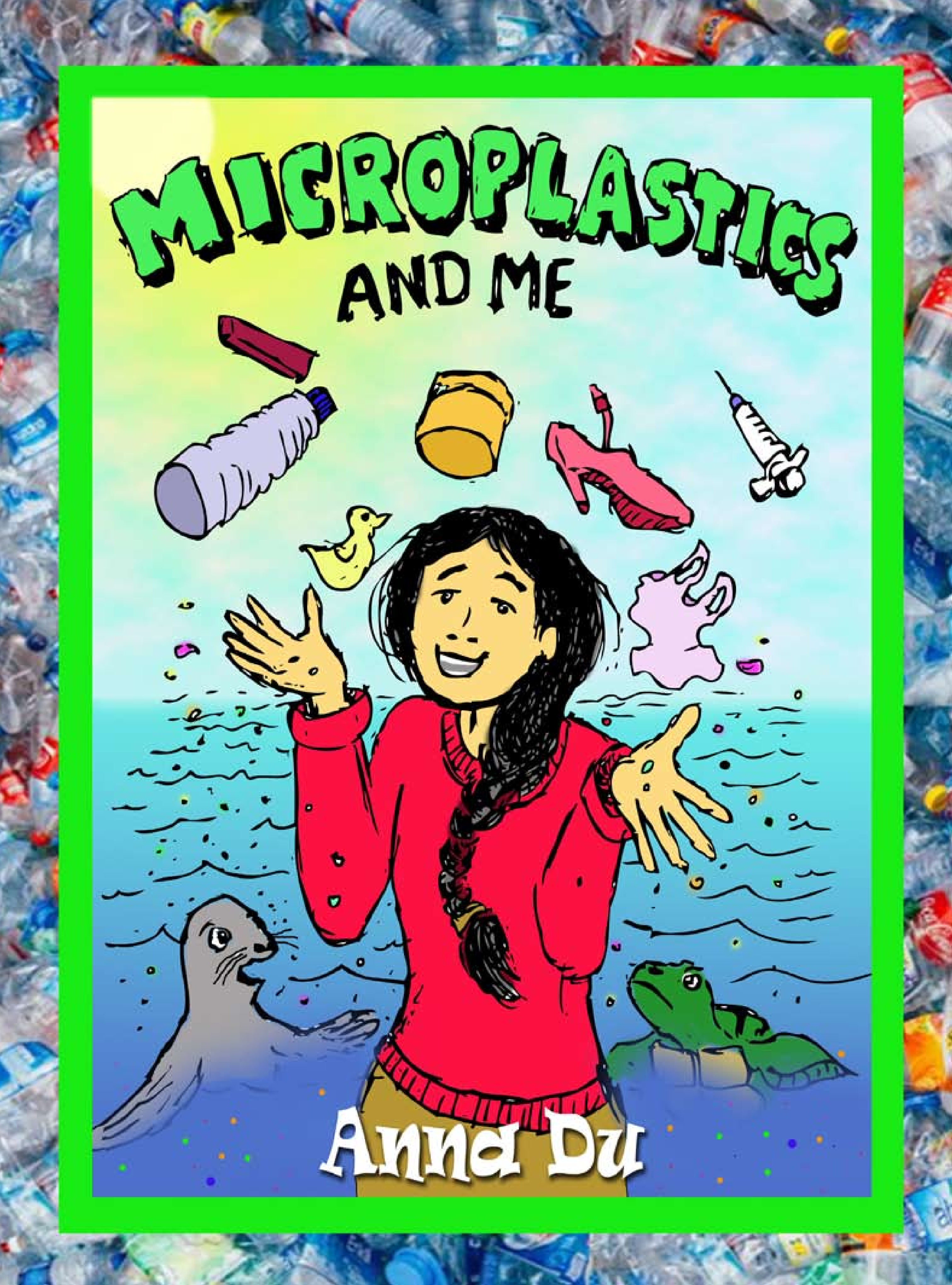
MICROPLASTICS
AND ME
Anna Du

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MICROPLASTICS AND ME

ANNA DU

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CONTENT

Chapter 1
The Blue Piece of Plastic That Caught My Eye...

As I turned around, something flashed in the sunlight. It looked like a glimmering piece of a jewel. I took a step closer, my bare feet digging into the warm sand, and I knelt down. Satisfaction filled me, as I picked up the best piece of sea glass that I had seen at the beach yet. Though it was smooth to the touch, you could tell it once would once have been sharp enough to cut. It was the perfect size, the perfect shape, and the perfect color to make a necklace. It wasn't a dull shade of brown, or a sickly shade of green. Rather, it was a soft, light blue, which wasn't a color often found on this beach. Instead of putting it with the other, normal pieces of sea glass, I put it in a much smaller pile, with exceptionally beautiful pieces of sea glass. Then, I turned away, looking for more pieces.

This is what I love about living in New England – it's just not possible to beat the sea glass there. As a self-confessed obsessive "maker," I've always considered jewelry making to be among my favorite hobbies. Pieces of sea glass are among the best centerpieces for jewelry. They make great gifts for my friends and are also environmentally conscious.

Right next to the ocean, I saw another piece of sea glass, and reached forward, ready to pick it up. However, before I could, I saw, out of the corner of my eye, someone trying to signal to me. Confused, I forgot about the sea glass, and turned around. It was my mom. I tried to ask her what she was trying to say.

"Watch out—" She didn't get to finish her sentence before a large wave crashed onto my back.

My mom shook her head as I shivered, with the cool water soaking through my clothes, saying, "I did warn you."

Once I came to my senses, I ran to the towel, near the tent my dad had set up. Shivering, I walked up to where my mom was sitting.

For a while, I just looked around, appreciating the view. This was just like any other lazy Sunday at the beach. Every week, I came here to pick up sea glass and just relax for a few hours. The sea gulls chirped, the waves lapped slowly on the sand, and the warm sea breeze drifted around. I loved how doing absolutely nothing allowed my thoughts to drift, and calmed me down, as I slowly dried off.

Looking around, I set my eyes on my dog and loyal companion, Andy, lying beside me. I've always seen him as a part of my family. In fact, Andy, or An-di in Chinese, means Anna's little brother. I absentmindedly rubbed his ears for a while, before noticing something next to his head, slightly covered in sand. It looked like another piece of sea glass. However, as I picked it up and brushed the sand off, it started to feel... wrong. The color didn't look the way I expected a piece of sea glass to look like—it was too sharp, too bright, and too artificial. It didn't reflect the sun in a way that was characteristic of glass. It also wasn't even on the spectrum on the thickness of sea glass. It was way too thin. Also, it didn't have the weight I expected for a piece of glass that big. It didn't feel like sea glass at all. Instead, it felt like a piece of plastic.

I scoffed and tossed it aside. For a while, I marched on, and continued my mission. However, I kept thinking back to that piece of plastic that I'd tossed aside, and I felt bad. After all, I reasoned with myself, some other sea glass enthusiast in the future might also be fooled by this piece of plastic, and it would be mean for me to just leave it behind. I picked it up and threw it out in the nearest public beach trash barrel. In a weird sort of way, I felt angry at that piece of plastic for making me go through all that effort for nothing. Even when I went back, something felt strange. I realized that instead of seeing nature all around me, from rocks to shells to sea glass, I could suddenly only focus on pieces of plastic.

Walking briskly along the shore with my dog at my side, I picked up piece after piece of what looked like sea glass but was actually a chunk of plastic. Even back at my pile of sea glass, I realized that some of the materials that I'd thought were sea glass... suddenly didn't look a lot like sea glass. Instead, they looked like even more pieces of plastic.

I remembered a video on plastics that my school had shown us weeks before. The video displayed the life cycle of a piece of plastic – from its start in a factory, to its end, either in a garbage can, or in the ocean. We learned that the amount of plastics that have accumulated in the ocean is so great that there is a plastic island called the Great Pacific Garbage Patch, which is larger than Texas. When I watched the school video about this problem, it had seemed so far away. After all, the Pacific Ocean was thousands of miles away. But now, all of a sudden, I could truly see how plastic waste affected me personally.

I wondered why I had never noticed plastics before. Before, if someone had asked me whether there were any pieces of plastics, any pollution on the beach, I would've said no. There was no way. However, now, I was starting to see how wrong that statement was. Perhaps, in my years going to the beach, I had been looking at the world through rose tinted glasses, never acknowledging the plastics that were there. But how could a place which I once thought was full of waves and rocks and sand and exquisite pieces of sea glass so quickly transform into a hulking, ugly heap of pollution in my mind? Where did these plastics come from? Was this how the world truly was? Was it really completely and utterly covered in... plastics?

CHAPTER 2

PLASTICS, PLASTICS EVERWHERE AND NOT A DROP YOU SHOULD DRINK

When I got home that day, I looked around my house, trying to find out how much of the materials that we use daily were made out of plastics. Things that I never thought about, that I only passed without a second glance, stood out to me, such as the plastic water bottles we used almost daily, the plastic bags just lying there, the pens that were tossed away without a second thought. I realized just how versatile plastics were. Most of the plastic objects I noticed, I realized I would throw it out after a very short period of time. Later, after searching plastic facts on the internet, I learned that the average work-life, or the amount of time a plastic item is used, is only around 12 minutes.

Plastics have had a long history, since the early 20th century. Manufacturers favor use plastics, because these materials are easy to manipulate. A manufacturer can easily change their chemical composition to emphasize different characteristics – some can be more flexible, others stiffer, some lighter, others heavier, some more brittle, others more durable. This is because plastics are long-chain synthetic polymers.

When I saw that online, I remembered what I learned about last semester, when my teacher was telling us an easier way to remember what the word 'polymer' meant.

"In order to know what polymer means, you need to break the word down. The first part, 'poly', means many. The whole word means many 'mers', or monomers, or molecules. That is how you know polymers are created out of monomers," my teacher said.

After that, we had an interesting class discussion where we were trying to find different types of long-chain polymers. It turns out, both starch and DNA, which stands for deoxyribonucleic acid, are polymers. Starch is created from long chains of glucose monomers, while DNA is made from nucleotides that transfer information from one generation to the next. Natural polymers are so similar to synthetic polymers, in terms of their elemental chemical makeup, that at first it's difficult to tell the difference between them. There is one main difference: although these particles are extremely similar to organic polymers, they don't degrade as easily. It's estimated that it takes over five hundred years for a piece of plastic to degrade fully in nature.

Starting from the early 20th century, plastics have been used to make everyday materials. The number of plastics being used and thrown out has increased so much that in the last 20 years, the amount of plastics produced is equal to the rest made in history. Though surprising at first, this statistic does sort of make sense, if you take a look at the amount of plastics used in our daily lives, from airplanes, to a lot of modern medical equipment, from glasses to plastic bags, and even Andy's Frisbee! It seems like nobody can live without plastics in the modern world.

A lot of those plastics end up in the ocean. In the year 2017 alone, 8 million metric tons of plastics were dumped into the sea. It's estimated that by the year 2050, all of the plastics in the ocean, combined, could weigh more than the sea life. Though this number seemed sort of abstract to me—after all, just how heavy is 8 million metric tons? — it did scare me.

However, what I discovered next was even scarier. The biggest problem is actually quite small. It's microplastics, plastics smaller than 5 millimeters, many around the size of 10 micrometers. That's thinner than a fraction of the thickness of a piece of paper, and smaller than is visible to the human eye! With all of these plastics ending up in the ocean, it really was a wonder to me that we weren't seeing chunks of plastics in any of the seafood that we eat.

However, it's entirely possible that the seafood that we eat includes microplastics we can't see. Plastics have been known to cause health concerns, such as lung, heart, and kidney damage, cancer, and even genetic mutations. These toxins slowly build up in the food chain through two different processes. The first one is bioaccumulation, where the toxins inside a single animal's body increases as the animals eats the plastics and can't get rid of them. The second one is biomagnification, where toxins get more concentrated in each level of the food chain, as predators eat other animals that have toxins inside their bodies.

Finally, the toxins reach the apex predators—which could be us. Eventually, plastics are likely to end up in all of our diets, no matter what we eat. This could be from directly eating seafood, to eating livestock that consume seafood byproducts, and even to plants that uses those livestock's manure as fertilizer. A recent study even shows that most of the salt brands that we use contain traces of microplastics. After reading that, even my favorite snack, salty pretzels, failed to cheer me up. Instead, every crunchy bite only led me to feel even more anxious about this growing problem.

It was just my luck that the main part of dinner that day was seafood. We were celebrating the arrival of my grandparents and my cousin, who had traveled to Massachusetts from Beijing for summer vacation. After learning that 73% of all fish have ingested plastics, and that plastic doesn't harmlessly pass through the animal's body—it gets stuck in their bloodstream—I was a little reluctant to even touch the fish.

My cousin James and I have had a history of tormenting each other. With only five years to separate our age, and clashing personalities, we show our rivalry with daily arguments and pranks. Armed with my new information, I found the perfect chance to play with him I told him facts about plastics that even scared me.

"Did you know that as as plastics break down they sometimes bind with other potentially toxic materials to create an even more toxic hybrid? This can then spread into the food chain, which means that those toxic substances could be in that fish!" I said cheerfully.

James scoffed, unimpressed. "Seriously? If you're so smart, then tell me why."

"I... I'm not too sure. I'll research it, though. But I do know that this piece of fish," I said, pointing at the fish, "probably has some plastics in it."

He rolled his eyes, but still glanced warily at the fish.

"Annaaah!" my mom yelled.

"Sorry," I said, smirking.

Needless to say, James avoided seafood for a good time after.

What my parents hated the most, was that all of the information I was sprouting off was true.

CHAPTER 3

IT'S THAT SCIENCE FAIR TIME OF THE YEAR AGAIN

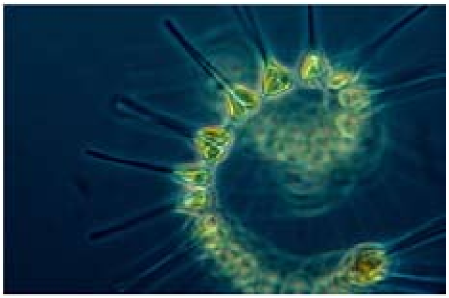
I sat down at my desk after I finished dinner, researching plastics again. This time, I focused more on cleanup efforts for plastics. After a bit of searching, I found many solutions online, and they all seemed to offer hopeful prospects for cleaning up the plastics. Some suggested large nets to corral the plastics onto the shore, and others were looking at self-propelled vehicles to vacuum up the plastics.

Later that night, I was lying on the bed and thinking about that day's events...

"Wait a minute," I said to myself.

A thought struck me suddenly. I realized something was missing. All the news reports and the scientific papers I was reading about the solutions so far were only suited to eliminating large plastics.

The first and arguably most popular method of cleaning plastics uses size-based filters. This method may work on larger pieces of plastics, but only because at that size, they are orders of magnitude larger than marine microorganisms. However, if we're talking about microplastics, that's a completely different story. Plastics come in all shapes and sizes. Even if someone made a net that was able to capture microplastics, there are also many marine organisms that have similar size. With no method of differentiating these animals, if someone were to remove all the microplastics from the ocean in this way, it would be deadly for the environment.



I also found some organizations that combined some of these methods to gather up the plastics. Some of them are using natural forces, such as wind and currents, to propel the nets to make the cleanup effort more efficient. Still, these cleanup methods can only reach down as far as the depth of the net, and can't focus on microplastics.

Many labs have also developed different ways to identify plastics. One of the chemical-based methods that works the best is to use Nile Red Dye. A person can treat suspected or known plastics with the dye, then observe how it fluoresces under a filtered light with a specific wavelength of blue. This method has proved accurate in correctly identifying plastics. However, this method is also very invasive, as you need to dye the plastics themselves. Not to mention, menthol is used as a solvent for the dye. Menthol is extremely toxic to all living animals, including humans. It's not as if you can dump bottle after bottle in the ocean, letting all the animals die as a result of your attempt to save them.

"But what about microplastics?" I exclaimed out loud, unsure if anybody heard me or not.

None of the methods I had read about would work for microplastics. So what could be done? After a while of restless tossing and turning, I gave up trying to sleep.

Getting up from my bed and turning on the light at my desk, I took out my notebook, and started brainstorming ideas. I tried my best to think deeply about what I had read earlier that day—ideas like ocean vacuums or nets. Now that I thought about it, those solutions seemed to rely on size-based filters—which would trap large plastic chunks as they float by. But wouldn't they catch fish and turtles too? Not to mention, they would also miss all the tiny pieces. Wouldn't they slip through? It seemed to me ideas like those would be completely ineffective when trying to clean up microplastics.

Then a thought hit me. Maybe I wasn't breaking down this problem down enough.

After writing that thought down onto the piece of paper in front of me, I was able to let go of that thought without worrying that I would forget it. Eventually, I got tired, stopped thinking about that problem for a minute, then fell asleep.

I was jarred awake when my dog licked my face, leaving a gooey trail of saliva that smelled a bit like salami.

“Eww, Andy!”

He licked me again, and my phone dinged. A friend was sending me a text.

‘1 more month until school starts again. Can’t wait for everything, especially science fair’

At that time, just looking at that text made me want to groan. I couldn’t honestly say I loved science fairs. In retrospect, I think that was because of my previous years’ projects. In my school, starting in first grade, we’re required to do science fair projects, even if we don’t start competing until 6th grade. My projects were never very original. Not only were they extremely simple, but they were also mind-numbingly boring.

After all, if I didn’t care about the subject I was investigating, how could I enjoy a science fair?

But this problem with plastics was something that I was really concerned about. What if I tried a science fair project on cleaning up microplastics in the ocean? Before this, science had all seemed so distant. After all, I was only 11 years old. How could I come up with something new, something that mattered? When I read books or watched TV about science & engineering topics, it was easy to get the impression that everything in the world has already been invented. But now I had a chance to make a potentially significant impact on the world. I would be given time at school and encouraged at home to work on my project. I might even be able to get out of some chores. :)

In my sleepy state, I quickly scribbled some vague thoughts on a scratch pad near my bed of what I wanted to do – to find, and potentially get rid of plastics in the ocean, or more specifically, microplastics. I only stopped when my dad called me to eat my morning fried rice.

As usual, I sat down at my desk right after my meal. I took out my notebook and started coming up with ideas to try and find plastics. I jotted down some of the ideas floating around in my head. I remembered how light that first piece of plastic felt when I picked it up. Perhaps I could use density as a method to identify plastics. It’s commonly used in a lab, after all. But after a little research, I quickly dismissed that theory. It turns out that different types of plastics have different densities – PVC, which is commonly used in plumbing, would sink in salt water, and PETE, which is used in everyday materials such as water bottles, would float. This method also isn’t reliable when trying to identify microplastics, because they change in density as they break up and bind to other materials.

Somehow, I needed to become more familiar with everyday plastics. Going into collector mode, I looked around the house for different objects that I could possibly use for plastic samples. I found:

- High-density polyethylene (HDPE): Plastic bags from our recent grocery trip
- Polypropylene (PP): Straws from a recent party
- Polyethylene terephthalate (PETE): Water bottles handed out at the gas station
- Polystyrene (PS): Foam peanuts from packaging
- Acrylonitrile butadiene styrene (ABS): Lego pieces from years ago, when James and I would compete to build the best structures
- Polyester (PES): Even my clothes have plastics in them

I found a list of what type of plastic made up what type of common household object, and I labeled my samples accordingly.

Carrying my collection of samples with me, I ran out my room to tell my parents, grandparents, and cousin about my idea. In my mind, I was preparing a speech to convince them to let me do this project. I thought they would be proud of me and encouraging. After all, they were the people always telling me to chase my dreams, and try to make a difference, and care about the environment.

While I talked, my parents and grandparents smiled and nodded, commenting about how much I had learned already. My cousin smiled and nodded along with them, but then, he spoke up with false concern. My eyes narrowed.

"Are you sure about this? I mean, you aren't exactly known for being the most motivated person in the family, and I would hate to see you disappointed when you finally gave up," he said with false concern.

My parents considered what he was saying, making slight noises of assent.

"I suppose it's all about the learning experience," my dad said.

My mom added. "While I agree with what James said, if you're able to prove to us that you're willing to spend your time wisely and you manage to keep on doing this while still keeping your grades up, we will be more than willing to help you! Just don't make a mess."

So that was that.

However, once my parents and grandparents left the room, my cousin's attitude hardened.

"What makes you think you can do something like this?" he sneered.

I crossed my arms, saying, "I don't exactly see you doing something to help the environment."

“You’re just like a butterfly, flitting around from one thing to another, getting all the attention. You can’t focus on this for very long even if you try your best! Let’s see how long this lasts.”

“But… butterflies… they’re important to the environment too! They’re good… pollinators!” I spluttered, trying to come up with something to say.

He rolled his eyes and stalked away.

His behavior rubbed me in the wrong way, so I steeled myself. It’s true that I’m not the most disciplined person, and rather than choosing to stick with one hobby, I do tend to flit around, losing interest quickly. However, this was something I could do if I put my mind to it. It was a problem I could solve. Along the way, I would prove to James I was more than just a butterfly.

CHAPTER 4
ELEMENTARY, MY DEAR WATSON

Summer seemed to be passing quickly. I was sitting at the picnic table in the yard and feeling a slight breeze as I flipped through my notebook, which was now filled with notes on plastics and potential solutions.

The thing is, I wanted to figure out exactly what were the differences between plastics and microplastics. I understood that they were different in terms of size, but I wondered if there were any other differences. And why, despite the fact that many people already know a lot about microplastics, were there still so few people who focusing on microplastics as part of the cleanup problem?

I figured out that this was because no one really knew exactly where in the ocean, microplastics might be piling up. With the larger, more visible pieces of plastics on the surface of the ocean, it's different. One only needs to travel to the right surface location to see the plastics right there in plain view. Scientists already have a method of predicting where these surface plastics will end up. They can follow the flow of the gyres, which are global patterns of ocean currents caused by wind, waves, and the Coriolis effect. These gyres cause the plastics to group together, in garbage patches. In fact, if you were to take a look at a detailed world ocean current map, you could find all of the garbage patches by simply finding the centers of the gyres.

Suddenly, Andy started barking crazily and put his paws on the fence. I knew immediately that the mailman had come. This is a case where Andy acts more like a protector or an older brother. ON the other hand , if you come to my house with a hamburger, or say a giant bologna in your hands, he would be happy to be your brother too.

When the mailman heard Andy's barking, he got this fearful look on his face. He spent a few moments just sitting in the car, before opening the door, running out and almost throwing the package down. Then he sprinted back to the car, shut the door, and drove away as soon as he could. I always found it funny how people could fear Andy when he was more like a giant, lovable teddy bear than anything else.

I went outside and picked up the package. I knew it was the book I had begged my mom to order the day before, which I had been waiting for. I ripped open the cardboard box and took out all of the bubble wrap... only to find another box inside. There were so much plastic packaging! Confused, I took out the box, and looked for my book. After dumping out the contents of the box, I finally found it at the bottom. But now, I was already interested. Why did my mom buy a random box? Now I was curious.

I opened up the box, and I found that it was a chemistry model set! In it were fake atoms, which you could use to model the shape of a molecule. I remembered that at science class, in school a couple of months ago, we had a lesson on photosynthesis. We learned that plants photosynthesize and turn sunlight, carbon dioxide, and water into glucose and oxygen. Glucose—that was the monomer for starch. My mom was giving me a hint. I could use this chemistry set to make models of plastic polymers.

I knew that the formula for glucose was C6H12O6, or six carbon, twelve hydrogens, and six oxygen. Working at the picnic table, I started snapping red, blue, and white “atoms” together. However, I just couldn't seem to get all the elements to fit. I couldn't get the structure right. So I fetched my laptop and searched it up. After I finally built my first glucose molecule, a flexible hexagon, I grinned widely. It felt like a Matrix moment, where the whole world suddenly became a bunch of spinning bits and bytes—only for me it was atoms and molecules. It occurred to me that everything around me was made up of different combinations of elements.

Now, my curiosity had piqued, and I Googled other polymers, especially the six types of plastics I had collected earlier. I wanted to see how their molecular structures differed from one another. When I was searching them up, I found the structure for nylon, and I built it immediately. Then, I put my model molecules in front of each sample I had collected. I tried to figure out how their molecular structure influenced their look, texture, stiffness, flexibility, and elasticity.

Just looking at the different types of molecule models themselves, especially glucose, I could see that their structures were very different. For instance, nylon, which is found in clothing, had a long and open structure that appeared more elastic. It was clearly more flexible than glucose, such as sugar, which is more stiff and hard. I felt like I had achieved a great personal breakthrough. Despite the fact that all these molecules were made using the same basic elements, the differences in the way they were bonded leads to different characteristics.

I learned that plastics, being man-made polymers, have similar chemical compounds to those found in living things, and they're all organic compounds, as they contain the same basic elements such as carbon, nitrogen, oxygen, and hydrogen. Though detection-wise differences in how they bond is only a small change, that small change is big enough to wreak havoc on the environment. The bonds within plastics are stronger than those between organic compounds, making them harder to break down. But the fact that they are so similar to organic compounds makes it a lot harder to identify plastics and separate them from marine animals without harming the environment.

CHAPTER 5
A NEW MENTOR

I had learned from one of my teachers that there was going to be a lecture about careers and science fair at a local university, which might interest me. So I asked my dad to drive me. To my surprise, the speaker turned out to be a polymer guru named Dr. Jon who's a senior researcher at a major local company that makes polymers for the semiconductor, automobile, and other high-tech industries. His speech really inspired me. After some hesitation, I wrote him an email to see if he might be willing to mentor a little girl like me. As soon as I hit "send" I thought to myself, Well, that was probably a waste of time. He'll never respond.

Minutes later I heard a ding coming from my computer, and it looked like I had new mail. I was amazed to see that he responded almost immediately!

Hello Anna,

I grew up with my dad as a scientist and it was sometimes challenging even then. You have a very good project idea.

I am happy to help you. Polymer analysis is less precise than analysis of small molecules. Mixtures of polymers are especially challenging. You would expect some polymers to bind heavy metals, but many probably would be inert.

Let's talk about this on the phone and see what we can do. A call after school hours is ok almost every day this week. Please let me know a day and time that are best for you. If possible, I'd like to include one of our analysis experts.

Jon

A few days later, I was in my room, my hands shaking. I sucked a deep breath in and pressed the call button. This was my first time on a phone with a scientist as famous as he was. For that matter, it was really the first time I'd spoken with any adult at all for any real length of time, except for close family members and teachers. I was extremely nervous, and must've repeated the same things over and over again. He was surprisingly patient and kind to me. After the phone call, I wrote back right away.

Dear Dr. Jon,

Thank you so much for calling me. I'm sorry I was a bit nervous today, I have never really had the chance to talk to such a knowledgeable scientist like yourself before.

I found the advice you gave me very informative, especially on the idea that polymers being long chains are less reactive when they're longer chains (in the center of the block of material as opposed to edges), and when they've broken apart due to brittleness, the ends become more reactive. This is a very fascinating way ofdescribing chemically what is going on with the microplastic density changes.

Thank you for all the help you have given me so far.

Sincerely,

Anna

The next day, I waited anxiously for his email back. I wasn't sure how he would respond - did I speak too immaturely? Would he think that I didn't know my subject as well as he thought? Did he suddenly realize that I was just a 12 year old, and thought that I had no idea what he was talking about? Thoughts like these plagued me the entire day, and when I got back home, I lunged for my computer, to check my email. His response stared at me from the Unread Emails section. I prayed that he wouldn't think I was too immature, and opened up the email.

Hi, Anna,

Regarding your idea, I make a few comments.

A central part of your hypothesis is that the plastic density changes when it is out in the environment. The tests we have been talking about above do not directly address this. Many small life forms do not have any mineral content so they probably are about the same density as water. Heavy metals are only a few parts per million, so even *if they built up hundreds of times that on the plastic they would only change the density a tiny amount. Now if something slimy grows on the particles, then the slime might catch sand or shelled sea life like diatoms and make them sink pretty well.*

HDPE has a density of about 0.97 g/cc, while sea water is 1.02 to 1.03, so all polyethylenes will float in the ocean. PVC is a whopping 1.38, so it sinks like a rock, even in the Dead Sea, which is 1.24.

Have you had algebra yet? If so, here is a fun calculation:

Problem statement: As it floats in the ocean, a one gram sample of HDPE starts to become covered in diatoms (density 2.0) How many grams of diatoms must the piece of plastic accumulate until the density of the piece reaches that of seawater, 1.03 g/cc?

We can speak again – the main thing is to figure out exactly what we will test and find a way to make it happen in time.

Jon

These were just the first of many emails that we sent each other. Over time, Dr. Jon has taught me many essential things. It turns out that nowadays, people are not only studying how plastics are made, but also how they break down. In fact, Dr. Jon told me that time and light have an effect on how polymers break down. Instead of being flexible and rubbery, plastics that are exposed to time and light become denser and more brittle. The material properties themselves are changed.

Then, as plastics break down, the ends of broken molecules become more reactive, allowing for more chemical reactions, and binding with other materials.

CHAPTER 6
A SEA OF MICROPLASTICS

A few days later, in school, we were learning about surface area. Our teacher was just explaining the formula for calculating the surface area of a cylinder, when it hit me. If you sliced a cylinder in two, all at once you'd have two more cylinder ends than before. As plastics break into separate pieces, their surface area must increase also. This would mean that the areas where plastics could potentially bind with other materials would slowly increase over time. I was excited thinking about this, on the drive home. I couldn't wait to see what Dr. Jon had written me today, and to discuss my new ideas. I ran into my room, as soon as my dad pulled up in to the garage.

"Boo!" I heard coming from behind me and I knew that it could only be one person -- James. He must have been hiding for a while in my room waiting to prank me.

"James you jerk, get out of my room," I yelled.

"What are you working on, *butterfly* - let me see," he said, as he tried to grab my laptop away.

"Who's this guy writing to you? Is he your boyfriend?" James said, trying to press all the right buttons to be as annoying as he possibly could.

"Oh my god. Seriously? He's a scientist who is helping me with my project, teaching me about surface area of particles. Now why are you still here? Get out, now," I exclaimed.

“Surface area? Are you kidding me? I learned that years ago, maybe even in kindergarten. In my school we’re way ahead of you guys in math. Don’t you know that? I bet you don’t know anything about geometry at all. I know a trick I bet you don’t know. How many times do you think you can break a brand new pencil in half?”

“I dunno, I guess I break pencils all the time. Probably like 4 or 5. Why?” I said.

“Ok, let’s try it. I think you can’t do it more than twice.”

So, I pulled out a new pencil and went for it. Once, twice, Snap!—no problem. But then the third time, I genuinely had a hard time.

“OK, you’re right,” I said as I stood up and physically pushed James out of my room. I just didn’t even want to hear his explanation about it. I didn’t want him taking any credit for helping me out with my project in any way. I’d never hear the end of it for the rest of my life. So I decided to look it up myself.

After doing a bit of research, I decided that James was somewhat right. This was a pretty relevant and interesting exercise. It turns out that geometry has a lot to do with how and why materials can break down. I could feel instinctively that this was going to somehow be useful knowledge for my project, but what did it all really mean?

Maybe this meant that plastics would become more and more stable over time. Like the grains of sand on a beach, as time goes by, chemicals and physical forces cause rocks to break down, and they become more and more stable shapes. I’d have to think more about it.

In the meantime I opened up the latest mail from Jon, and decided to reply:

> *Dear Dr. Jon,*
>
> *I actually have tried to do some fun experiments involving plastic densities before, at programs at the MIT before. I've attached some pics. Basically, you can end up with plastics perfectly neutrally buoyant or plastics separated on the top and bottom of concentrated salt solutions in alcohol. One of my first thoughts regarding how to remove microplastics from the ocean was that density could be used somehow. But it seems that so many toxic chemicals or high pressures need to be used and that would cause so much sea life to die, that it would defeat the purpose.*
>
> *Yes, I did take Algebra, and I do some math for fun at home most nights. I'm pretty sure that the answer to your question is roughly 0.13g. I got it by M_HDPE * (d / d _ HDPE - 1) / (1 - d / d_diatom). Believe it or not, I actually really enjoy doing math :)*

Hope to hear from you soon again. Thanks again so much. I am writing this right before bed, so I'm a bit sleepy now.

Hope you have a nice day.

Sincerely,

Anna

I did some more research every time I emailed him. I found out that microplastics get into the ocean through multiple different methods. Some go in the ocean already as microplastics, such as from your mom's cosmetics, or from your toothpaste. The others, that come in as larger pieces of plastics, all have different stories. These particles might be broken down through biological processes. For example, sea turtles swallow plastic bags, thinking they're jellyfish, and fish eat plastics too, such as broken up water bottles, or bottle caps, then poop them out.

Plastics can also be broken down by physical forces such as the constant motion of the waves. The other way is for them to be broken down is by chemical processes, such as being damaged by ultraviolet light. Their chemical structures break down, and eventually they end up as smaller, divide into smaller and smaller pieces. As time passes by, plastics gradually gain density mostly by bonding to heavier compounds, sinking to the ocean floor. Though the life experiences of these plastics are different, the fates are the same.

Once plastics reach the bottom of the ocean, things get way more interesting. On the surface, conditions are still somewhat predictable. But on the bottom of the ocean, it's a completely different world—there is no wind, and surface waves don't affect currents that are so deep. So what does happen down there? We know water movements could be affected by different factors, such as the temperature, salinity, density, topology (terrain) and other things. Maybe it's all so complicated that microplastics' final destiny is unpredictable after all. They're all going to get lost in the ocean. Not to mention, as microplastics circulate over and over again through the life cycles of countless animals in the marine ecosystem, these particles seem destined to spread further and further. All at once, my dreams of making a difference seemed quite hopeless.

Something James said earlier hit me, that night as I prepared to go to sleep. Maybe James was right—maybe I didn't really have all the math skills let alone all the engineering knowledge I needed to solve such a huge problem. Maybe it was time to get interested in something else.

CHAPTER 7
MAYBE THIS WILL WORK

The next day was another beach day. That's what I love about summer – almost every day is a beach day, and it's always a good way for me and Andy to have some wet and salty fun. This time, I prepared two bags. One bag was always there – for the sea glass I collected. However, the second bag was a new addition – it was for the plastic trash that I found.

As I walked along the beach, Andy followed me. A life-long lover of sticks, he kept on bringing me his favorite toy. But, as I bent down to pick up a particularly bright piece of plastic, I noticed that he wasn't by my side. He was looking for sticks again. Looking back, I realized that he kept returning to the same area, thirty feet from the shore. I then noticed that I was sticking around one area too, maybe ten feet from the shore, along a band filled with shells, and sea glass. Looking at the shore, I noticed that all of the heavy rocks were on the same place as well - right next to the shore. Even the sand itself seemed to display a sort of gradient of textures along the coastline. I realized that the beach was sorting itself in different ways.

This led me to a new thought. If these seemingly random materials were being sorted, why shouldn't the same kind of sorting happen with microplastics at the bottom of the ocean as well? I remembered that in a science class, a few months ago, when we were learning about density, our teacher mentioned that in a river with gold deposits, the gold always ends up in the bends of the river. This is because the gold, which has a higher density than nearly all the other materials in a river, moves best in regions with high water flow.

The intense movement and mixing of water is called turbidity. However, when there is less turbidity, in corners and bends—places where rivers slow down—the gold sinks. That is why all the gold ends up aggregating in one place. That's what makes it possible to "pan" for gold the way the California miners in the 1800's used to do.

The Great Pacific Garbage Patch is really no different from this. The regions where ocean current flow is lowest—in the center of gyres—is where all the large plastics settle. So, since nature has this ever-present tendency to sort things according to size and density, that must mean that there are probably large "microplastic patches" on the ocean floor.

After all, in order to make something related to nature, we need to learn about nature first. If we observe nature, we could learn a lot: the solution might be already there. In recent years, there have been many innovations inspired by nature. For example, Olympic athletes use swimwear that imitates the skins of dolphins and sharks, and Velcro is modeled after burdock burrs. Maybe, I thought, different types of microplastics gather in specific places. If a person could study the various physical, chemical and other factors associated with deposits of plastics, such as pH, temperature, or salinity, maybe they could learn to predict where lots of microplastics might be found.

After all... wouldn't it be easier to find the problem first, before cleaning it up?

I'd be sort of like Andy searching for sticks at the beach. Instead of looking through the entire beach, he knew that if he went to that band a certain distance from the water, then he would find a lot of sticks. Maybe there were areas like that underwater—areas that were sort of like plastic mines, hiding tons of microplastics.

This reminded me of a concept I recently read about in a book. A woman in the 1800's named Hertha Ayrton, against all odds, became a mathematician and physicist recognized by the Royal Society in England for her work on waves. During those days women weren't even allowed to have college degrees, and were usually discouraged from academics. But, despite that, Hertha became the first women to present her ideas in front of the Institution of Electrical Engineers; it's surprising to me that not too many people know about her. One of her biggest contributions to science was demonstrating that the waves you find in the patterns of electricity or even lights are not much different from the waves in the ocean. This is the reason why electromagnetic waves (like infrared light waves) look like ocean waves when they represent them in diagrams. Not to mention, Hertha described how you can find these same wave patterns in ripples in the sand at low tide. This is due to the fact that they're all related to each other. Places where the sand deposits are areas where the velocity of the water is a little bit less than in other areas.

I have a hunch that this same type of action may be happening to plastics underwater as well. They are probably sorting themselves into waves or pockets of particles and being mixed with mud and sand and other particles, based somewhat on density. There are always patterns in the Universe caused by the forces all around us.

So instead of trying to come up with ways to clean plastics up passively... maybe I should come up with a more active way to locate them first.