes a time when an individual BCI will stop working and require removal. Alternatively, the study involving the BCI could end, and scientists must reclaim the technology. The longest-lasting implant has been in service for almost ten years: Nathan Copeland, a spinal cord injury survivor, received the implant in November 2014 from the University of Pittsburgh. Previously, researchers thought these implants could only safely last five years, but infection risk and study parameters determine timeframes on a case-by-case basis.

Despite dangers and complications, invasive BCIs hold the potential to help people who have lost limb function or communication abilities due to conditions like ALS, spinal cord injuries, or stroke. Various research studies are developing therapeutic BCIs for people with disabilities, and any BCI projects focus on increasing the communication capabilities of these patients, who may otherwise be unable or limited in their abilities to share their
thoughts. CortiCom, a partnership with APL and the Johns Hopkins University School of Medicine, is one such project seeking to improve communication options for its participants. APL has previously worked on a variety of therapeutic BCIs, all to improve life for people with disabilities.

Francesco Tenore, PhD, a staff engineer for the Human and Machine Intelligence program at APL, describes a hypothetical scenario where he's implanted a BCI in the brain region that controls the upper limbs. When a motor neuron in our brain fires, it triggers a tiny muscle movement. These movements are the signals a BCI is trying to pick up, and the reception quality of these signals depends on whether the BCI is invasive or noninvasive. If Tenore wants to ensure he's getting useful information from motor neurons, he'll ask the person to move their arm around, for example. "If I see neural activity that's happening in synchrony with when the user is moving their arm, then I know I'm in the right place."

Tenore puts this process in much simpler terms by referencing the “brain atlas”—a tool he and other researchers can use to determine which areas of the brain would allow them to tap into which functions. Some researchers on APL's upper floors are perfecting this brain atlas for their colleagues to use in BCI research and development. It's a tedious process using imaging of the brain and many hours of experimentation, but the good news is it’s universal. “The brain has a specific structure to it that allows us to know where on top of it we would need to position ourselves in order to get access to information that, for example, controls our upper limbs,” Tenore says.
Every hour these researchers put into their work moves us closer to perfecting BCI technology. However, APL researchers are not focused on creating a BCI that gives us something like the mental encyclopedia Riley wants. Instead, they are focused on developing therapeutic BCIs and moving them outside the lab, leaving their commercial counterparts to tackle recreational concepts. The ability to download an encyclopedia to your brain falls perfectly into the ranks of the other technologies these companies are working on.

Companies like Facebook, who attempted to create a BCI that would allow the user to text by just thinking, or Google, whose BCI intentions remain slightly fuzzy despite filing a patent. Maybe Encyclopedia Britannica will announce its own BCI and fulfill Riley’s dream.

Regardless of who is working on which kind of technology within the BCI realm, all research teams will have similar problems to overcome: invasive versus noninvasive and all the issues that come with either. So, like I told Riley, we likely won’t see the arrival of a mental encyclopedia during our lifetime. Or if we do, we would be well into our golden years and past the age to benefit in the way Riley hopes to—by skipping school.

The next time Riley brings up this computer, and I know he will, I’ll be ready with a better argument. He still has to learn fractions because how else would he function if the computer lost internet access?
The family seemed to breathe a collective sigh of relief as my sister delivered the good news: My nephew was not being hospitalized for a COVID-19 infection. But he was being hospitalized, nonetheless.

The then-two-year-old had been displaying cold-like symptoms for several days but was not sick enough to warrant concern until earlier that morning. Because it was a Saturday, his parents had shuttled him to the nearest walk-in clinic, where they were told to turn around and take him to the hospital instead. The rest of the family, including the toddler’s grandparents and me, waited anxiously for news on the other side of North Carolina. My sister called later to tell us her son had a case of RSV pneumonia.

Respiratory syncytial virus, or RSV, is typically a benign illness, generally appearing as cold-like symptoms in healthy adults and older children. However, it can be very dangerous for at-risk populations, such as adults over sixty or children under two. Almost everyone will contract RSV at some point in their lives, but most cases are not severe enough to be thought of as anything other than a cold. When RSV does manifest more seriously, it has the potential to cause severe disease—like the pneumonia my nephew developed—hospitalization, and death. Fortunately, recent research efforts have resulted in several preventive options for at-risk populations.

“RSV is the most common cause of pneumonia in babies worldwide,” explains Dr. Kawsar Talaat, an infectious disease physician and vaccine scientist at Johns Hopkins Bloomberg School of Public Health. “Older people are more likely to be hospitalized with RSV pneumonia than younger adults and older children, so that’s why these [treatments] are targeting
them,” According to Talaat, the key is not preventing RSV altogether but suppressing it from becoming RSV pneumonia or another more severe infection.

One option already on the market is vaccines, at least for adults over sixty. In May 2023, the Food and Drug Administration (FDA) approved the use of vaccines developed by major drug companies Pfizer and GSK. The Pfizer vaccine, Abrysvo, saw more than 65% efficacy rates for preventing disease altogether and 88% for preventing severe disease during clinical trial phases. GSK’s vaccine, Avexry, which received approval in May, saw even higher efficacy rates: more than 80% for preventing disease altogether and 90% for suppressing severe illness.

Vaccines are a viable option for preventing RSV infections, but they are not always the best. Talaat explained that a vaccine for babies might not be the most effective option because their immune systems are not fully developed. To solve this problem, researchers at Pfizer are developing a vaccine for mothers to receive prenatally, allowing the mother to develop and pass on RSV antibodies to the baby.

“[Antibodies] will protect the baby after they’re born, through the RSV season, which will be fantastic because that is their first RSV season. That is where they are more likely to be super sick and get hospitalized,” Talaat explains. Ideally, these antibodies would protect the baby for the first few months after birth. A vaccine or other treatment would boost immunity as the original antibodies dwindled.

Antibodies are not just for prenatal immunity. Treatments using monoclonal antibodies have now been FDA-approved for use in adults over sixty and children under two. These antibodies, replicated from an antibody specialized against RSV, would support the immune system of at-risk populations who may not respond well to the vaccine.
“Effectiveness [between vaccines and antibodies] is probably about the same,” says Talaat. “They act in different ways.” But because babies and older adults often have a diminished response to vaccines, monoclonal antibodies may provide an edge, offering "passive immunity," where they benefit from the antibodies without making them.

So why is it so important to protect from RSV infection? RSV can worsen other health conditions, regardless of age. However, mitigating the chances of developing severe infections in older adults—which could lead to a loss of lives—is important. Babies who contract RSV have the additional risk of long-term health implications, like a possible link to developing asthma. Fortunately, with preventive options becoming accessible, even long-term health effects might be of little concern someday.

“It’s fabulous!” Talaat exclaimed as she talked about the future of RSV treatments. “Absolutely fantastic.” However, Talaat wants public health officials to recognize the power and responsibility they now hold. “I think it would be relatively obscene if in the United States we [had these treatments] and the rest of the world had nothing. It’s important to know that high-income countries are not where the biggest morbidity and mortality is, so it’s important to make sure the options we have are available to everybody.”

However, “a vaccine is only as effective as the number of people that get it,” Talaat warns. As researchers continue to develop vaccines and treatments for viruses like RSV, we can always take steps at home to prevent infections. RSV is spread like the common cold or flu, so taking precautionary measures to kill germs can go a long way. Washing hands, cleaning frequently touched surfaces, and covering mouths when coughing or sneezing can help prevent the spread of RSV and other illnesses.
My nephew recovered from his RSV pneumonia after several “boring” days in the hospital, but the scare has stayed with my family. The now-four-year-old developed a persistent wheeze after his illness and frequently develops colds. I think we’re all a little on edge whenever we notice a sniffle, expecting a return to the hospital at the first sign of fever. Fortunately, his health is improving, and we may soon have a way to protect him beyond what our family can do at home.
Introduction

Micronutrients—any substance our body requires in small amounts—are an essential part of our diet. Unfortunately, many people worldwide are experiencing micronutrient deficiencies, and they might not even be aware. I didn’t know I was deficient in some of these vitamins and minerals until I started to experience symptoms.

Micronutrient deficiencies are an international health concern, affecting over 2 billion people in industrialized and developing countries. Deficiencies can cause many symptoms, including brain fog, low energy, hair loss, and a weakened immune system, but these should improve if a deficiency is treated quickly enough. Unfortunately, prolonged deficiencies can increase the risk of developing lifelong health problems like cancer, chronic disease, and the acceleration of the natural degeneration from aging. Each micronutrient has its own symptoms and long-term effects, dependent on its role within our bodies.

I wrote this blog series to raise awareness of micronutrient deficiencies and their health concerns. These blogs are not an exhaustive list of concerns or intended to provide medical advice. If you believe you are experiencing a nutrient deficiency, consult a healthcare provider to determine the next steps.
Dizzying Deficiency
The Dangers of Low Iron Levels

“You should call your doctor,” the American Red Cross volunteer told me in a serious tone. I, a seemingly healthy college freshman, had just been told I did not meet their required hemoglobin levels for donating blood. They wanted at least 12 grams per deciliter, and I tested at 10.5, below the normal range for a female my age. Hemoglobin is an iron-containing protein in the blood responsible for transporting oxygen. Low hemoglobin is often a sign of low iron levels. I waited patiently through the volunteer’s spiel about adding iron-rich foods to my diet or taking an iron supplement. When I proudly told him I did take an iron supplement after he finished his spiel, he seemed concerned.

Iron deficiency—a lack of sufficient iron in the body—is a common problem, especially among women. The Centers for Disease Control and Prevention’s Second Nutrition Report, released in 2012, reported iron deficiency was the second most common micronutrient deficiency among women ages 12 to 49 in the United States. The World Health Organization recognizes lack of iron as the most common deficiency globally, with everyone from infants to older adults not receiving enough of this essential mineral.

Iron is responsible for various bodily functions; if someone has low iron levels, they’ll likely start to feel it. That's because iron is the carrier of oxygen in our bloodstream, and a lack of it can often result in fatigue, brain fog, or muscle weakness. I had noticed these symptoms in myself before my blood drive rejection but blamed it on lack of sleep. These symptoms are unpleasant, but far from the worst conditions lack of iron can cause.

Anemia—low levels of red blood cells—is arguably the most well-known complication of iron deficiency. Symptoms of anemia and iron deficiency often overlap but can also include
dizziness and feeling unusually or unexplainably cold. Iron deficiency does not always cause anemia, though; the deficiency can also present as other conditions, such as fibromyalgia or restless leg syndrome. New evidence suggests non-anemic iron deficiency could be just as concerning: Iron deficiency can have severe health effects, including hypothyroidism or developmental delays in children.

I signed into my doctor’s office for a hemoglobin check a month after my failed blood donation. I’d faithfully taken my iron supplement every day before the appointment, and my bloodwork showed that my hemoglobin levels were back to normal. I even tried following the advice of a previous doctor and took the capsule with a glass of orange juice, based on research showing vitamin C helped with iron absorption. Maybe it was a placebo, but I had started to feel more energized as the month went on.

So, how much iron do we need? The recommendations for iron intake vary considerably based on a person's age, lifestyle, and other health factors. A well-rounded diet featuring iron-rich foods (think red meat and dark, leafy greens) should allow most people to meet their recommended intake. However, some people may not properly absorb nutrients from food and require a supplement. Talking to a doctor or nutritionist is always recommended before adding supplements to your diet.
Got Milk? Maybe You Should
Calcium Deficiencies and Related Concerns

Anyone born before 2010 is likely familiar with the famous “Got Milk?” campaign of the 1990s and early 2000s. The often-star-studded ads encouraged kids to drink more milk through creative, eye-catching commercials and print ads. Most people probably can’t tell you what company the ads represented, but they knew the message: Drink milk.

Whether you’re a fan of dairy products or not, milk contains several essential nutrients, including calcium. Because of its role in bone growth and development, calcium is essential for growing children—the target of those ad campaigns. Despite the importance of calcium for a healthy skeleton, a 2014 study found that 3.5 billion people globally were at risk for experiencing calcium deficiency. Similarly, the U.S. Department of Health and Human Services found that nearly 40% of the U.S. population does not consume enough calcium, leading the department to designate it as a micronutrient of concern in their 2015 Dietary Guidelines for Americans report.

Inadequate calcium intake can have various effects on the body, ranging from minor to severe. The human body maintains a range of ~2.2 to 2.7 milligrams per deciliter of calcium within the bloodstream, regardless of the calcium level consumed in the diet or supplements. If someone is not ingesting enough calcium to maintain this level, the body will begin taking it from other places through a process called resorption. Resorption targets bones—dissolving them to release the minerals—and can create a slew of problems within the body, including weakening bones.

Resorption can also make it hard to test for calcium deficiencies in patients. The highly regulated calcium levels in the blood—maintained by resorption—mean that blood tests are ineffective in looking for this deficiency. Instead, healthcare professionals must observe a patient's diet and supplements to get an accurate picture of calcium intake.
Daily calcium intake varies by age, sex, and overall health. Pregnant or breastfeeding women have different requirements than other women their age. There is some debate surrounding the appropriate amount of calcium per day: The World Health Organization recommends 500 milligrams daily for an average, healthy adult, but the National Institute of Health recommends adults take over 1,000 milligrams daily.

As long as someone doesn’t have a health condition that prevents calcium absorption, going with the higher numbers for recommended intake is probably better. According to the Mayo Clinic, adults should not experience any adverse effects from taking too much calcium as long as they stay below 2,500 milligrams per day. Ingesting calcium above that amount has risks and negative health effects, just like taking too little. However, you should always talk to a doctor or healthcare provider before adding supplements to your diet.

So, whether you’ve “got milk” or calcium supplements, calcium deficiency is typically easy to prevent.
Are You Vitamin D Fortified?
The Dangers of Vitamin D Deficiencies

In my previous post, we learned about the importance of calcium and how to ensure we are getting enough of it. Now that we’re getting our daily calcium, is our body using it? That’s where vitamin D comes in: Our body needs vitamin D to absorb and use calcium. Unfortunately, vitamin D deficiency is yet another common concern. A 2011 study estimated that 81% of children and 95% of adults are not getting enough vitamin D daily.

Our body uses vitamin D in numerous processes, including reducing inflammation, metabolizing and absorbing calcium, and regulating some cell-related processes. Lack of vitamin D can cause bone- and growth-related issues because of the nutrient’s synergy with calcium. The National Institutes of Health warns that vitamin D deficiency can harm bone health, causing osteomalacia (commonly called “soft bones”) in adults and bone deformities (commonly known as “rickets”) in children. Vitamin D also plays a role in our mood, with numerous vitamin D receptors present in the brain. People with low vitamin D or a deficiency might experience depression because of the nutrient’s role in these pathways.

Vitamin D is an interesting micronutrient because it is available to us in three ways. One of these is through diet, with many foods like egg yolk and fish being rich in vitamin D. Supplementation is also an option, like other nutrients. But the last way is the most interesting: Vitamin D is a hormone our bodies naturally create. Most people probably know we can get vitamin D from the sun, but the process is not common knowledge.

When we expose our skin to sunlight, a specific type of sterol—a subclass of steroids—reacts with ultraviolet-B radiation and makes pre-vitamin D3. Pre-vitamin D3 quickly converts to vitamin D3—the preferred form when taken as a supplement—then passes through the liver and
kidneys for further processing. These organs modify it into the circulating form (in the liver) and biologically active form (in the kidneys) for use in the body. Pre-vitamin D3 and vitamin D3 also absorb ultraviolet-B light and form their own photoproducts.

With our bodies capable of making vitamin D, this is arguably the easiest deficiency to fix—at least in the summer. Researchers do not have a consensus on the amount of sunlight needed for sufficient vitamin D because it varies between people and environmental conditions. In winter, with more of our body covered and less direct sun, we would need more sunlight compared with summer to produce the same amount of vitamin D. Some experts believe this may be one factor of seasonal depression, especially in countries that receive significantly less sunlight during winter months.

Some groups are more at risk for vitamin D deficiency, including breastfed infants, people with darker skin tones, those with low sun exposure, older adults, people with conditions that limit fat absorption, and people who are experiencing obesity or have had bariatric (weight loss) surgery. These populations cannot effectively produce or process vitamin D for use in their bodies.

Sunlight might not always be the best option for someone to fulfill their vitamin D needs. In addition to the concerns of specific groups above, there is also the risk of sun-related health conditions, like skin cancer or sunburn. With these concerns in mind, we must explore other options for meeting vitamin D needs, including diet and supplements. The Mayo Clinic recommends adults try to maintain 600 international units (IU), or about 15 micrograms, of vitamin D daily. Fortunately, vitamin D deficiencies are relatively easy to treat and prevent, thanks to the three ways it is available to us. If we are not meeting our vitamin D needs with diet and sunlight, supplementation is an option. However, consulting with a doctor is always recommended before taking new supplements.
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Author’s Biographical Sketch

Brianna Ross was raised in the mountains of western North Carolina. She attended Young Harris College (YHC) in north Georgia and earned dual Bachelor of Science degrees in Biology and Environmental Science. After graduating from YHC in 2022, she pursued a Master of Arts in Science Writing from Johns Hopkins University (2022-2024). Her future career goals include working as an in-house science writer for a research facility, laboratory, or university and completing freelance editing and writing work. She looks forward to future opportunities in the sciences and science writing.