your horizons, a place that to me is full of wonder, and you are seeing our own garbage. You see laundry detergent bottles and bleach bottles, children's toys, toothbrushes, plastic buckets, storage containers, packing straps. All this stuff out there in the middle of the ocean, it just makes me sick. And I want everyone to feel that, too."

It turned out this part wasn't so hard. She has found that ocean trash is a unique environmental issue. It is that rare green cause that transcends politics and ideology—once people see and understand it. Garbage floating on the waves, it seems, has the power to unite. Ten thousand visitors showed up at the docks in the days after the *Kaisei*'s return, eager to tour the ship and see the array of trash and ghost nets that the crew put on display on the deck, to learn about the gyre and to hear how that distant place was full of all of our trash.

"I've never talked to anyone who has seen the pictures or the video we've brought back, or who came to the ship to learn what it's really like out there, who then says, 'I don't care.' That's why I'm hopeful."

6 NERDS VS. NURDLES

THE SCIENTISTS TRYING TO FIGURE OUT THE jabberwock-sized problem of the gyre garbage patches tend to be characters. Miriam Goldstein is no exception.

Goldstein came to the work at Scripps after a post-college break from academia that included stints as a construction worker, an environmental consultant, a naturalist at New Hampshire's Mount Washington and a salesperson at a biological curiosity shop in Soho called Evolution. Now she represents a new generation of ocean researchers eager to launch their scientific careers by uncovering the extent and consequences of marine plastic pollution.

Goldstein is, she says, part of a new army of nerds taking on the legions of nurdles. "There's a lot we don't know yet, and it will take years of study to really get a handle on the extent of the problem and its impact," she says. "But we don't need to know everything to know that we should stop putting trash in the ocean. We already know that should stop."

She tends to see the state of the sea as the ultimate in societal heedlessness—an unintended and untended lab experiment run wild, in which the world finds out just what happens when we dump fifty years' worth of plastic into the ocean. Now, Goldstein says, it's time to assess the damage and figure out where to go from here. As part of that effort, she has been on extended sea voyages four times in less than two years, gathering data for Project Kaisei, Scripps, NOAA (National Oceanic and Atmospheric Administration, the most fitting acronym in government) and her own dissertation on the impact of plastic micro-debris in the North Pacific. Her work is part of the ground-floor research finally being done systematically on ocean trash after a decade of being left to a few capable but extremely shorthanded mavericks and gadflies.

In an ocean culture dominated by old salts with tan and craggy faces, the fair and freckled Goldstein seems the unlikeliest of oceanic heroes, quite the opposite of veteran sailor Mary Crowley, who thinks storm-swollen seas are a fun sort of challenge. The young scientist, by contrast, describes herself at sea as an "accomplished barfer." To her credit (or, according to her family, as evidence of her insanity), she charted her professional course despite knowing her landlubber tendencies, revealed during her very first sea voyage. This was a half-day whale-watching excursion off the coast of her native New Hampshire, which she organized at age ten, dragging her reluctant sister, brother and parents along as she pursued her passion.

"Let me just say, we're not really a very outdoorsy family," she recalls with a laugh. "The entire family spent the entire time barfing over the rail. We have pictures of the four of us lined up."

For her doctoral studies at the University of California, San Diego's Scripps Institution, she prudently planned to focus on coastal pollution, which would have safely limited her sea excursions to knee-deep wading into tide pools. That changed in 2008, however, when she started reading about the gyres, the garbage patch and ocean plastic—and how little we really knew about it. She proposed that the University of California Ship Fund devote some of its grant money and research vessel time to studying the matter, which the institute honchos soon agreed was a good idea, leading to the August 2009 SEAPLEX voyage (Scripps Environmental Accumulation of Plastic Expedition) to the garbage patch. The only caveat: Goldstein, queen of the tide pool explorers, had to take charge as chief scientist and see her idea through, an intimidating but unrefusable opportunity that knocked the twenty-five-year-old ocean scientist out of her wading boots for good. Initially planned for two weeks, the voyage was expanded to three when Project Kaisei offered to provide a second ship and more financing for an in-depth look at deep-sea ocean plastic.

The journey shattered Goldstein's expectations and ended up shocking her whole team despite weeks of burrowing through piles of reports, papers and news clippings she thought would prepare her for what lay ahead. She and her colleagues had spent long hours planning the trip, obsessing on how they were going to find the trash, and what they would do if they started roaming around this vast ocean desert without finding anything. It's a big ocean out there, they kept reminding one another. You can go out looking for something and the weeks can fly by—and then you come up empty. That was Goldstein's fear as the 170-foot *New Horizon* left port in San Diego. She knew marine biologists who went to sea time after time looking for certain organisms or feeding patterns or weather phenomena, and they just never found them. This was the oceanic equivalent of one of those space launches in which the parachute doesn't open or the radio goes dead or the probe drifts off into space without ever establishing contact with mission control. Things are spread out at sea, and the ocean seems to delight in frustrating scientists and crushing their attempts to uncover its mysteries.

So Goldstein and her colleagues were taken by surprise when it turned out to be all too easy to find the garbage at sea. As it happened, they simply set course for the gyre and the trash found them. They had been conditioned by press reports and the very name—Pacific Garbage *Patch*—to expect an actual patch, a visible aggregation of garbage, which news story after news story described as a kind of floating island of debris twice the size of Texas. But they did not find a bunch of trash in one place. What they found were high concentrations of small plastic bits spread across the entire 1,200 miles of ocean they traversed and trawled, finding plastic in every net. Jellyfish and sea slugs would come up in the net, swimming amid the plastic. Inside the jellies, plastic could be seen through their transparent bodies. It was far worse than they had imagined, not an island, but that damn plastic chowder. And it was everywhere.

"After days of endless plastic," Goldstein recalls, "we were all getting really depressed." But the prevalence of plastic had a silver

lining. Finding it meant they had a good shot at understanding it. Three grueling, thrilling weeks followed of water sampling, manta tows (a special net shaped roughly like a manta ray deployed on the side of the ship), microscope work, plankton preserving (rotting plankton, Goldstein says, is not a smell you want to experience if at all possible) and captures of plastic debris small and large.

Goldstein's primary interest is how the unusual critters that live in the gyre, most of them small and many of them microscopic, interact with the debris and plastic in their midst. Do they peacefully coexist? Is it poisoning them? Do these added surfaces to cling to and lay eggs on—in an area of the sea where there is no land for a thousand miles—give a leg up to some creatures in the ecosystem at the expense of others? And what happens if those tiny crabs, barnacles and other opportunistic hitchhikers cling to a hunk of plastic and get swept by the gyre to a place where they don't belong? Nature's fragile balance, its chains of prey, predator and symbiont, could be altered by the plastic taxi service. Preliminary evidence from the expedition, Goldstein says, suggests this is exactly what's happening, though the degree of benefit and/or harm to various species will take years of study to work out.

Goldstein has an answer for those who might shrug and wonder if such questions really matter in the grand scheme of things. In a word: yes. And here's why: Half the oxygen we breathe emanates from microscopic phytoplankton sloshing around the surface of the ocean. After literally billions of years of performing that essential, priceless service, those vital organisms now must swim and feed and survive in a sea of plastic soup. Figuring out what's up with those organisms is, Goldstein suggests, a pretty vital matter. If we are inadvertently killing them off, the result could be far less visible, but even more devastating, than deforestation.

The other big questions that the SEAPLEX/Project Kaisei expedition sought to explore were equally compelling:

Now that we know that one in ten lantern fish has ingested plastic, what is this new part of the fishy food pyramid doing to these vital creatures that the rest of the food chain depends on? Many plastics can leach potentially toxic chemicals over time, particularly as the plastic begins to break down from the action of weather, wind and wave. Is that happening, and with what effect?

Are plastic particles acting as collectors of toxic chemicals, transporting and concentrating what is known as POPs—Persistent Organic Pollutants? This is the opposite of the leaching problem—plastics not giving off toxins, but acting as magnets for even worse chemicals. Pesticides, chemical fertilizers, half-combusted fuel, solvents and other man-made pollutants roll and rain into the oceans every day by accident and by design, and many of these chemicals are hydrophobic. That is, they hate water, won't dissolve in it and just wait for something better to come along that they can stick to. Weathered, cracked, sea-scoured bits of plastic become sponges for these POPs, and this is not a good thing. Yes, the plastic can take the chemicals from the water, but then little fish eat that plastic, and a chain reaction called bio-magnification begins.

This is the scenario the researchers are trying to gauge to see if it threatens marine ecosystems and human food safety: Let's say the little fish eats ten tiny pieces of POPs-infused plastic. Then a bigger fish comes along and eats ten of those tiny fish. Now we have a fish that has imbibed the equivalent of one hundred contaminated pieces of plastic. Then a bigger fish eats a bunch of those, and so on up the food chain, with the chemicals becoming progressively more concentrated in the larger sea creatures. This is bio-magnification. At some point, some of those larger creatures end up in the seafood

case or the canned goods aisle at your local supermarket. We simply don't know what that means, but if Goldstein's team has its way, we will know in a few years.

"We just might not like what we learn," she says.

Even the most basic questions about the trash-ocean interface still await answers. The Scripps researchers are trying to accurately estimate the true size and concentration of the debris in the Pacific Garbage Patch and, more to the point, whether or not it is growing over time. The data is mixed on this: Observations in the Pacific by other researchers suggest the plastic has increased since the 1990s, even doubling in some areas of the patch. On the other hand, the largest collection of data from water samples in the North Atlantic gyre—twenty-two years' worth made by students on training voyages with the Sea Education Association—show that the plastic concentrations have held steady there, against all expectations. Researchers had assumed that, since plastic production has more than tripled in the past twenty-two years, there should be more plastic in the ocean, rather than the steady state it seems to have achieved (in the Atlantic, at least). Is there some mechanism removing the plastic—unknown currents, chemical reactions, plastic-eating microorganisms? Or is there really more plastic there despite the data, uncounted because it has broken down into such small particles that it remains undetected?

To help answer this, the Scripps researchers are doing two things: supplementing their manta tows with data from bucket samples from the gyre, and trying to figure out how plastic at sea ages. This latter problem is tougher than it sounds. Unlike archaeologists, who can carbon-date artifacts, or paleontologists, who can infer the age of a dinosaur bone from the geologic strata in which it was buried, the ocean plastics investigator has no way of telling the lineage of a 5-millimeter bit of plastic. The stuff has no chemical signature, no provenance, no forensic trail. It could be a year old, five years old, fifty years old—you just can't tell. In a landfill, you might infer the age of a piece of plastic from the junk it's buried with, the same as a geologist (*Oh, that hunk of blue polystyrene is sitting on top of a June 1973 edition of* Life *magazine—could be a clue!*). Ocean-borne plastic bits offer no such context. So Goldstein has pools of seawater filled with plastic baking in the sun and cooling at night on her lab roof back in San Diego, trying to come up with an age gauge for marine plastic debris. She'd like to run this experiment for two years or so; her professors told a stricken Goldstein they think it would be better to keep it going for two decades. Like landfills, she says, ocean plastic research is forever.

Everything about ocean trash is not a question, however. Here's what we do know: The United Nations estimates that a minimum of 7 million tons of trash ends up in the ocean each year, 5.6 million tons of which (80 percent) is plastic. The Sea Education Association data from the North Atlantic Gyre suggests that plastic concentrations in the ocean waters of the major gyres can easily reach 130,000 or more pieces per square mile of ocean surface; one survey of the Pacific Garbage Patch zone found concentrations nearly three times that level. The 5 Gyres research group, meanwhile, estimates that the total plastic content of the gyres exceeds (probably by a lot) 157 million tons, equal to 63 percent of all plastic made in the world in 2011. The group considers that estimate to be extremely conservative.

Even so, that's a big bag of plastic. It would take 630 oil supertankers to carry that much plastic. By contrast, the British Petroleum Gulf of Mexico oil spill in 2010, the largest maritime environmental disaster in history, released an estimated two-thirds of a million

tons of crude oil. That whole oil spill could fit on two and a half supertankers.

To be clear, all of these ocean plastic numbers are at best educated guesses so far, based on slices of data collected from small sections of the biggest geographic feature humans will ever experience. There is a great deal of mystery left in that most ancient of things, the ocean, its newest resident, plastic, and how the two combine. A lot of the numbers and "facts" repeated in news coverage—claims that a hundred thousand marine mammals are killed each year from ocean plastic, that 80 percent of the trash at sea is from land sources rather than ships, that there is an actual garbage island looming somewhere in the Pacific—have no known sources with any credibility. The myth-making is a distraction, Goldstein worries, because the made-up information could erode the credibility of real science, and also probably understates the true problem. The research needed to firm up the data and answer the big questions is just barely getting under way.

As is often the case with environmental matters, more data often makes things look worse, not better. What we know so far makes clear that the matter of ocean trash goes way beyond what initially upsets most people: its aesthetics. It is yet another stress on a vital ecosystem that is already overtaxed by overfishing, acidification and climate change.

But plastics are a very different matter from global warming, about which politicians, if not many scientists, can find room to debate whether or not it exists and if it does, whether or not humans are causing it. As Goldstein points out, there's really nothing to debate about who and what is turning the oceans into plastic soup, as plastic is a completely man-made substance. It doesn't come from trees, volcanoes, space or bugs. It's all ours, and it enters the oceans through only one of three ways: accident, negligence or deliberate dumping.

"It's ours," Goldstein says. "We made it. We own it."

A HUNDRED years ago, not a shred of plastic could be found in the ocean because there was no plastic at all. It is hard to believe that the invention of the most ubiquitous substance in the human environment was preceded by radio, movies, recorded music, the airplane, the telephone, neon lights, air-conditioning, the lie detector, the electric vacuum cleaner, windshield wipers, color photography, the helicopter, the escalator, sonar, Kellogg's Corn Flakes and the theory of relativity. All were invented and put before consumers without need or benefit of plastic. All (except for relativity) are today unimaginable without plastic, from the helicopter's transparent cockpit bubble to movie DVD discs to the hose and power cord on the vacuum cleaner.

Plastic has gone so fast from zero to omnipresent that it's slipped beneath conscious perception. Take a moment and scan the room you're sitting in. Everything from pill bottles to DVD cases to the knobs on kitchen cupboards to the buttons on your pants to the elastic in your socks to the foam inside your seat cushion to the bowl you put your dog's dinner in to the composite fillings in your teeth—you get the picture—is plastic. It's everywhere.

Now take a walk on any public beach anywhere in the world and take a good, close look at the sand, at the broken bits of shells gleaming in the sunlight. Notice a flash of teal, a tinge of dark green, a bit of red or orange or yellow? Pick up the tiny sliver of color and see: Most are not pretty shell fragments, dried sea foam, eggshells or any other natural objects, though the sand and salt so readily camouflage them as such. They are bits of plastic, pieces of bottle

tops and cups, remnants of wrappers and foam cups. There is virtually no beach in the world where the sand is devoid of these synthetic particles, though the average beach walker rarely notices. You have to really look closely for them. But when you do, the depressing realization strikes: Once again, as with plastic in the home, they are *everywhere*.

There is a special irony in plastic assuming the role of threat to nature. Plastic conquered the world because, early on, the chemical and manufacturing industries championed it as the miracle substance that would free humanity from the tyranny of nature. Piano keys and billiard balls no longer had to be made from the ivory of slaughtered elephants. Increasingly scarce metals mined across the globe could be replaced by infinitely sculptable plastics that could be produced in any half-decent laboratory in the country. Ladies' stockings could be extruded from nylon-spewing nozzles instead of silk-spinning caterpillars. All we needed were fossil fuels and imagination. Plastic was freedom.

The age of plastic (and the modern derivation of the word from the ancient Greek *plastikos*, which means "moldable") started with a Belgian-born American chemist, Leo Baekeland. He set up his own research lab with the million dollars paid him by George Eastman, the father of popular photography and founder of Kodak, after Baekeland invented a better type of photo paper. In 1905, the chemist used his Kodak earnings to finance experiments with a synthetic form of shellac (a natural finish made from excretions of the female lac bug found in India and Thailand). Instead, he stumbled on a polymer made with coal tar and formaldehyde and a number of inert ingredients (cornstarch among them) that could be shaped in infinite ways, that dried hard and strong, and once set, proved highly heat resistant—it wouldn't melt or lose its shape. He dubbed his invention Bakelite, and it became the first completely synthetic industrial and consumer plastic. It also is, to this day, the coolest plastic, rich, lustrous, solid and substantial in a way other plastics are not. The relatively heavy, durable, glossy Bakelite plastics were used in early twentieth-century telephones and radio cabinets—stylish retro items that are highly collectible today—as well as a host of more mundane items, from electrical insulators to chess pieces to cabinet knobs and Kodak cameras. Because of his invention's versatility, Baekeland chose for his company's emblem the letter "B" with the mathematical sign for infinity above it, which he had embossed on all genuine Bakelite products.

The success of Bakelite and the infinite possibilities it hinted at sparked a surge of experimentation and invention among the big chemical companies in the 1920s, 1930s and 1940s as they vied to patent the next "miracle material." In rapid succession, polyvinyl chloride (PVC, currently used in everything from plumbing to computer cases), Styrofoam, synthetic rubber and plastic wrap made their debuts in a variety of products, most of them commercial rather than aimed at consumers. A big exception to this marketing rule was nylon, the first synthetic plastic fiber, which was introduced to the public by the DuPont Company at an unintentionally appropriate location, the former massive landfill that became the site of the 1939 New York World's Fair. Initially developed as the ideal toothbrush bristle, it was the formulation of nylon into synthetic silk that created a World's Fair sensation—stockings with no seams. More than 64 million pairs sold in their first year on the market.

As it did with other industries, World War II mobilization ramped up the plastics business tremendously. The First World War knew only wood, metal, wool, cotton and leather. A quarter century later, everything from combat helmet liners to parachutes, gun sights to

cockpit windscreens was made from plastic, a quick and ready stand-in for scarce raw materials. The first iteration of Dow Chemical's Saran Wrap—which was a transparent green film with a putrid chemical smell—was used to wrap not sandwiches, but whole planes and artillery pieces to protect them from water and sea salt during transoceanic voyages.

When the war was over, plastic manufacturers had considerable excess capacity—and so new generations of products made of plastic were conceived, made and marketed whether they represented improvements over old materials or not. The disposable cups, spoons, forks, knives and plates that followed—an entire disposable economy—were born out of a kind of industrial hangover from the war effort, combined with cheap oil (the essential ingredient in many plastics) and America's then-ironclad control of the global oil supply. Now, though, plastic was pitched not as a substitute for the "real" thing, but as an improvement, a convenience, a freedom. Dow figured out how to make Saran Wrap clear and with no smell, and suddenly everything was being hermetically sealed. Plastic chairs, tables, counters, curtains and Tupperware invaded the American home (and, a short time later, the American landfill), supplanting wood, cloth, tile, metal and glass.

In the 1960s, plastic surpassed aluminum in volume as a raw material, and in the 1970s, it surpassed steel. It has continued to grow, reaching 51.5 million tons of plastic manufactured in 2010. That one year's worth of plastic outweighs the entire U.S. Navy's 286 active ships (which itself is so huge that the U.S. fleet represents more tonnage than the next thirteen largest navies of the world *combined*). Indeed, a year's worth of plastics would outweigh a navy of more than five hundred Nimitz-class aircraft carriers, the largest ship ever built, each one capable of carrying ninety aircraft plus more than five thousand crew and troops. Of course, there are only ten of these huge ships in existence. Plastic, when you hold it in your hand, seems so light as to be inconsequential, yet collectively it is that unimaginably huge.

This deceptive, alluring quality, plastic's horrifying convenience, helps explain why, for more than a half century, this miracle material, this great innovation that set us free, was only half baked, for no one thought through its life cycle, its afterlife. It takes 8 grams of oil to make a single plastic ketchup bottle, which will not be recycled because the ketchup residue inside is "contamination" and recyclers want clean plastic. Dirty plastic is just too hard to recycle, too costly. Failing at the birth of the age of plastic to think this through, to consider the life cycle of substances that do not occur in nature and that are, for all intents and purposes, immortal, is like failing to think through what to do with nuclear waste at the birth of nuclear power . . . which is exactly what we did.

Every year, a significant portion of this manufactured plastic remains unaccounted for. The American Chemistry Council reports that 34 percent of the annual plastic production, 17.5 million tons of it, is used for packaging—plastics that get thrown away very quickly. The EPA, meanwhile, has tracked 13 million tons of plastic packaging as waste, which means more than 4 million tons a year (the equivalent of forty of those super aircraft carriers) remain unaccounted for. Many ocean pollution researchers believe a substantial portion of this "ghost plastic"—these forty missing aircraft carriers we somehow misplace every year—finds its way into the ocean.

Which is how an oceanic garbage patch is born.

The most common types of plastic found there—primarily at the surface but also found as deep as one hundred meters—are polyethylene (used in a host of products, including plastic grocery bags), expanded styrene (Styrofoam), polypropylene (rope, nets, carpet, prescription bottles) and PET (notwithstanding its propensity to sink once broken up).

Whatever the type, pretty much every piece of plastic that ever entered the clutches of a gyre is still in there, ocean scientists say, except for what washes up on the beaches of Hawaii, which lie within the gyre's convergence zone and are inundated daily with plastic debris. They're still trying to come up with a number to describe the measurable and identifiable quantity of plastic in the garbage patches. Not supposition, not guesses, not extrapolations, but a real number.

So far, the scientific term most often used to describe how much debris is out there is: a lot. Some scientists, such as Miriam Goldstein, prefer a slightly more exact term:

"A *whole* lot."

So HERE's the big question, the one that eats at Mary Crowley and Miriam Goldstein and the crews who wander and plumb the five gyres: What sort of economy, what sort of society, could lose track of a fleet of forty aircraft super carriers of plastic year after year, without blink or blame?

And what, besides building oceans of plastic and mountains of garbage, can be done about it?