

FEATURE

What Can Covid-19 Teach Us About the Mysteries of Smell?

The virus's strangest symptom has opened new doors to understanding our most neglected sense.

By Brooke Jarvis

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Danielle Reed stopped counting after the 156th email arrived in a single afternoon. It was late March, and her laboratory at the Monell Chemical Senses Center in Philadelphia had abruptly gone into Covid-19 lockdown. For weeks, there had been little to do. Reed, who is famous in her field for helping to discover a new family of receptors that perceive bitter flavors, had spent years studying the way human genetics affect the way we experience smell and taste. It was important but niche science that seemingly had little to do with a dangerous respiratory virus spreading around the globe.

And then one Saturday, she checked her email. Reed watched in amazement as the messages proliferated. It wasn't how many threads there were, though that was overwhelming, but the way they seemed to grow like Hydras, sprouting in all directions. Recipients copied other people they thought might be interested in the discussion, who added more people, who added still others, across a huge range of countries and disciplines. The cascading emails were all responding to the same rather obscure news alert, meant for ear, nose and throat doctors based in Britain. It was titled: "Loss of smell as marker of Covid-19 infection."

The week before, Claire Hopkins, the president of the British Rhinological Society and an author of the alert, was seeing patients in her clinic in London when she noticed something odd. Hopkins, who specializes in nose and sinus diseases, especially nasal polyps, was accustomed to seeing the occasional patient — usually about one per month

— whose sense of smell disappeared after a viral infection. Most of the time, such losses were fairly self-explanatory: A stuffy, inflamed nose keeps odorants from reaching the smell receptors at the top of the airway. Sometimes these receptors are also damaged by inflammation and need time to recover. But patients were now arriving with no blockage or swelling, no trouble breathing, no notable symptoms, other than the sudden and mysterious disappearance of their ability to smell. And there were nine of them.

At first, it didn't occur to Hopkins to think about the recently declared pandemic that was dominating the news. None of the patients had traveled to Italy or China, so they didn't meet the government's criteria for testing or quarantine: The virus, she understood, was not yet spreading in Britain.

As each new patient told a strange yet similar story, she began to wonder. A colleague in Italy, where the virus was known to be spreading, had mentioned that frontline doctors were losing their senses of smell and taste. Hopkins assumed that a mild version of Covid-19 was causing a standard post-viral loss of smell. But shortly after seeing the nine patients, she attended an online chat for physicians hosted by the American Rhinologic Society. A French doctor posted that he had recently seen an increase in cases of sudden smell loss without any blockage. Had anyone else noticed something similar? Yes, several doctors from the U.S. replied. They had started to hear rumors from colleagues in Iran and Italy of odd spikes in patients who had unaccountably lost their sense of smell.

Hopkins decided to keep digging. She found that in China, an unusual number of ear, nose and throat specialists — doctors who would have been sought out by patients troubled by an unexplained loss of smell — had contracted the virus. A report in South Korea found that of 2,000 people with mild cases of Covid-19, 30 percent lost their sense of smell. The same week that patients were streaming through Hopkins's office, there was an article in a German newspaper about a virologist named Hendrik Streeck who went door to door interviewing some of the country's earliest patients. He found smell loss in two-thirds.

None of these anecdotes amounted to the sort of rigorous proof that Hopkins, with her research background, was used to seeking. She also doubted that her theory would attract much public interest, even in the face of a world-changing pandemic. A career studying smell had taught her that most people simply don't consider the sense to be particularly interesting or important. It was always hard to get financing to study smell or smell disorders, and patients who lost their olfaction often told her that their friends and family shrugged the condition away: It was only smell, after all.

Still, Hopkins and Nirmal Kumar, the president of ENT UK, decided to put out an alert, hoping it would at least encourage their fellow nose doctors to take extra precautions.

Then, that same weekend, Rudy Gobert — the Utah Jazz star whose Covid-19 diagnosis caused the N.B.A. to abruptly suspend its season (just after Gobert mocked the danger by touching all the microphones at a news conference) — announced that he had lost his sense of smell. Hopkins's alert ricocheted around the world, picked up by news outlets and shared on social media by people desperate for information about the workings of the new virus and any signs that they might already have been exposed. It also kept landing, over and over, in the inboxes of Danielle Reed and hundreds of other scientists who studied smell in some way.

The breadth of their backgrounds was stunning, even to one another. There were neurobiologists and otorhinolaryngologists, virologists and food scientists. There were chemists and data specialists, cognitive scientists and nutritionists, geneticists, psychologists, philosophers — an indication of how complicated the interplay of smell, taste and human life is. Like Hopkins, many of them were used to their work being as underappreciated as the senses they studied.

Smell is a startling superpower. You can walk through someone's front door and instantly know that she recently made popcorn. Drive down the street and somehow sense that the neighbors are barbecuing. Intuit, just as a side effect of breathing a bit of air, that this sweater has been worn but that one hasn't, that it's going to start raining soon, that the grass was trimmed a few hours back. If you weren't used to it, it would seem like witchcraft.



Stephanie Gonot for The New York Times

But of course you are used to it. You may even take it for granted. Perhaps you would rank smell, as most adults in a 2019 survey did, as the least important sense, the one you would be most willing to lose. Perhaps you would even agree with the majority of young people who, in 2011, told McCann Worldgroup, a marketing company, that smell was less valuable to them than their technological devices. As PC Magazine trumpeted, with a mixture of scorn and glee: **MAJORITY OF KIDS WOULD RATHER LOSE THEIR**

SENSE OF SMELL THAN LOSE FACEBOOK.

The writers of that headline seemed to see disregard for smell as shocking, a marker of a technology-obsessed and perhaps uniquely shallow generation. That reaction would have come as a surprise to Immanuel Kant, who wrote, in 1798, that smell is both the “most ungrateful” and the “most dispensable” of the senses. Charles Darwin considered smell to be “of extremely slight service” to humans. Until quite recently, one smell researcher told me, most general medical textbooks didn’t bother to include a chapter on smell or taste, apparently considering them insignificant afterthoughts to the functioning of the human body. From Plato and Aristotle (Plato considered smells “half-formed,” and Aristotle wrote that “man smells poorly”) to Descartes and Hegel (one called vision the “noblest of the senses,” while the other dismissed smell and taste as too pedestrian and vulgar to be included among the senses in his aesthetics), we have spent centuries writing off our own sense of smell.

One reason we have discounted smelling is our belief that we’re bad at it. Smell was the province of lesser animals, we told ourselves, of pigs rooting out truffles and sharks scenting blood, while humans were creatures of reason and intellect who managed to stand up and grow huge brains and leave that life far behind — and, literally, below — us. Scientists followed Paul Broca, a 19th-century neuroscientist, in pointing to the relative smallness of our olfactory bulbs as evidence that our brains had triumphed over them, and likewise over the need to pay much attention to smell at all. In the late 1950s, a pioneering ear, nose and throat specialist, Victor Negus, summed up the consensus view in a book about the comparative anatomy of the nose. “The human mind is an inadequate agent with which to study olfaction,” the specialist wrote, “for the reason that in Man the sense of smell is relatively feeble and not of great significance.” For centuries, when scientists studied smell at all, they tended to focus on isolating particular odorants (they thought they could find the odor version of primary colors) and creating elaborate organizational systems that shuffled them into various categories (“History is littered with the wrecks of Universal Classifications of Smell,” the smell scientist Avery Gilbert wrote in his book “What the Nose Knows.”) Questions of how humans smell and how our smelling, in turn, interacts with our bodies, our health and our behavior were of far less interest. The sense, after all, was seen as practically vestigial: an often handy, sometimes pleasant but ultimately unimportant holdover from our distant past.

The notion of smell as vestigial has itself come to seem outmoded. That’s because of a renaissance in smell science. While we have long understood the basic mechanisms of vision and audition, it has been less than 30 years since the neural receptors that allow us to perceive and make sense of the smells around us were even identified. The discoverers

— Linda Buck and Richard Axel — were awarded the Nobel Prize in 2004.

The revelation opened the door to a new way of understanding the olfactory system, as well as to a new, ever-expanding world of research. A system assumed to be unsophisticated and insignificant turned out to be quite the opposite. Where vision depends on four kinds of receptors — rods and three types of cones — smell uses about 400 receptors, which are together estimated to be able to detect as many as a trillion smells. The complexity of the system is such that we're still unable to predict how, or even if, a given chemical will be perceived by our olfactory system. The old quest to map odorants and their perception is now understood to be a wildly complicated undertaking. Joel Mainland, a neuroscientist at the Monell Center who is working on the problem, told me that while maps of color vision are easily presented in two dimensions, an eventual olfactory map might require many more.

Recent studies have begun to puncture our conviction that we are too sophisticated to be good at smelling. Our brains know the difference between exercise sweat and fear sweat, and between a glass of wine that has recently contained a fruit fly and one that has not. They seem to compel us to sniff our fingers shortly after we shake other people's hands, searching for information about them that we're not consciously aware of processing. One inventive study found that, provided we're willing to crawl around with our faces in the grass, humans are fully capable of finding a scent trail while blindfolded — not as well as a dog, granted, but we can follow it. Another found that we can tell, just from sniffing a T-shirt another person has worn, whether that person's immune system is similar to our own. (If it's different, we find the person more attractive.) But here's what's really impressive: Our noses can also distinguish between two groups of mice that have different immune systems.

Several years ago, the Rutgers scientist John McGann took a critical look at Broca's 150-year-old dismissal of our olfactory bulbs and found it to be mistaken: Our bulbs are shaped a little differently, but when you compare how many neurons they hold with those of other mammals, humans are solidly "in the middle of the pack." There are, he pointed out, even some odors we can smell better than rodents or canines can.

A much-discussed unit of measurement in smell studies is the J.N.D. — the Just Noticeable Difference, or the degree to which chemicals have to differ from one another in order for us to tell them apart. In November, a new paper in *Nature* advanced the quest for a map of olfactory perception by creating a model that can predict what odorants will smell like by contrasting their chemical makeup with that of other smells. The work relied on volunteers comparing hundreds of different odors and found them to be almost frustratingly good at it. "The failure to reach an absolute J.N.D. provides for yet additional

evidence of an exquisite sense of smell in humans,” the authors said. “To rephrase this result: It is simply very hard to generate two multicomponent odorants that humans cannot discriminate.”

One of the authors, Noam Sobel of the Weizmann Institute of Science in Israel, also worked on the scent-trail study and the one about handshakes, as well as a study that found that an automatic sniff reaction — taking longer breaths when something smells good and shorter ones when something smells bad — is a reliable predictor that someone will eventually wake up from a coma. In the early days of the pandemic, he was spending his days at testing centers in Tel Aviv, trying to figure out whether an artificial nose could sniff out the novel coronavirus — not a crazy notion, because dogs are learning to do it, and because at least one human has proved her ability to identify sufferers of Parkinson’s disease just by smelling them. Sobel and his colleagues also started a website, SmellTracker.org, where people who were worried about Covid could track changes in their ability to smell a variety of common household items.

We think that smell is less important to us than our other senses only because we’re fooling ourselves, Sobel told me. After all, you wouldn’t eat a beautiful cake if it smelled like sewage, but you would probably try some ugly gloop that smelled like cinnamon. Covid, he hypothesized, could kick off a sort of global reckoning, forcing our conscious minds to recognize what our brains have known all along. “People are unaware smell is important until they lose it,” he said. “And then they’re terrified.”

The growing mess of emails that followed Hopkins’s alert in March quickly became so unwieldy that the scientists decided to move to a more formalized group. Within days, it had 500 members, from dozens of countries, and a name: the Global Consortium for Chemosensory Research. (The group eventually stabilized at around 630 members, from 64 countries.) “We decided to become a global organization,” explained Valentina Parma, a psychologist who, along with Reed and seven others, helped found the G.C.C.R.’s leadership committee. “We all got together to try to figure out what’s going on.”

The sheer number of questions was daunting. How many Covid patients experienced smell loss? How fully did smell disappear? (Smell loss is known as anosmia when it’s complete, and hyposmia when it’s partial.) Was Covid-related smell loss truly distinct from that caused by other viruses? How many patients would be able to recover their olfaction, and how long might it take?

Many patients were reporting loss of taste as well as smell, but this, too, was complicated. Thanks to a process called oral referral, which causes us to perceive what’s happening in the nose as if it’s inside the mouth, smell is integral to our experience of taste. People

often struggle to separate the two, certain that they have lost their sense of taste when the taste buds — which detect only sweet, salty, bitter, sour and umami flavors — remain fully functional. There was also the question of the sensations we experience through neither olfaction nor taste, but via the nerves of our trigeminal system: the coolness of mint, the spice of peppers, the bubble of carbonation. Were these also affected? (The three, together, are known as our chemosensory senses: those we use to detect the presence of chemicals in our environment.) Answering these questions could help solve the most urgent puzzle: What exactly was happening inside patients to make their sense of smell disappear in such an unusual way? Could Covid-related smell loss teach us anything new about how the virus worked? Or about how we did?

As a panicked world closed down around them, members of the G.C.C.R. started meeting online every day, working on a plan to survey people with respiratory illnesses about their symptoms. There were so many eager researchers, from so many countries, that the survey was quickly translated into more than 30 languages. Though the group considered using several of the more objective olfaction tests developed in recent decades, they decided, given the urgency of the situation, to use the simplest method: asking patients to assess their own perceptions. The survey included, along with rating scales for smell and taste and multiple-choice options about diagnoses and symptoms, a series of open-ended text boxes where people could write as much as they wanted about what they could and couldn't smell.

It turned out that they wanted to write a lot. Many people went on for pages and pages, offering enormous detail and torrents of feeling. “This was freaking people out,” says Pamela Dalton, an experimental psychologist at the Monell Center who studies the interaction between cognition, emotion and the way we perceive odors, and who also worked on the survey analysis. They wrote things like “I’m inhaling, and there’s nothing there.” People frequently described themselves as feeling adrift — disconnected from a world that felt wrong, uncanny, confusing. Reed noticed that many respondents, ejected from the system because they reported symptoms that weren’t recent enough to be included in the design of the study, signed back in with falsified dates so they could still participate. Those answers wouldn’t be included in the analysis, but Reed understood why they mattered. “Ultimately, people just want to tell their story,” she said.

In a matter of weeks, 40,000 people took the survey, and the members of the G.C.C.R. began to search for patterns in the data. They quickly established that people who lost smell and tested positive for the coronavirus weren’t encountering the typical nasal blockage — they often referred to the loss as “sudden” and “creepy” — and that they were also noticing genuine impairments not just to their olfaction but in many cases to their

taste and trigeminal sensations as well. This clearly wasn't the typical pathology of smell loss following a virus.

The scientists also noticed that a disconnect was forming between what the data showed and how the wider world responded. Early on, data from apps for tracking symptoms showed that smell loss was more common than the fever or cough the virus was known for; it also had the diagnostic advantage of pointing directly to Covid, rather than to another respiratory illness. And yet schools and restaurants and airports continued to use forehead thermometers to screen for fevers — a symptom that many people with Covid never experienced. Later G.C.C.R. analysis showed that smell loss was, in fact, the most reliable predictor of Covid, and that this was true even for people assessing their own smell loss (which, research has shown, is something people tend to be quite bad at). Reed and other researchers also found that objective smell tests, in which patients have to prove themselves against actual stimuli, were able to catch many extra Covid cases among people who failed to realize when their sense of smell had changed. “The better we ask questions about smell,” Parma says, “the more people we find.”

In Britain, Hopkins was growing frustrated. The weeks kept passing, and smell loss still didn't appear on the official list of symptoms recognized by the National Health Service — a list that determined who qualified, or didn't, for coronavirus testing. One of her patients, a physiotherapist, was told to keep reporting to the I.C.U. where he worked, even though his family was sick and he had lost his sense of smell. He convinced his team that he should be allowed to self-isolate, but Hopkins wondered how many other people were in similar situations, sent out into the world to spread a virus they were assured they didn't have. “I can still put in my symptoms into NHS 111” — the portal through which patients access care from the National Health Service — “and claim to have muscle ache, fatigue, loss of smell, diarrhea and be told that I don't have coronavirus,” she told the BBC in mid-May. “I think that is now actually, clinically, negligence.”

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Months later, after the N.H.S. officially recognized smell loss as a Covid symptom, I asked Hopkins why she thought that recognition of smell loss as a symptom of Covid had taken so long. In part, she replied, the trauma of the serious cases had obscured, in the data as

well as from public notice, a symptom that was primarily noticeable in people with only mild disease. But she also believed that there was another important factor, unrelated to the virus. Covid arrived in a world that had spent far too long not taking smell seriously.

This may be the moment for a belated disclosure: Part of what interests me about the science of smell is that I myself am anosmic. (The outsider to whom smell looks like a superpower? That's me.) I have no idea if my inability to smell is congenital or if my olfaction stopped working before I had the chance to remember it. I did have a lot of ear infections when I was very young, which are known to damage smell. Infants aren't routinely screened for smell disorders, as they are for hearing or vision, and it's common for anosmic people not to realize fully that they're different until, on average, their early teens. That's about how old I was when my sister came home to find me blissfully cuddling our skunk-sprayed dog, and the pieces began to fall into place. (Years later, the same sister came home just in time to stop me from lighting a match in a cabin I had accidentally filled with propane.) Before I learned what anosmia was, I assumed, whenever people brought up the things they were smelling, that this was a skill I had yet to figure out, that I just wasn't doing it right.

One thing you notice when you can't smell is how much time people who can smell spend talking about it. Friends are always curious about whether I can taste food (I love food, though I care primarily about textures and the flavors the actual taste buds perceive), but that's the main difference they imagine. They don't seem to realize all the other ways that smell is constantly on their minds. Smell is no big deal, until it's missing.

As the pandemic progressed, the G.C.C.R. surveys showed that the experiences of patients who lost their sense of smell were beginning to diverge. There were those — about three-quarters of Covid patients, Reed says — who recovered their olfaction fairly quickly, from a few weeks to a couple of months after losing it. Then there were those who gained it back slowly, over the course of many months. But there was a smaller percentage who, at six months, didn't seem to be recovering it at all.

This was what Chrissi Kelly, another G.C.C.R. member, feared might happen. In 2012, she lost her own sense of smell after fighting a virus she caught on an airplane. She spent the next two years feeling depressed, forgetful and like a fundamentally different person than she was when she could smell. “Life lacked color, luster,” she told me. “My sense of humor had deserted me.” The experience was so destabilizing that she began digging into scientific papers about smell loss — there weren’t many of them, and there was almost nothing for a lay audience — and contacting their authors, searching for possible treatments. She started practicing “smell training,” a little-known technique for recovering some olfaction by regularly smelling strong odors, and she started a support group on Facebook for other people with the condition.

Before Covid, the group, called AbScent, had grown to around 1,500 members, most of whom lost olfaction after a head injury, a virus or a sinus disease. And then the pandemic began. It soon became a nearly full time job just to process the flood of thousands of distressed people who were asking to join AbScent. In the group, people mourned specific smells and flavors, shared their struggles with nausea and weight loss or gain as they navigated an altered relationship with food. They commiserated about the new dangers of life: food poisoning, gas leaks, not noticing that dinner was burning. (This month, a Texas family whose members lost their sense of smell to Covid narrowly escaped a house fire after the only uninfected member, a teenager, smelled smoke and woke everyone else up.)

Many people also struggled with depression, symptoms similar to those of post-traumatic stress disorder and feelings of relentless isolation and disconnection from the world around them. It felt, some people said, as if they were living their lives in black and white, or trapped behind a sheet of glass; their sense of normalcy and well-being had disappeared with their olfaction. “I feel alien from myself,” one person wrote. “Detached from normality. Lonely in my body. It’s so hard to explain.” Another described feeling “discombobulated — like I don’t exist.” Kelly kept the group closed, out of respect for what she described as the “profound depths of sorrow and anger and anxiety” that people shared there.

Kelly sometimes noticed that requests to join the group would suddenly increase from a certain city or region, only to later read about a new spike in cases. She committed herself to responding to each person individually, spending hours every day. “It still feels like an emergency response,” she said over Zoom more than six months after the official start of the pandemic. As the numbers ballooned and the Covid patients began to overwhelm the discussion, Kelly started a separate support group just for them, which quickly dwarfed the original.

And then, quite suddenly, many people in the group began reporting something new.

Their sense of smell seemed to be returning, yet it was coming back ... broken. Things no longer smelled the way they had, and usually the new smell was bad: Food smelled like gasoline or cigarettes, or scented body wash was like burning rubber. Terrible smells even intruded when nothing odorous was around. A boyfriend no longer smelled or tasted right, and the poster had begun to avoid kissing him but had not told him why. “Poo now smelled better than coffee,” another person noted. Analysis of the G.C.C.R. surveys later found a similar pattern: As the pandemic progressed, the symptoms — known as parosmia, incorrect smells, and phantosmia, phantom smells — went from nearly unknown to incredibly common. Kelly and Hopkins and other researchers collaborated on a paper analyzing the posts in AbScent and found that, on average, three months elapsed between smell loss and the arrival of faulty smells. To manage what she called “the rising tide of parosmia,” Kelly spun off yet another support group.

In all three groups, as people shared their tips and experiences, Kelly noticed them sharing something else as well: overwhelming relief at having at last found others who understood what they were going through. Many had been told by friends or family that smell was no big deal, really, and they should buck up and be grateful that they hadn’t lost one of their really important senses. (A University of Warwick researcher noticed something similar 20 years ago, writing that what seemed to unify anosmics was “the expressed feeling that each was the only person in the world to be affected by the condition. This appears to be a direct reflection of the lack of sympathy that anosmics encounter concerning their condition.”) This was difficult, but worst of all was hearing something similar from doctors, who basically shrugged while explaining that there was no treatment.

When we talked, Kelly searched for a way to describe how excruciatingly frustrating these dismissals felt to the group’s members, then said, “It’s the great silent scream.”

Before the pandemic, Sandeep Robert Datta, who runs a neurobiology lab at Harvard, was studying what he described as both the basic mechanisms and the ongoing mysteries of olfaction: just how neural receptors capture smells, how that information travels to the brain, how the brain puts it all together to create an integrated smell that we recognize as pizza or gasoline. “We still understand so little about how our noses detect odors,” he told me.

As part of that work, the lab sequenced cells in the epithelium — a sheet of neurons and supporting cells lining the upper nasal cavities — and olfactory bulb of mice to determine what RNA each cell expressed. Datta’s attention, like that of most other researchers, was focused on the receptors that actually perceive odorants, the ones whose discoverers won the Nobel. He never gave much thought, he said later, to the cells that surrounded them.

In the early days of the pandemic, while Datta was quarantined away from his lab, he spent his time reading updates on the new virus and scrolling the discussions on the G.C.C.R. message board. Early analyses of the coronavirus showed that it used its distinctive spikes to attach to the cells of its hosts via a certain protein, known as an ACE-2 receptor. Datta's thoughts drifted to those mice epithelia. He realized that he, as well as a few other researchers who had collected similar troves of data, already had information that could show whether the sensory neurons of the olfactory system were vulnerable to a direct attack by the virus — what he saw as “the natural hypothesis” to explain the sudden smell loss.

The data, however, showed otherwise: There were no ACE-2 receptors on those all-important neurons. But they were expressed on some of the other, barely studied cells that surrounded them. Some were stem cells, which allow the sensory neurons to regrow when they're damaged. (Olfactory sensory neurons are the only type of neuron directly exposed to the outside world, so they sustain an unusual amount of damage. They're also a rare part of your nervous system that is able to renew itself.) Others were “sustentacular” cells, which seem to provide various kinds of support to the neurons: metabolic and physical, plus maintaining the right salt balance in the mucus that is essential for odor detection.

Studies on hamsters, which unlike mice are naturally susceptible to the coronavirus, confirmed that these cells were indeed capable of being infected by the virus. This could be an explanation for the different paths that patients' olfaction tended to take after being impaired by Covid, Datta and other scientists hypothesized. For some people, olfaction might simply have been interrupted for a few weeks while their sustentacular cells were knocked temporarily out of commission — either by the virus or by the body's own immune response as it tried to fight it off. For others, the cells might have been so damaged in the fight that the neurons they supported actually died and had to regrow slowly, over the course of months. (This theory could also explain the belated but widespread wave of parosmia: When the axons that connect the olfactory epithelium and the brain are disrupted, they're known to reconnect in strange ways, as if an old-timey telephone operator plugged a wire into the wrong call. Still, no one knows why the wrong smells are so often such unpleasant ones.) And then there might be people whose epithelia, and especially their stem cells, sustained so much viral damage that their neurons would never be able to regrow, and their sense of smell never able to recover.

It's a compelling and even likely theory, other researchers told me. But they stressed that there's a lot about olfaction, just as there is about the new virus, that we simply don't yet understand. Sensory neurons could turn out to be infectible after all, or the virus could be

using other unknown cells as an entry point. There is evidence that the virus may have found a way to overcome the protective barrier around the brain to invade the central nervous system directly, perhaps even via the pathways provided by the olfactory system. That, too, could explain smell loss, as well as some of the other troubling neurological effects that patients have experienced. We also still don't know what's happening to disrupt taste and trigeminal sensations, though there is some debate that the virus could be similarly targeting the support cells for taste and smell receptors.

If smell scientists have learned anything in the recent renaissance, it's not to underestimate how much, or how intimately, the chemical senses intertwine with the rest of the brain. While what we see must pass through various parts of the brain before it reaches our centers for memory or emotion, smell has a nearly direct pathway. "They're built together," Datta said of the brain and the chemical world that it perceives. "They're meant to function as a unit."

It's common to lose smell acuity as you age. Nearly one in five Americans over 40 reports a changed sense of smell; one in eight has a measurable olfactory dysfunction; one in 15 experiences phantom odors. Before Covid, an estimated 3 percent of Americans had little or no smell at all.

We don't have good data on how many people are born without a sense of smell, though the National Institutes of Health estimates that it may be one in 10,000. We also don't know how to cure congenital anosmia; which parts of the olfactory system usually fail to work; or how the condition interacts with things like genetics, chemical signaling, memory or neural diseases. "That," Sobel, of the Weizmann Institute, told me, "is kind of pathetic."

As the science of smell has expanded, researchers have learned that olfaction, far from being an unimportant sideshow, is interlaced with many diseases that concern us deeply. Smell loss is an early warning sign of neural diseases like Alzheimer's, Parkinson's and schizophrenia, which is also strongly associated with parosmia and phantosmia. People with depression have decreased olfaction and smaller olfactory bulbs on average, and the size decreases according to the severity of the depression. Children with autism have different automatic sniff reactions than those who are neurotypical, and they use more parts of their brains to process odors. They can also follow social cues better if they can smell a mother's odor, even if she isn't present.

Olfaction is also bound up, in ways that we're only beginning to understand, with our immune systems. Both, after all, depend on the body's ability to recognize and respond to chemicals in the environment, and some immune cells even depend on olfactory

receptors to respond to invaders. (In fact, there are olfactory and taste sensory receptors scattered throughout the body: in the kidneys, the small intestine, the lungs, the stomach. They seem to be “smelling” and “tasting” their surroundings to alert tissues when there are pathogens or other dangers nearby.) A wide spectrum of autoimmune or immune-mediated diseases, from multiple sclerosis to rheumatoid arthritis to lupus to recurrent pregnancy loss, are associated with smell loss or irregularity. Richard Doty, a pioneering smell researcher at the University of Pennsylvania, told me that the link is so strong that he has sometimes wondered if it’s a sign that some of these diseases might have undiscovered viral causes. There are also unexplored links to the thyroid and hormones. Untold questions are still waiting for answers, wrote the authors of a 2013 meta-analysis: “The different connections between smell and autoimmunity, genes and hormones may suggest that this is another tessera of a mosaic which is waiting the answer of Oedipus.”

“We used to think,” said Dalton, the experimental psychologist, “that the chemical senses were the poor orphan or poor cousins” of the sensory world. Lately, though, smell scientists more often refer to olfaction as the Cinderella sense: one that is perceived completely differently once you stop ignoring and disparaging it.

So why are we so convinced that humans are bad smellers? Many scientists believe that it comes down to how intensely personal our experience of smell is, how difficult it is to share it with others. Research shows that people are much better at differentiating among different smells than correctly identifying a single one — a problem I heard researchers call the “fuzziness” of smell, the “tip of the nose” feeling we get when we encounter something familiar that we can’t quite name. We may not be bad at smelling, but we are bad at putting what we smell into words. (Kant again: “Smell does not allow itself to be described, but only compared through similarity with another sense.”) With vision, we have a concrete vocabulary to lean on: red or blue, dark or bright. (As I was writing this, I noticed how much I, and the people I interviewed, relied on visual metaphors — smell is overlooked, the world loses color — even when discussing a distinct sense.) Even if we’re perceiving a color differently from the way someone else is — which is, in fact, pretty often the case — we still have a shared language that we can all lean on to discuss it. With smell, we find ourselves flailing.

The subjectiveness of our experience means that coherent analogies can be hard to find. The same molecular compound can, for a variety of reasons, smell totally different to two people. In fact, even the very same person can experience it differently at different times, especially if their own chemistry is altered by being, say, hungry or hung over or pregnant. Our genetics determine whether we can smell cyanide, and whether we will experience the pheromone androstenone as smelling like vanilla or like a grim

combination of dirty socks and urine or like nothing at all. Genetics plus life experience, the natural attrition and regrowth of your epithelium (it may be that the more you smell an odor, the more receptors you develop that can perceive it), mean that 30 percent of your receptors may be different from those of the person next to you. Culture, too, plays a role: Whether you think lemon smells “clean” or not may depend on whether you grew up associating it with cleaning products or with hot, overripe citrus groves.

Our descriptions of smell also lack resolution, Mainland, the neuroscientist, notes: Though Pantone lists dozens of shades of blue, each of which can be quantified precisely in hue and saturation, we can really describe a banana scent only as banana-y. (If our experience of vision were as dissolute as smell, the philosopher Daniel Dennett has written, “the sky would go all birdish” when a bird flew by.) Yet the intensity of a smell can completely change the way we experience it. Mainland, who often asks volunteers to describe smells in his lab, told me that he has one vial that is perceived as grapefruit at low concentrations but rotten egg at high ones, and another that slides from black currant to cat pee. As Parma says: “With vision, we agree on where we stand. With odor, it’s like a kaleidoscope.”

That turns out to matter quite a lot. Being able to describe and discuss what we smell helps us smell it better. Think of sommeliers, who learn to pick out the distinct aromas of wine in large part by learning a language for them. Or consider, as the cognitive scientist and philosopher A.S. Barwich explains in her book “Smellosophy,” that beer experts have lots of descriptors for bitter flavors, which they prize, while wine drinkers, who consider bitterness a sign of a failed wine, have few.

Asifa Majid, who studies language and cognition at the University of York, has written about languages in Southeast Asia that have genuine lexicons for odors: sets of words that work much like color words, each describing something inherent in the experience of a smell rather than comparing it to other things. While Westerners trying to describe smells tend to hem and haw and squint into space, searching for descriptors, speakers of these languages are declarative and decisive. (Majid described, to *The Atlantic*, how her own ability to name smells looked in comparison: “Some kids were following me around and laughing. Like, ‘How can you be such a moron?’”) Huehuetla Tepehua, an Indigenous language in Mexico, likewise has at least 45 different words that express specific olfactory experiences. People who grow up in such cultures are better at detecting, discriminating and naming odors. One also doubts that they would require a scientific renaissance to tell them that smell matters.

Western psychology is frequently, and justifiably, criticized for being skewed because such a disproportionate number of its study subjects come from just a few WEIRD

countries — Western, Educated, Industrial, Rich and Democratic. Smell scientists have also begun to talk about what it means that many early scientists and theoreticians of perception, as well as the people they studied, were also ODD: They were Older people (whose senses of smell were therefore naturally diminished); they lived in Deodorized societies, where many natural smells were unwelcome; and they were also generally Desensitized to smells because of living in cultures that paid little attention to them, and because of the dulling effects of urban pollution and even, perhaps, their common affinity for smoking. It may be no wonder at all that they found smell so unworthy of consideration.

This leads to some interesting questions. What if we've spent so much time dismissing the importance of smell because of some odd (or ODD) accident of history? And what if we might rediscover it, in part, because of another?

As the virus ripped through New York City last spring, Pablo Meyer, another G.C.C.R. member, stayed inside his apartment, listening to ambulance sirens. Every morning, he tested his own sense of smell to assuage the persistent fear that he, like so many of his neighbors, had contracted the coronavirus. He then spent his days reading replies to the G.C.C.R. survey as they poured in from around the world. One person's sense of smell disappeared entirely over the course of cooking a single meal. Someone found a boyfriend's signature pasta dish suddenly disgusting, while someone else doused a worryingly bland breakfast with hot sauce to no effect. A sommelier failed to notice that the cat's litter box was full, and a self-described former bloodhound, always the first in any group of people to notice an odor, nearly gagged on food that smelled of nothing. "Nothing is savory anymore," someone wrote. "Coffee is just bitter. A cake is just sweet. A burger is just salty."

Meyer began to feel as if he knew the people personally — the ones who described smells in terms of tea and fruit, or meat and gasoline, or blue Powerade and lollipops. The way they described their senses felt so intimate, he said later, "you could almost see the type of person they are." He was becoming convinced that people believe they are bad at describing smells simply because they so often are asked to do so in labs, sniffing single, isolated molecules (when the more familiar odor of coffee is a blend of many hundreds of them), cloistered away from the context of their real lives and the smells that actually mattered to them. Given the right opportunity, he said, "people become very, very verbal."

For Meyer, an IBM researcher who specializes in using algorithms to analyze biological data, and who was one of the people who insisted that the G.C.C.R. surveys should include open text boxes, this was exciting news. For years, scientists studying smell have been working off just a few, deeply deficient data sets that link different chemicals and the way

humans perceive them. There was, for example, a record created in the late 1960s by a single perfumer, who described thousands of smells, and study after study relied on a single “Atlas of Odor Character Profiles,” published in 1985. It drew on the observations of volunteers who had been asked to smell various single molecules and chemical mixtures, rating and naming them according to a supplied list of descriptors that many scientists felt was flawed and dated.

More recently, Meyer and many others had been using a new data set, painstakingly created by scientists at the Rockefeller University in New York and published in 2016. (I visited the lab in 2014, while Leslie Vosshall and her colleagues were building their data, and was surprised to find I could “smell” one of the vials, though it probably just triggered my trigeminal system. When I told Vosshall that it seemed minty, she replied: “Really? Most people say, ‘Dirty socks.’”) But while the new data set was a significant improvement — 55 people smelled 480 different molecules, rating them by intensity, pleasantness, familiarity and how well they matched a list of 20 descriptions, including “garlic,” “spices,” “flower,” “bakery,” “musky,” “urinous” and so on — it was still a sign of how limited the field was.

This was why Meyer, along with his colleague Guillermo Cecchi, pushed for those open text boxes in the G.C.C.R. survey. They were interested in the possibilities of natural language processing, a branch of machine learning that uses algorithms to analyze the patterns of human expression; Cecchi was already using the technology to predict the early onset of Alzheimer’s, when it is most treatable, by analyzing details of the way people speak. Many researchers had written about the possibilities of using artificial intelligence to finally make a predictive olfactory map, as well as to look at links between changes in olfaction and all the diseases to which those changes are connected, but sufficient data was never available.

Now Covid had provided researchers with a big, complicated data set linking olfactory experience and the progression of a specific disease. It wasn’t constrained by numerical rankings, monomolecules or a few proffered adjectives, but instead allowed people to speak freely about real smells, in the real world, in all their complex and subjective glory.

When Meyer and Cecchi’s colleague Raquel Norel finished analyzing the open-ended answers from English-speaking respondents, they found, with surprise and delight, that their textual analysis was just as predictive of a Covid diagnosis as people’s numerical ratings of smell losses. The algorithms worked because people with Covid used very different words to talk about smell than those without it; even those who hadn’t fully lost their olfaction still tended to describe their sensations in the same ways, repeating words like “metallic,” “decayed,” “chemical,” “acid,” “sour,” “burnt” and “urine.” It was an

encouraging finding, a proof of concept that they couldn't wait to explore in a lot more depth — first in the G.C.C.R. responses in other languages and then, in the future, in other data sets related to other diseases. Meyer got excited when he talked about it. “Anything where smell changes,” he told me. “Depression, schizophrenia, Alzheimer's, Parkinson's, neurodegeneration, cognitive and neuropsychiatric disease. The whole enchilada, as they say.”

I had a hard time imagining the olfactory “map” that scientists have dreamed of for so long. Would it, I asked Mainland, look something like a periodic table? He suggested I think, instead, of the maps that scientists have made of “color space,” which arrange colors to show their mathematical relationships and mixtures. “We didn't know how useful color space was until people started inventing things like color television and Photoshop,” he explained, adding that the map itself isn't the goal, but rather the ability to use it to understand why we smell what we do. After that, what will be really interesting are the applications we can't yet imagine. “It's hard to understand the utility of the map,” he said, “until you have the map.”

At the beginning of October, I watched on a webinar as Veronica Pereda-Loth, a G.C.C.R. member, shared a different type of map, which she and other researchers had created. Using data from France, where an especially large number of people had filled out the survey, researchers overlaid the timing and geography of self-reported smell and taste loss with lockdowns and hospital admissions. They found that increases in anosmia had been a more timely indicator of surges in viral transmission than the data the government was using. They could also see the effects of lockdowns clearly in the surveys: New-onset smell and taste loss began to decline five days after lockdowns began, while it took 15 days for the government's hospital-based indicators to show that they were working. Smell-and-taste tracking could be “a crucial tool for detecting next waves,” Pereda-Loth argued. Yet it remained difficult to get smell taken seriously; when someone asked how that fact was being communicated to governments, there was a lot of rueful laughter. Europe's autumn spike, which eventually brought new lockdowns, began shortly afterward.

Parma thought that the G.C.C.R. message board would start to quiet down once lockdowns ended and people went back to their own labs, but instead she saw more and more proposals for ways to study the group's data, and more small groups of new collaborators, spinning off to chase new questions. Dalton imagines a future in which smell checks on infants and children, which could give far more insight into their overall health than a hearing test, become routine. She and Reed, as well as some other researchers, have begun developing coronavirus screening tests for public places, based

not on fevers but on ability to smell. Hopkins, who partnered with scientists from Belgium, Italy and elsewhere to publish more than 30 papers about the way the virus and olfaction intertwine, expects more attention to the study of smell training and other as-yet-unknown treatments for people who have lost their sense of smell. It's a problem that she thinks will be taken much more seriously in a post-Covid world in which many people, possibly millions of them, never fully recover their olfaction.

If smell was ignored before, off in the hinterlands, you could say that Covid put it on the map. But studying smell, scientist after scientist told me, had already reshaped the way they thought about the world and their place in it. They went, they said, from thinking of smell as a "bonus sense" to a dominant one, and "from a secondary sense to one of the primary things that influences our life." The geography had shifted even as they were working to chart it.