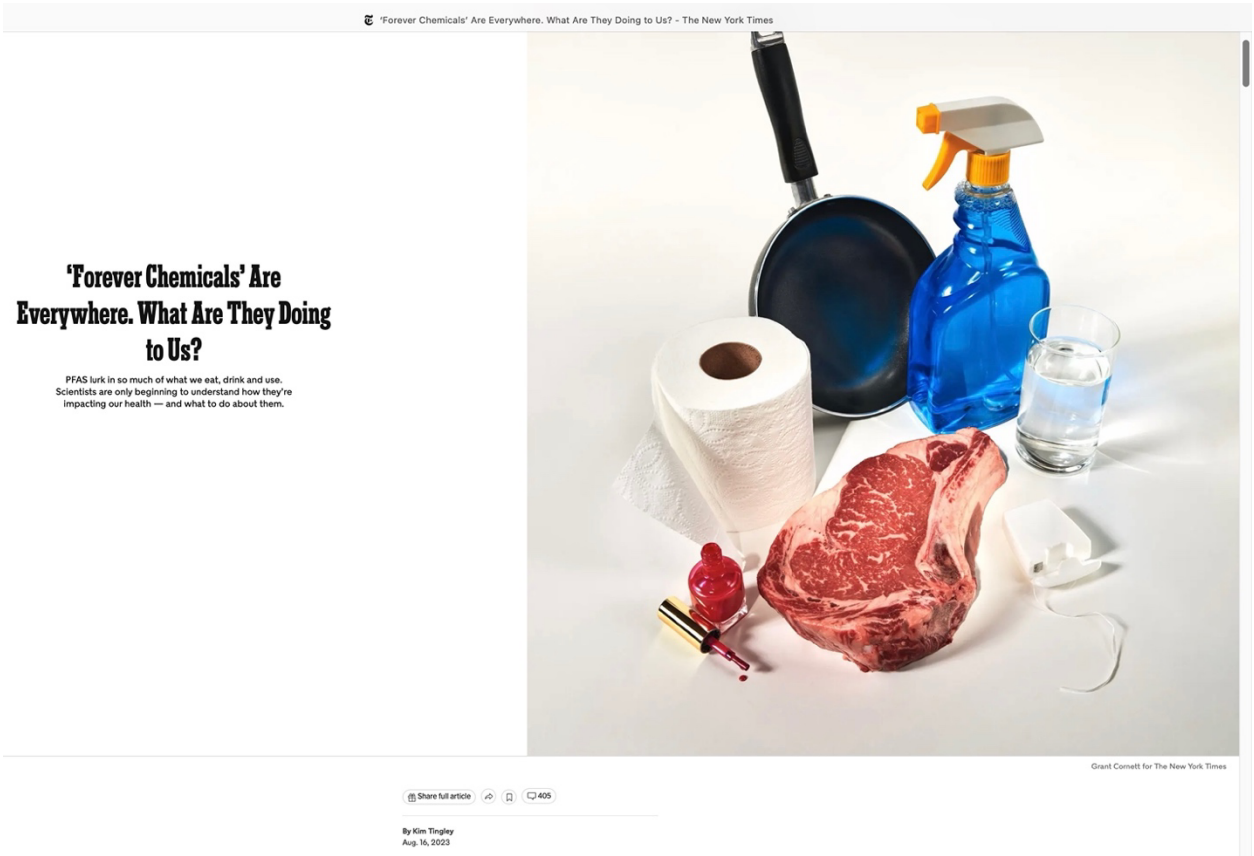

The Faroe Islands, an incongruous speckling of green in the North Atlantic, are about as far away as you can hope to get on Earth from a toxic-waste dump, time zones distant from the nearest population centers (Norway to the east, Iceland to the west). Pál Weihe was born in the Faroes and has lived there for most of his life. He is a public-health authority for the nation, population around 53,000; chairman of the Faroese Medical Association and chief physician of the Department of Occupational Medicine and Public Health in the Faroese hospital system. He is also vice chairman of the Faroe Islands Art Society; a widower; a grandfather. A crumpled funeral program and half-empty juice boxes share space in the back seat of his Land Cruiser.

Despite the remoteness of his location, Weihe's medical career has been defined by his efforts to protect the Faroese from exposure to chemicals that reach the islands from across the sea. His research clinic is a cozy two-story house on a hill just above the Tórshavn harbor. Medical textbooks in English and Danish (the Faroes are part of the Kingdom of Denmark) line the walls, hinting at the scope of this task: "Basic and Clinical Immunology"; "Klinisk Social Medicin"; "Marine Medicine Research Collection"; "Gynaekologi"; "Hunter's Diseases of Occupations." His colleagues are almost all women, and at 73, he is decades

their elder. The slender mahogany chairs he has chosen for the conference room, made by a local carpenter, bow to the future: “They have a feminine shape,” he said, “and this is a house of women.”

On a blustery morning in early April, the house was relatively quiet because of the Easter holiday, but two staff members, Jóhanna Petursdóttir and Marita Hansen, had come in with Weihe to examine volunteers enrolled in an ongoing study that began in 1986. Back then, Weihe and a Danish professor of environmental medicine, Philippe Grandjean, recruited more than 1,000 pregnant women, and later their newborns, to study the impact of mercury from seafood on fetal and child development. The Faroese mother-infant pairs showed that exposure to the toxin in the womb, even at low levels, can cause learning and memory deficits in children, findings that led to global advisories for pregnant women to limit their fish intake. Grandjean and Weihe continued enrolling new groups whenever there was funding to do so and moved on to assessing the impacts of other pollutants.

In 2009, Grandjean happened to be reading a toxicology journal when a study caught his eye. The authors had exposed rats to one of a group of common chemicals that are classed together as “per- and polyfluoroalkyl substances,” or PFAS for short. The chemicals, many of which repel water, oil and grease and can often withstand high heat, are used in countless consumer products. They also linger in the environment. The exposure, they found, damaged the rodents’ immune system. The question was whether the same would be true in people.

Grandjean, who had never heard of PFAS, was intrigued. By then, he and Weihe were investigating whether several other persistent chemical pollutants affected how children responded to routine vaccination. So it was relatively easy to add PFAS to their study. Over the prior 23 years, they had periodically asked the children from their mother-child groups for biological samples: blood and hair trimmings. They also saved samples from the children’s mothers around the time of their birth. This biobank, a portion of which is preserved in a dozen freezers in the basement of the national hospital, served as a kind of time machine: Grandjean and Weihe were able to test for chemicals in the serum of babies who were now years and even decades older.

Around the same time, other potential health impacts of PFAS were starting to receive attention in the United States. Lawsuits filed beginning in the late ’90s raised serious concerns about a DuPont factory near Parkersburg, W.Va., that used a type of PFAS called PFOA to make Teflon. For decades, the company

had dumped waste containing the chemical into the Ohio River and unlined pits on its property, polluting both the air and drinking water of tens of thousands of people. As part of a settlement, DuPont funded a study to determine if residents had been harmed by the chemicals. Its major conclusions, published online in 2012, were damning: The evidence, including blood samples and health surveys, indicated a "probable link" between PFOA and high cholesterol, ulcerative colitis, thyroid disease, testicular cancer, kidney cancer and pregnancy-induced hypertension.

Grandjean, Weihe and their colleagues published their own paper in 2012 showing that PFAS reduced the number of antibodies that children maintained after they received tetanus and diphtheria vaccinations. (Weihe was so alarmed at the apparent lack of protection for some of them that he called their parents to offer them boosters.) Between the Faroese and the Ohio Valley residents, however, there was a crucial difference. The Faroese had not been exposed to high levels of the chemicals, as the subjects in the DuPont study had; the levels of PFAS circulating in the bloodstreams of the Faroese were akin to U.S. and European averages. If such relatively small quantities of PFAS could interfere with the immune system, Weihe and Grandjean asked, what other processes might be affected? And how long might it take for those outcomes to appear? The two researchers have been seeking answers by documenting the health of the babies in their study as they move through childhood and into adulthood.

Even today, many Americans, including physicians, are unfamiliar with PFAS — perhaps in part because they used to be called PFCs, and the alphabet soup of "P" abbreviations that refer to individual variations is confusing. Among those who are aware of the chemicals, few seem concerned about their possible exposure. If practically everyone has ingested some PFAS and most of us haven't noticed any effects, the thinking goes, how bad for us could it be?

"I've heard some people say, 'Well, if everybody is exposed to PFAS, how come we aren't all dead?'" Jamie DeWitt, a professor of pharmacology and toxicology at the Brody School of Medicine at East Carolina University, told me. In fact, she says, "People actually *are* dying." DeWitt cited a report in The Lancet that calculated that about nine million people each year die from chronic diseases caused by environmental pollutants of all kinds. "We need prevention," DeWitt says. "And that means acknowledging that environmental exposures lead to diseases."

Confounding that acknowledgment for PFAS is the breadth of health conditions with which exposure to the chemicals has been associated: the cholesterol and cancer outcomes highlighted by the DuPont study and the decreased vaccine response demonstrated in the Faroese children, but potentially others that have yet to be proven as persuasively. Those include endocrine disruption, metabolism and immune dysfunction, liver disease, asthma, infertility and neurobehavioral issues — their diversity a potential result, as Linda Birnbaum, former director of the National Institute of Environmental Health Sciences (N.I.E.H.S.) and the National Toxicology Program put it to me, of the fact that "PFAS has a great deal of complexity."

Many of these health problems are common and chronic. Are PFAS contributing to their development, and if so, how much? Would reducing our contact with the chemicals meaningfully improve our overall health?

The chemicals known as PFAS have been found in a dizzying array of goods, notably waterproof, stain-resistant and nonstick ones and several kinds of household cleaning products, even brussels sprouts (although data on those is limited). They are also associated with a wide variety of health problems. Credit...Grant Cornett for The New York Times

The first variation of PFAS (pronounced pee-fas) was discovered accidentally by a DuPont researcher looking for more stable refrigerants in the 1930s, then used by scientists in the Manhattan Project during the uranium-enrichment process. Many of the chemicals also stabilized explosives and made excellent protective coatings and lubricants for electronics, reducing surface tension such that both water- and oil-based substances slid right off; some also maintained their properties under extreme heat. They were subsequently incorporated into waterproof, stain-resistant and nonstick consumer products. (The chemicals also have vital uses in medical devices, cellular networks and in the aerospace and renewable-energy industries.) The special durability of PFAS derives from their structure. There are thousands of variations, each a unique chemical, but all of them include carbon atoms bonded to fluorine atoms. Many PFAS have bonds that are so strong that no one is sure how long it takes for them to break down on their own in nature; it could be hundreds or even thousands of years. For this reason, PFAS are often referred to collectively as "forever chemicals."

DuPont and 3M, which was manufacturing PFAS and using one in Scotchgard, began studying the potential health effects of their formulations in part as an occupational-safety measure. Initially, scientists assumed that because the first compounds were so stable and resistant to change — "inert," in chemistry parlance — it would be impossible for them to interact with biological systems. The companies' in-house experiments, along with other studies, quickly overturned that notion. By 1965, DuPont had indication that PFAS increased the liver and kidney weight of rats.

In the late '70s and early '80s, the companies were seeing alarming signals in their animal studies — in one study, monkeys exposed to extreme levels of PFAS died — and among their employees. In 1979, DuPont observed that workers who had contact with the chemicals appeared to have higher rates of abnormal liver function. In 1981, 3M researchers alerted their DuPont colleagues that pregnant rats exposed to PFAS had pups with eye irregularities; that year, an employee at a Teflon plant gave birth to a child with one nostril, a keyhole pupil and a serrated eyelid. In 1984, DuPont detected PFAS in the tap water of three communities near its West Virginia factory.

In 1998, 3M told the Environmental Protection Agency that it had tried and failed to identify members of the public *without* PFOS — a type of PFAS it was producing — in their blood. Two years later the company, which was the only U.S. maker of PFOS, announced that it planned to phase out its manufacture

of the chemical. (3M had occasionally shared data with the E.P.A. in the 1980s; DuPont's human and animal research wouldn't become known until 2001, after a lawsuit forced the company to turn over documentation related to PFOA to opposing counsel, and he alerted the E.P.A. and other agencies.) In 1999, the National Health and Nutrition Examination Survey, an ongoing project run by the Centers for Disease Control and Prevention to track the health of the U.S. population, began testing for PFAS in participants and would confirm 3M's observations: The chemicals were present in virtually everyone.

This revelation was met with a collective shrug by federal health officials and policymakers. More than two decades later, in fact, PFAS production remains largely unregulated. There are more than 12,000 variations of the chemicals, very few of which have been investigated for their potential health effects. Using data from the E.P.A. and other government agencies, the Environmental Working Group, a nonprofit research and advocacy organization, has mapped more than 41,000 places in the United States and its territories where PFAS are potentially being made, used or released: military sites, airports, landfills, wastewater-treatment plants, oil refineries. This year, the group announced that more than 2,800 domestic locations are confirmed to be contaminatedwith the chemicals.

PFAS can be removed from tap water, but according to the E.P.A., tap water typically accounts for only about 20 percent of a person's overall exposure to the chemicals; we also eat them, inhale them and rub them on our skin. Testing by government agencies and watchdog groups have found PFAS in carpets, furniture, nail polish, shampoo, mascara, nonstick cookware, dental floss, raincoats, fast-food wrappers, pizza boxes, microwave popcorn bags, yoga pants, sneakers, sanitary pads, tampons, menstrual cups, bedding, upholstery, children's pajamas, paint, vinyl flooring and artificial turf. They're in the protective equipment used by firefighters and medical personnel. They're in an especially effective foam for putting out fuel-based flames. They're in dust and the household cleaning products you might use to get rid of it. They are in flamingos in the Caribbean and plovers in South Korea. They are in alligators. They are in Antarctic snow. In Europe, they've been discovered in organic eggs; in the United States certain states have found them in produce and meat. Last year, a study of PFAS in freshwater fish in the United States revealed median levels so elevated that eating a single serving could be equivalent to drinking PFAS-contaminated water for a month. In June, the U.S. Geological Survey reported that it had tested private wells and public water supplies and found at least one PFAS in 45 percent of the nation's tap water.

Lately, statistics like these seem to appear ever more frequently in the news. In response to growing apprehension about the pervasiveness and toxicity of the chemicals, new regulations are in the works in the United States and the European Union. The E.P.A. has a “PFAS Strategic Roadmap,” and the White House has created a PFAS strategy team whose mission, among other goals, is “to understand and to significantly reduce the environmental and human health impacts of PFAS.” For decades, members of communities whose drinking water was found to contain significant levels of PFAS — Pease and Merrimack, in New Hampshire; the Cape Fear watershed, in North Carolina; the Great Lakes region; and many others — have been virtually alone in pressing public-health agencies to offer them both testing and, based on those results, medical guidance. Often, those agencies simply advise people worried about their exposure to consult their family physician. But chronic exposure to pollutants is not well covered in medical school. “People want to know, could this have contributed to my high cholesterol, my miscarriage, my loved one’s cancer?” Courtney Carignan, an exposure scientist and epidemiologist at Michigan State University, told me. “These are reasonable questions, and doctors are often very dismissive. They don’t have the knowledge to answer those questions.”

Last year, the National Academies of Science, Engineering and Medicine — whose publications typically reflect scientific consensus on a topic — reviewed all the studies that had been published related to the impact of the chemicals on humans. The resulting report is the first to offer three tiers of specific medical guidance based on the amount of PFAS detected in someone’s blood. Those in the middle category, it says, should pay close attention to their cholesterol and be checked for hypertensive disorders during pregnancy. Currently, this advice would apply to most of the U.S. population.

The Faroe Islands are distinguished by their precipitous cliffs, fjords and valleys. Waterfalls cascade down grassy slopes, where sheep are plentiful, and seabirds nest in crags. But the landscape is less inherently hospitable to humans. Nearly a century ago, the Danish poet Nis Petersen, who spent a year on the southernmost island, Suðuroy, wrote that a third of the male population perished outdoors, presumably succumbing to rocky or watery deaths. When the inhabitants of this dire locale discovered, sometime around the ninth century, that they could chase pilot whales into shallow bays, slaughter them and harvest their meat and blubber to avoid starvation, they interpreted the annual summer arrival of the creatures, laden with nutrients, to be “a gift from heaven,” Pál Weihe told me — “a kind of blessing.” The event, known

as *grindadráp*, eventually became a cultural rite, rather than an act of desperation, one that persists in defiance of vigorous protests from animal-rights groups.

Moral arguments, however, were not Weihe's concern when, as a young doctor in the 1990s, he began telling anyone who would listen that children and any women who might become pregnant should avoid eating whale meat. Roughly a decade before, while a resident in environmental and occupational medicine at Odense University Hospital in Denmark, he met Grandjean, an expert on the neurological damage caused by lead exposure. Grandjean, an enthusiastic bird-watcher with the extravagant eyebrows of a rockhopper penguin, had fond memories of banding storm petrels in the Faroes in his late teens and was familiar with the grindadráp. He had also been reading in news reports that mercury was accumulating up the marine food chain, with concentrations peaking in top predators like pilot whales.

The neurological damage that acute mercury poisoning could cause was, like the dangers of lead poisoning, well known. But it was unclear how much people should worry about low-level exposure over the long term. To answer a question like that, scientists cannot perform randomized clinical trials in a perfectly controlled setting — the kind of experiment that most convincingly demonstrates cause and effect. Recruiting hundreds of participants, randomly assigning some of them to ingest mercury at varying levels and others (the controls) to ingest a placebo and then waiting a lifetime to see what happens would be unethical and impractical.

Instead, researchers impose those controlled conditions on animals or on human cells, then compare their findings with observational studies in people. In such epidemiological studies, scientists seek out volunteers who have already been exposed to a toxin, for example, and ask about or monitor their health after the fact. But because the subjects have not been randomly assigned to experimental or control groups, it is always possible that another, related variable is influencing the outcome.

Weihe and Grandjean realized, however, that the Faroe Islands offered circumstances uniquely suited to epidemiology. Everyone's living conditions are roughly uniform: same environment, free health care and schooling for all, similar genetic backgrounds. Moreover, after a grindadráp, whale products are distributed free to anyone who wants them, so presumably people's mercury exposure was as random as their taste preferences.

In 1985, Weihe and Grandjean advertised in the Faroes for pregnant women willing to enroll themselves and their future child in an environmental-health study. More than 1,000 agreed to take part. When they gave birth, they surrendered samples of their hair and umbilical-cord blood and tissue. Then the researchers waited until the children entered school. Even after seven years, more than 90 percent of the women returned with their first graders — an unheard-of retention rate in epidemiology — and the children underwent neurological assessments. The tests showed that 7-year-olds whose mothers had the highest mercury concentrations when they were born were also at the highest risk for language, attention and memory deficits, among other issues. They also scored lower on I.Q. tests. Those results, published in 1997, were the basis for the E.P.A.'s estimate of how much mercury people can ingest daily without ill effects. In the Faroes, meanwhile, women heeded Weihe's advice to avoid whale meat, and their overall mercury levels, along with those of their children, fell.

Nearly 15 years later, when Grandjean and Weihe wanted to learn more about the health impacts of PFAS, they were able to examine the frozen samples of mother-child pairs enrolled from 1997 through 2000. After checking the women's PFAS levels at delivery, they then tested blood taken from the children after vaccinations for tetanus and diphtheria, at ages 5 and 7. They found that for each doubling of maternal PFAS levels, the children's antibody concentration after the shots was 40 percent lower. For each doubling of PFAS among the children, their antibody concentration was 50 percent lower.

In Weihe's clinic in April, he, Hansen and Petursdóttir were receiving teenagers from their fifth mother-infant group who were born in 2009. The first subject arrived with his mother and younger sister. He kept his eyes on his sneakers as Hansen took a clipping of his curly blond hair, tied a string around the lock and dropped it into an envelope. Then Petursdóttir beckoned him over to draw blood. She had learned to do this last year on babies from the sixth group, when they were just three months old. The stress of inserting a needle into the tiny veins of squalling infants, and the anxiety of their parents as they watch researchers try to do so, is a major obstacle in recruiting babies for studies generally. "Every day I was worrying about what to wear because I was sweating," Petursdóttir told me. "I couldn't wear colors." The Kelly green turtleneck she had on that day was a hard-earned sign of confidence; she and her colleagues had gotten samples from more than 600 babies.

Weihe ushered the family into an exam room. At his direction, the boy, an avid soccer player, stood on a plate to measure swaying, first with his eyes open, then closed; held a penlike instrument in each hand, trying to keep it still; and pushed a button in response to a signal to gauge his reaction time. After he was done, Weihe emerged from the exam room. “I have told the boy and his mother that this is a completely normal young man,” he said.

“I would be surprised if he wasn’t,” his mother told me. Still, she said she appreciated the extra testing her son receives as a study participant.

Precisely where the Faroese are encountering the PFAS — and how they can, in turn, prevent further exposure — is a conundrum. There is no PFAS production on the islands, and the drinking water is already pure. The toxins must come from abroad, presumably in food and consumer products. “That means when you transform this into public-health advice it is quite difficult,” Weihe told me. “In communication before, we really emphasized what you can do.” Indeed, when women stopped eating pilot whale, it took about three months to clear the related mercury from their bodies. But expelling PFAS can take anywhere from several days to 70 years — and that presumes you can figure out how to avoid taking in more.

Credit...Grant Cornett for The New York Times

The sheer range of health problems that have been linked to PFAS exposure makes it hard to picture how a single type of contaminant could contribute to all of them. If you list the dizzying number of ways you might interact with the chemicals and draw a line from each of them to a list of potential outcomes, you end up with a mess of scribbles and the conclusion that everything causes everything.

Describing how PFAS act on our biology becomes even more convoluted when you factor in how many variations there are. Scientists have a decent understanding of how some of the earliest formulations, like PFOS and PFOA, behave on a cellular level. But health data on newer formulations is extremely limited. It's safe to say that once we eat, drink, breathe or absorb PFAS molecules, some readily bind to one of our major blood proteins. (Stanford University researchers reported this property in 1956.) As blood circulates throughout the body, it delivers PFAS to our organs and other tissues. Some PFAS molecules resemble the fatty acids we burn for fuel and use as cellular building blocks, says Carla Ng, an associate professor of civil and environmental engineering at the University of Pittsburgh. Our cells thus recognize them as beneficial and bring them inside their outer membrane as they do other resources. "The things that PFAS look like," she says, "are the things our body is used to dealing with as food and parts of ourself."

Some PFAS appear to travel with other fatty acids to the liver, where they can accumulate in its cells and proteins. (Tests of cadavers have shown that newer formulations of the chemicals may congregate in other tissues, including the brain, but the data on them is limited.) A 2022 review by researchers at the Keck School of Medicine at the University of Southern California, along with colleagues elsewhere, found "consistent evidence" from rodent experiments and epidemiological studies that PFAS increase the risk of liver impairment, including nonalcoholic fatty liver disease. This result is particularly worrisome, because rates of the condition have soared in recent decades.

Once inside cells, PFAS have been shown to increase oxidative stress, creating structural damage that has been associated with a wide range of conditions, including cancer, diabetes and cardiovascular disease. They also can penetrate the nucleus of the cell, where our DNA resides. Perhaps most problematically, they are known to bind with at least 14 receptors. (The dioxin in Agent Orange, by comparison, binds with only one.) Those actions influence how cells express or suppress genes that, in turn, govern how cells perform fundamental functions like producing energy and storing fat. When cells aren't working properly, they cause glitches in the organs they make up. Those impairments can unfold in various ways, depending on which receptors PFAS target, where the cells are (say, the liver or the brain) and when they encounter the chemicals — in utero, for instance, or during adulthood. As a result of the activation or deactivation of a particular receptor in a particular tissue, however, there could be numerous intermediate cellular interactions unspooling over decades, Sue Fenton, a reproductive endocrinologist at the

N.I.E.H.S., told me. Rarely does any disease have a singular cause. Yet while it's impossible to say that PFAS alone caused any one person's illness, it is possible to estimate the burden that those chemicals, like other toxins, put on people's bodies.

'They are all problematic. When they're tested, they all do the same stuff.'

The liver appears to be disproportionately impacted by PFAS, where they likely act on its cells in multiple ways. The organ produces cholesterol and has a critical role in detoxifying blood and balancing blood sugar. It helps regulate our metabolic and immune systems, as well as our estrogen and testosterone levels. That's one theory as to why testicular cancer has been associated with PFAS exposure, demonstrated in a case study of U.S. Air Force servicemen published in July. (Bisphenol A, or BPA, a chemical found in plastics that can mimic estrogen, also binds to nuclear receptors, but to fewer of them; it does not persist in the body or the environment.)

Grandjean and Weihe suspect that PFAS may also throw off the endocrine system, which is driven by the hypothalamus region of the brain and encompasses hormone-producing organs throughout the body. Specifically, they wonder if PFAS are "obesogens," chemicals thought to disrupt the system's metabolism, potentially affecting the body's ability to maintain a stable energy balance. To test this hypothesis, they plan to ask the teenagers in their study to undergo scans to measure their bone density, muscle mass and fat tissue now that they're entering puberty. "Obesity is an epidemic," Grandjean told me. "And we can't explain it by lack of physical activity or changing habits."

Body composition can be easily measured, and abnormalities in or changes to it can hint at problems that are harder to see. In March, a 20-year study by researchers who are part of the N.I.H.'s Environmental Influences on Child Health (ECHO) consortium found that increased prenatal exposure to PFAS was associated with lower birth weight, a conclusion supported by rodent studies. That could be significant, as low birth weight (less than 5.5 pounds) is strongly linked in turn to infant mortality, developmental issues and chronic conditions later in life, like heart disease, cancer and diabetes. Cells are particularly vulnerable during development. In utero and in infancy, they

divide more rapidly than they can repair themselves when damaged; the insult persists like a crack in the foundation of a building — a hidden weakness that, in certain situations, might prove catastrophic. Fenton says this phenomenon may explain why the offspring of mice exposed to PFAS are more likely to develop metabolic problems and liver damage in adulthood. “Something programs them for a lifetime of disease,” she told me. “It’s something that may take years to see. We don’t have it completely figured out yet.”

Of all the organs and systems PFAS can affect, the most complicated to assess is the brain. Neurological outcomes are tricky to define and test for in people — or to observe in animal proxies — and countless variables may play a role. “Are PFAS the cause of ADHD? Do they increase the risk of autism? There is plenty of evidence to say we should be concerned,” Alan Ducatman, a clinician and professor emeritus at the West Virginia University School of Public Health, told me. “There’s not enough evidence to say we know,” he added. “But we really do need to know.”

A major obstacle to gleaning that information, however, is the fact that there are thousands of varieties of PFAS. So far, human health data exists for a tiny fraction of them. Leaders in the industries still using the chemicals argue that each PFAS formulation should be considered separately — a health outcome linked to one type doesn’t necessarily apply to another. “All PFAS are not the same, and they should not all be regulated the same way,” the American Chemistry Council, a lobbying organization, wrote in March, responding to an E.P.A. draft proposal to limit six kinds of PFAS in drinking water. To consider them individually would be virtually impossible — which might well be the point.

In 2020, Linda Birnbaum and 15 other researchers published their scientific rationale for the regulatory management of PFAS as a chemical class in the journal Environmental Science and Technology Letters. “They are *all* problematic,” she says. “When they’re tested, they all do the same stuff.” Scott Belcher, an associate professor of biological sciences at North Carolina State University’s Center for Environmental and Health Effects of PFAS, concurs: “I have not seen a PFAS tested for toxicity that’s not toxic.”

At this point, you may be wondering how much PFAS is inside of you. A lab can tell you how much (of some types) is in your blood — if you can afford to pay hundreds of dollars out of pocket to be tested. But there is not much you can do with the results. In 2019, the Agency for Toxic Substances and Disease

Registry, a branch of the C.D.C., published "an overview of the science and guidance for clinicians" on its website. The 21-page document, however, offers scant actionable advice. "For asymptomatic individuals exposed to PFAS," it says, "insufficient evidence exists at this time to support deviations from established standards of medical care." The agency recommends that physicians respond to patient queries using language like this: "It is possible that PFAS contributed to your health problems, but there is no way to know if PFAS exposure has caused your illness or made it worse." For communities with contaminated water or other significant exposures, PFAS-REACH (Research, Education and Action for Community Health) has published more specific guidance that aims to "inform patient and clinician decision making" on its website.

There are, in fact, a few ways to remove PFAS from the body, though none of them are medically approved for that purpose. Donating blood or plasma is one way. (This passes the chemicals on to someone else.) Women also tend to have lower PFAS levels than men do because they eliminate PFAS during menstruation, childbirth and nursing. Dialysis removes certain PFAS, and at least one cholesterol-lowering medication appears to do so as well.

The state of the science of PFAS has thus left physicians with concrete reasons for concern but incomplete information about how to identify patients who may be most at risk or how to help them. The most urgent questions now, says Tracey Woodruff, an author of the ECHO birth-weight study who directs the program for reproductive health and the environment at the University of California, San Francisco, are: "How do we quantify health harms? And what's the extent of these exposures that we should be addressing?"

Defining those parameters is especially tricky when it comes to immune function. Though the Faroe Islands studies showed that PFAS exposure reduced antibody production, they couldn't prove that fewer antibodies led to more cases of tetanus or diphtheria — perhaps those children's immune systems still worked just fine. In 2020, many researchers raised concerns that significant exposure to PFAS might make people more susceptible to the coronavirus and, later, less protected by vaccination. By year's end, Grandjean, who is also a research professor at the University of Rhode Island (the Faroe Islands study is part of its Sources, Transport, Exposure and Effects of PFAS program), was co-author of a paper in PLoS One that linked exposure to a PFAS called PFBA with more severe Covid-19.

Obstetricians are among the doctors most in need of solutions, because PFAS cross the placenta and are excreted in breast milk. Babies are so much smaller than grown-ups that when they ingest the milk, their PFAS levels become several times that of their mother — probably the highest they will be in their lifetime. Suppose a woman discovers that she has been heavily exposed to the chemicals: Are there steps she can take to reduce the amount she passes on to her newborn? Or to strengthen her child's resilience against PFAS-related harm? (Breastfeeding enhances immune function.) And what about young adults born before PFOS production ended in 2002, when average levels of the chemical were six times what they are now — should they be monitoring certain aspects of their health more closely?

"When I talk to families, I try to be real," Elizabeth Friedman, a pediatrician and the medical director of environmental health at Children's Mercy Kansas City, in Missouri, told me. "Are there risks associated with PFAS exposure? Yes, it looks like there are. If you breastfeed, will you expose your baby? Yes, you will. Do we know that that will cause harm? Will it be more or less beneficial if you feed them formula? What's in your tap water?" (If the drinking water is contaminated, formula mixed with it will be, too.) Science still has not come up with a cost-benefit analysis that she can use in these conversations with parents. "People don't get answers to their questions," says Friedman, who is also a regional director of a national network of pediatric environmental-health experts. "But they feel heard."

Among the groups most likely to be exposed to PFAS in their drinking water are those in low-income communities or who live near military or industrial sites. Subsistence fishing and hunting, which many rural and Indigenous people rely on, increases that risk. Until very recently, the responsibility for setting public drinking-water standards for PFAS has fallen to states, local governments and tribes. In March, the E.P.A. determined that two kinds of PFAS — PFOS and PFOA — are "likely to be carcinogenic to humans" and proposed a goal of removing them almost entirely from public drinking water. (The suggested regulations also set thresholds for four other PFAS.) The agency has stated that if approved later this year, the rule "will prevent thousands of deaths and reduce tens of thousands of serious PFAS-attributable illnesses." But complying with the standards will be expensive. In June, 3M and DuPont (along with its sibling companies Chermours and Corteva) agreed in federal court to pay a total of $10.3 billion and $1.19 billion, respectively, for testing and cleaning up public water supplies to U.S. cities and towns. (DuPont's legal circumstances have been complicated by corporate restructuring beginning in

2015: Its PFAS entities are now split among the three businesses, with Chermours having absorbed Teflon and other chemicals operations.) None of the companies has admitted liability. 3M has pledged to stop the production and use of all PFAS by 2025. But though reducing PFAS in tap water will reduce it in people, what exists already will simply move somewhere else — into toxic waste sites, the soil, the ocean.

The problem of PFAS pollution goes beyond drinking water: The Faroe Islands demonstrate as much. PFAS is entering the environment — plants, animals and people — through many routes. In the United States, chemical manufacturing is regulated by the E.P.A. through the Toxic Substances Control Act. Under the law, companies seeking approval for new chemicals test their own products and report the results, but failure to do so is punishable by relatively small fines. In February, the European Chemicals Agency released a proposal recommending a sweeping ban on the production and use of PFAS in the European Union, including imported products. Absent that sort of broad government regulation, however, people have few options but to try to avoid exposure to PFAS on their own.

One afternoon this spring, Grandjean, Weihe and I sat around the kitchen table in Weihe's clinic. He was heating up lemon sole for lunch that he had cooked the previous evening for a family gathering. Grandjean, who like Weihe is 73, was recounting a formative lesson he'd learned from one of his mentors, Irving Selikoff, a physician and researcher at Mount Sinai Hospital who died in 1992. In the 1950s, Selikoff was a founder of a medical practice in Paterson, N.J., and began treating workers from a nearby asbestos plant who, over time, developed startlingly high rates of lung cancer and mesothelioma. The studies he later conducted, and the attention he drew to prior research, helped lead to the regulation of asbestos. Grandjean recounted what he characterized as one of Selikoff's "famous dictums": "When you look at your tables, don't forget that the people behind them are real, though the tears have been wiped away."

He ran his hand across his cheek. "He had seen them," Grandjean went on. "He said to me, 'You may not have seen the victims, but don't forget.'"

It's a lesson that Grandjean has had much cause to consider since, and one, sadly, that will probably continue to resonate. The proposed E.P.A. regulations only cover six PFAS variations, and new formulations are entering the market all the time. "There are literally thousands of PFAS structures being used. We're discovering them every day in water," Scott Belcher, the North Carolina

State biologist, told me. “If we’re putting these chemicals out into the environment before we understand how they’re working, are we experimenting on humans? That’s kind of de facto what we’re doing.”

To mitigate the harms of PFAS, companies have begun making them so that the human body expels them much faster — within days as opposed to years. But that also makes them harder to detect. These variations still last indefinitely in the environment, and there is evidence that at least some of them may be just as harmful as their predecessors: Though people eliminate them more quickly, they may also be re-exposed more frequently, which many scientists fear will make the chemicals equally detrimental. And even brief exposures to toxins during development can have irreversible consequences. Either way, the rollout of new PFAS has many researchers and advocates anxious that we’ve missed an opportunity to examine and change the systems that allowed most people on Earth to consume substances that raise such serious health concerns.

“I really think even scientists who are not involved don’t fully appreciate that there is no chemical safety testing,” Belcher says. “There is this mythical ‘they,’ that ‘they’re’ taking care of this, and it must be safe because it’s out there. That’s a common misconception about how this works.”

Weihe wishes the Faroese were less sanguine about the chemicals’ having made it all the way to them. “I must say, I would like them to be more angry and more upset and more furious,” he told me. Perhaps as they, along with the rest of us, become data points on graphs that describe the harms that result from exposure, they will be. But studying if and how a ubiquitous substance causes chronic illness is by its nature a lifetime project: Those who take it on, and those whose suffering they document, are as likely as not to be gone before any final reckoning.

Prop Stylist: Noemi Bonazzi

Kim Tingley is a contributing writer for the magazine. She has written about circadian-clock genes, the mental-health crisis among American children and the challenge of developing “universal” vaccines.

https://www.nytimes.com/2023/08/16/magazine/pfas-toxic-chemicals.html