The Anthropocene and Riding the EAC to Sydney

Before we jump into it with our first Gene-trepreneur, Dr. Molly Morse of Mango Materials, and her founder story, I think it's important for us to get some quick perspective to better understand exactly when you and I are living across the vast timescales of human history.

∞

Earth's geological timeline is split into several main parts called eras. Each era is split into periods, and each period is divided into a number of epochs.

Right now, we are living in an epoch known as the Anthropocene, which basically translates to a time when the Earth's environment is *significantly* impacted by the presence and will of the human race. I don't know how you feel about this, but I find it both extremely exciting and absolutely terrifying. I guess it depends on how much faith you have in collective humanity.

Paul Crutzen, the Nobel prize-winning scientist who actually coined the human-dominated term for this epoch, stated that "this name change [from the previous twelve-thousand-year Holocene epoch during which human civilization originally sprouted] stresses the enormity of humanity's responsibility as stewards of the Earth."[1]

Even though we know we are currently living in it, we have difficulty pinpointing exactly when the Anthropocene began. Nearly every scientist agrees about humanity's impact on the environment,

1 Carrington, Damian. "The Anthropocene Epoch: Scientists Declare Dawn of Human-Influenced Age." *The Guardian*, Guardian News and Media. August 29, 2016.

but the nature of various scientific fields has led to some differing opinions about where to place the official Anthropogenic stamp on Earth's timeline.

From a biological perspective, some hypothesize that the ball began rolling some fifty thousand years ago when humans burned down forests and hunted animals to extinction—so long, giant kangaroos.[2] But most suggested starting dates are far more recent: the 1600s, 1800s, and even the 1900s. Let's quickly look at each.

The 1600s: Colonialism leading up to the seventeenth century left a dark shadow in human history with mass deaths from disease and slavery. But these dark times were like a rejuvenating face mask for the environment! Human catastrophe allowed regrowth of vegetation on lands previously used for farming, leading to a measurable decrease in atmospheric CO2 levels around 1610.[3] This direct correlation between decreasing human presence and decreasing CO2 levels presents solid evidence of humans' impact on the world.

The 1800s: The early nineteenth century is also claimed to be a good candidate due to the rapid industrialization that negatively affected the environment and increased those CO2 levels right back up again thanks to fossil fuels.[4] During Britain's Industrial Revolution, landscapes close to cities were so soot-covered that they caused British peppered moths to change from their normal white color to a black pigmentation in order to blend in. This is a great example of humans completely altering natural selection pressures, which in this case favored mutations for dark coloration in moths to avoid predation.[5]

Lastly, the 1900s: Perhaps the most agreed upon time to mark the beginning of the Anthropocene is the mid-twentieth century. This is when various scientific disciplines can agreeably converge based upon their own qualifying criteria. You see, for geologists, concrete signals

---

2 Biello, David. "Did the Anthropocene Begin in 1950 or 50,000 Years Ago?" *Scientific American*, April 2, 2015.

3 Lewis, Simon L, and Maslin, Mark A. "A Transparent Framework for Defining the Anthropocene Epoch." *The Anthropocene Review*, vol. 2, no. 2, 2015, pp. 128–146.

4 Steffen, Will, et al. "The Anthropocene:" *Environment and Society*. December, 2007, pp. 12–31.

5 Webb, Jonathan. "Famous Peppered Moth's Dark Secret Revealed." *BBC News*, BBC. June 1, 2016.

need to show up in the global geological record in order to make a distinction between epochs.[6] The best signal to check off that box corresponds to nuclear bomb tests (and their resulting radioactive particles being spread out across the planet) in the mid-1900s.[7] This "Great Acceleration," as Crutzen calls it, brought about by nuclear waste and rapid technological advancement post-World War II, is the most widely accepted time to mark the transition from the Holocene into the Anthropocene.

No matter where the specific starting point goes down in the textbooks, though, we have more signals now than ever before that tell of the alarming power humans wield over the fate of the planet. Atmospheric changes, deforestation, mass extinctions, rising sea levels, incredible amounts of damaging marine plastic, and more all show us how we're having more impact on Earth than any other animal in known history. And as the adage goes: "With great power comes great responsibility."

Encouragingly today, with new advancements in biotechnology, we are not only able to recognize the wrongs of our historical past, but we are also able to right a few of them as well, thereby redefining our relationship with the Earth to shape a better present and inspired future.

∞

For example, humans have driven many species to critical endangerment and even extinction. It is now within our grasp to genetically rescue or even resurrect species in some cases that humans have negatively impacted. We can do this with cutting-edge genetic engineering tools, which we will discuss forward from chapter 7. We will also talk about renowned Harvard professor George Church and non-profit Revive & Restore, some of the world leaders in the spaces of genetic rescue and de-extinction, later in chapters 9 and 10.

---

6 Stromberg, Joseph. "What Is the Anthropocene and Are We in It?" *Smithsonian.com*, Smithsonian Institution. January 1, 2013.

7 Carrington, Damian. "The Anthropocene Epoch: Scientists Declare Dawn of Human-Influenced Age." *The Guardian*, Guardian News and Media. August 29, 2016.

Biotech is also enabling us to move away from one of the most environmentally detrimental practices in our society—relying on an animal-based economy for foods and materials. We can apply medical-grade tissue engineering and food-grade microbial production (just like brewing beer) to create protein-rich foods and goods without the methane-producing machines commonly known as cows. There is a multi-trillion-dollar market to improve the food and materials space around the world in this way, and it is currently taking off not only in Silicon Valley, but also globally as we see more support from forward-thinking governments like Israel, Japan, USA, UK, Singapore, and more.

Additionally, microbes are being used to help solve the impending food crises predicted to occur from the rising population by increasing crop yields. Simultaneously, bacteria can help protect crops from pests and diseases naturally, thereby vastly reducing our reliance on harmful agricultural chemicals and leading to countless beneficial outcomes in a sort of domino effect down the line. This is just the tip of the iceberg too. There is so much more to be optimistic about—bioremediation, solving infertility, tackling invasive species, etc.—and we will delve into all of it as deeply as we can within the scope of this book.

As amazing as these prospects are, what really excites me now, and will hopefully invigorate you as well, is that the biotechnology and entrepreneurial culture we have today is allowing small groups of individuals to take on established industries and affect more positive global change at a faster rate than was previously thought possible.

Through the efforts of those who think BIG and have the mindset to improve the world around them out of curiosity and their intrinsic sense of duty, we are seeing a major shift toward the power of the few to help solve the problems of the many. Synthetic biology (a.k.a. synbio: applying engineering principles to biological systems) and sustainability founders are truly saving the world, and you will hear the stories, impacts, and visions for the bio-based future from the amazing Gene-trepreneurs profiled and interviewed in this book. Some of them have even made it onto the *Inc.* and *Forbes* "30 under 30" lists!

For this reason, I think we really do have cause for hope. There are a rising number of synbio and sustainability superheroes like our first featured Gene-trepreneur and her inspiring tale, but of course, more are always needed. It's time to bring all hands on deck to change our current circumstances for the better. "Avengers assemble..."[8]

Main Takeaway:

It's an exciting time to be alive, and it's truly do or die.

– Humanity has come to a crossroads in our relationship with the world around us, and it's going to be mutual success or mutual destruction.

Mango Materials and Finding Nemo

"And I was floored ... completely horrified," Molly Morse told NPR. "It changed my life and I was like that is freaking ridiculous, and I'm going to change it."

What was so horrific?

"There was this huge, gigantic-like fish-tank-type structure full of clamshells, like [plastic foam] clamshells from McDonald's," she recalls.[9]

That simple scene horrified an elementary-school-aged girl so much that she'd go on to found an incredibly promising company dedicated to ridding the world of the massive problem she witnessed that day. Dr. Molly Morse of Mango Materials is a biopolymer Gene-trepreneur.

Morse and her startup Mango Materials produce biopolymers to create plastic replacements that are cost competitive with traditional, polluting, and generally petroleum-based varieties. She founded the company in 2010 out of Stanford University and has grown it into a multi-million-dollar operation since. Their technology has the potential to revolutionize the plastic replacement industry with a product that is carbon-neutral and can help tip the scales in Mother Nature's favor. And to give you some context into the great problem

8 *Avengers: Age of Ultron*. Directed by Josh Whedon. Performed by Robert Downey Jr., Chris Evans, Scarlett Johanssen. Marvel Studios. May 1, 2015.

9 Joyce, Christopher. "Replacing Plastic: Can Bacteria Help Us Break The Habit?" NPR. NPR, June 17, 2019.

that Mango Materials is posed to help solve, let's take a quick dive into the world's oceans.

∞

Our oceans are absolutely littered with plastics. Go to the world's most desolate islands or into the deepest ocean ravines and you will certainly find plastic and man-made trash scattered about. If you venture to any beach in the Pacific especially, you will likely see garbage washed up along the shore in vast quantities due to the countries that surround this body of water and the ocean's natural currents.

But this is nothing compared to the huge conglomeration of trash you'll find offshore in an area called the Great Pacific Garbage Patch (GPGP). Sitting at three times the size of France in the middle of the Pacific Ocean, the GPGP is filled with plastic waste, fishing equipment, and tsunami debris that is a gauntlet of death for wildlife to mistakenly consume and become entrapped within. It's also still growing.

By 2025, it is estimated that the output of plastic into the world's oceans will be around 155 million metric tons.[10] To contextualize this, the average weight of an adult person is 137 pounds, which means that the mass of plastic going into the oceans will be equivalent to almost 2.5 billion people (about one-third of the world's current population) every year.[11] Isn't that crazy?

However, all hope is not lost as progress is being made.

Many solutions today include government policies taxing plastic bags or banning single-use plastics like the United Kingdom is planning to do.[12] Enterprising individuals have also turned to making products like the 4ocean bracelets that advertise themselves as taking one pound of plastic out of the ocean for each bracelet made.[13]

---

10 Liu, Marian. "Great Pacific Garbage Patch Now Three Times the Size of France." *CNN*, Cable News Network, March 23, 2018.

11 Quilty-Harper, Conrad. "The World's Fattest Countries: How Do You Compare?" *The Telegraph*, June 2012.

12 Chiorando, Maria. "UK Government Announces Plans To Ban Single-Use Plastics." *RSS*, 26 Oct. 2018.

13 4ocean. "4ocean Is Actively Cleaning Our Oceans and Coastlines."

Furthermore, the Seabin Project is essentially a floating waste bin that sucks up trash in harbors before it gets swept out to sea.

Additionally, a large-scale operation by The Ocean Cleanup is getting underway. The operation involves dragging what looks like an extremely large pool noodle with a ten-foot hanging skirt below it across the water in a U-shape to capture and tow all debris to an area where it can be collected and removed. The Ocean Cleanup states that when fully deployed, their operation can expect to remove about 50 percent of the GPGP every five years, which is brilliant![14]

We certainly need to support a variety of ways to clean up this marine crisis and to help prevent more sea creatures from dying. We also need to keep what is currently out in the oceans from breaking down into dangerous microplastics.

Synthetic biology actually offers a promising solution to this called bioremediation wherein microbes can be selected for, or even engineered, to more efficiently consume plastics. Bacteria have long been breaking down leaking hydrocarbons (what plastic is chemically made of) from the seafloor as food, so it's nothing new. But humans can take advantage of them to employ this bioremediation process where we have congregated high quantities of plastic, such as in landfills, or when we want to clean water, like in water treatment plants, for oil spills, etc.

Microbes can be immensely helpful machines, like little Roombas for the sea, to help remove dangerous toxins from the environment. But it cannot all be about cleaning up the mess we've made. We have to fix problems at their sources too, and that's where companies like Mango Materials can really shine.

Mango Materials is using methanotrophs, a type of methane-consuming bacteria, to convert methane gas (heavily responsible for global warming) into polyhydroxyalkanoate (PHA) polymers. These biopolymers can be crafted into biodegradable replacements for a wide variety of commercial uses including packaging, cosmetics, apparel, and more. It is not an easy feat though!

---

14 Ocean Cleanup. "The World's First Ocean Cleanup System Launched from San Francisco." *The Ocean Cleanup*, September 8, 2018.

Dr. Morse is accomplishing this via gas fermentation, meaning that bacteria are taking the methane right off your local wastewater treatment plant and formulating it into these carbon-based polymers beneath their cell walls—kind of like chipmunks stuffing their cheeks. Typically, fermentation requires sugars in solution, like in the beer-brewing process, so you have to be clever about fermenting from gas.

Furthermore, these methanotrophs are not readily industrialized, so they basically must be trained for the job. You might think this training would include genetic engineering to buff up the microbes' carbon-fixation capabilities, but at Mango Materials not much genetic engineering is actually required because Dr. Morse has been doing controlled selection of these bacteria since the company's founding to improve their efficiency. It's like choosing between steroids to build muscle rapidly or consistently working out. And these bacteria have been hitting the gym for a long time getting buff. (In fact, you may see them come out with their own annual calendar sometime soon just like those annual firefighter calendars—which methanotrophs will be Mr. / Mrs. January through December?)

Interestingly, the biopolymers at Mango are also specially formulated depending on the intended end use—whether the PHA polymer will be used with injection molds to create packaging or will be fiber extruded to create filaments for apparel.

Dr. Morse says that about 90 percent of their time and energy is now focused on creating PHA fibers for apparel because Mango's primary concern is with plastic in the marine environment. According to the company's site, 60 percent of clothing contains polyester (which is plastic-based) and only 17 percent of our clothes are recycled. The other thirty billion pounds of textiles are discarded into landfills where the plastic breaks into small pieces that leach into our water supply.[15]

Additionally, many small polyester fibers come out of our clothes during normal, everyday wash cycles. These fibers then find their way into the oceans where they are consumed by small organisms and make their way up the food chain into humans, not to mention the

15 "Applications." *Mango Materials.*

damage they impose on sea life in their own right. The great thing about Mango's process is that the biopolymers they create are biodegradable (meaning prone to enzymatic attack), therefore minimizing the microplastic threat to wildlife and us.

If an animal, like a sea turtle for example, consumes any (as they are often known to mistake pieces of plastic for jellyfish—a very delectable food item if you are a sea turtle), in the long run they won't be harmed. Crush, Squirt, and the rest of the *Finding Nemo* turtle gang riding the East Australian Current (EAC) will definitely owe Mango a fin tap and noggin bump of gratitude.[16]

Obviously, it's better if these materials have a chance to be recycled so the methane can be recaptured and turned into biopolymer-based products once more. But again, if any of Mango's polymers happen to end up in the oceans, there are plenty of microorganisms to break them down safely.

Business-wise, Mango Materials is very competitive with traditional PHA plastics, but the problem, as with most biotech companies, comes with scaling up. (Biotech is generally pretty expensive compared to building a software as a service—a.k.a. SaaS—business as they require lab equipment, lab space, reagents, scientific software, etc.)[17] Dr. Morse says the greatest challenge the company faces is acquiring funding to scale.

Mango Materials generates plenty of interest from investors, but the issue is angels and venture capitalists (a.k.a. VCs) want quick returns, and the cost of equipment to expand Mango's operation is not cheap. Additionally, investors want to see the concept proven over a long period of time. The company currently has years of data as they have been employing their technology in the field since 2015 in an anaerobic digester (no oxygen) at a Redwood City, California, waste treatment plant. Dr. Morse says they will likely be there for another year or two but will then build a larger unit if everything works out with their funding model.

---

16 *Finding Nemo*. Directed by Andrew Stanton. Performed by Ellen Degeneres and Alexander Gould. Pixar Animation Studios. May 30, 2003.

17 Hyde, Embriette. "Building Synthetic Biology Companies at Scale: Practical Advice from Seasoned Investors and Entrepreneurs." *SynBioBeta*, September 19, 2018.

Very promisingly, though, Dr. Morse stated that even within the past six months, she has seen a massive change in the demand for plastic replacement. It stems from growing consumer awareness brought about by National Geographic and other organizations drawing attention to the huge issue of plastic pollution.[18] As demand grows, financial backing of biopolymer companies like Mango Materials will likely see a substantial boost. It's really about playing the long game for the good of the world and not about making a quick buck.

I really believe that Mango Materials with Dr. Morse at the helm can have an extraordinary impact on sustainability and is employing exactly the right strategy by focusing their efforts in apparel. Since their biopolymer can be extruded into filaments and incorporated into clothing like traditional polyester, there are countless opportunities in the truly colossal fashion and textile industries. And I have a brief personal story related to this next.

But first, I also want to pass this question off to you. Given the choice between purchasing a normal cotton/polyester blend shirt or one with Mango's biopolymer in it (and assuming similar price points), which one would you choose?

Grad Gown Gifts and Black Hole Closets

Coming out of my senior year of college, I dedicated a couple of months to working on a "side-hustle" if you will to reduce some of the plastic-based fabric waste I witnessed coming from the graduation industry.

Every year in the US, more than 3.6 million students graduate from high schools and 3.7 million students graduate from various college programs, plus all of the children who have middle school, elementary, and kindergarten / pre-k ceremonies utilizing gowns as well.[19] Most of the graduation apparels (caps and gowns) are made out of single-use, plastic-based polyester and are simply worn to take pictures in and walk across a stage.

---

18 Treat, Jason, et al. "We Depend On Plastic. Now, We're Drowning in It." *We Depend on Plastic. Now We're Drowning in It.,* May 16, 2018.

19 "The NCES Fast Facts Tool Provides Quick Answers to Many Education Questions (National Center for Education Statistics)." *National Center for Education Statistics (NCES) Home Page, a Part of the U.S. Department of Education.*

Ask yourself, if your school did not offer rentable, re-usable graduation apparel, what did you do with your overpriced, single-use cap and gown? After that momentary usage, most are typically thrown into the garbage or tossed into that black hole of a closet or drawer you've got never to be seen again (at least until you move and decide to finally throw them away because they don't "spark joy" for you anymore).[20]

I thought of this startup idea about one hundred days before graduation and called it Grad Gown Gifts. The mission was to recycle caps and gowns into personalized keepsakes post-graduation (throw pillows, decorative caps, signing frames, etc.) so they wouldn't end up in landfills like the millions that already call those places home. It was like the 4ocean bracelets removing plastic from the ocean but for grad apparel.

∞

My vision for the company was to become a hybrid between Shutterfly (a company where you send them pictures and receive a scrapbook) and online artist-based marketplaces like Design By Humans, Society6, Threadless, or in some cases Etsy (where artists and artisans sell their craft from personal online storefronts).

And since you should always have an exit plan, even when you first begin a startup endeavor, my proposed exit strategy, if successful, was to sell it to Jostens—a behemoth supplier of graduation apparel, or a similar enterprise down the line. I thought it would be perfect for a company like Jostens because they could sell their apparel products on the front end and then recycle them into personalized keepsakes as an environmentally beneficial, back-end business too. It would make them more of a company with a cause.

But when you look deeper into it, what would have stopped Jostens from just replacing me? What barriers to entry were in place preventing them from doing their own version of Grad Gown Gifts?

My advantage was weak: being ingrained in the university infrastructure as a student/recent graduate while Jostens was already a

20 *Tidying Up with Marie Kondo*. Netflix, 2019.

widely distributed grad apparel brand with relationships established around the country. I could have also possibly applied for a patent on a frame design to house graduation caps in place of the felt backing, but they could have come up with their own version just as easily. And I thought perhaps my company would be so small that Jostens wouldn't want to invest their time and money into setting up their own operation when it would be cheaper to acquire me or let me keep taking a small cut of the pie. But if it was small forever, it wouldn't really be creating the desired BIG impact, would it?

Additionally, I ran into many problems with the supply chain (contract manufacturing, the insane cost of personalized framing, licensing art, building an artist base, finding quality content from the public domain, etc.). For example, I went to a local framing shop to inquire about pricing for a ten-by-ten-inch custom frame. From this small local business, I was quoted approximately $45 each. I also ventured to a well-known craft store—that may or may not have been the name of the regional manager of Dunder Mifflin's Scranton branch—and they quoted me around $90, which included a substantial discount from a custom framing sale they were running at the time! Ridiculous, right?

Looking at the insight from potential customers I had obtained (mainly freshman college students straight out of high school), most said they would pay something like $25 for a framed decorative cap. The custom framing cost alone, not to mention the price of shipping, the labor costs for artists/artisans, licensing, etc., made this absolutely impractical on a small-scale to run. And if I somehow managed to figure the supply chain and financials out, again, what would stop a big graduation apparel company like Jostens from copying the process over to their infrastructure?

There were many other considerations, and I learned many valuable things from the process. But in the end, Grad Gown Gifts was not meant to be.

However, even though Grad Gown Gifts did not fully come to fruition and was not an endeavor in synthetic biology (simply satisfying my passion to aid in sustainability), I am so grateful I pursued the idea because it taught me that some problems do not have viable

business fixes on the back end; usually the best way to solve a problem is at its roots.

In this case, the option far better than Grad Gown Gifts would be to use a more eco-friendly, biodegradable material to tackle the problem at its source in the cap and gown manufacturing process—something like gas fermentation with microbes perhaps? And this is exactly what Dr. Morse is so well-positioned to accomplish with Mango Materials. If anyone from Jostens reads this, please reach out to her.

The best outcome of this project was that it led me to attend an entrepreneurship conference in NYC called Next Gen Summit. There, I encountered entrepreneur Eric Koester, who inspired me to write this book, which has driven me to connect with so many amazing synbio and sustainability startup founders and experts you will read about in the upcoming chapters. This personal experience also goes to show that entrepreneurial failures, even small ones, can lead you to your next big thing in unexpected ways. Onward and upward!

Main Takeaways:

If you desire long-term returns, make sure your endeavor is in a space with barriers-to-entry or you'll get eaten up alive.

– For example, nothing was really stopping people from selling fidget spinners in their heyday, was there? Heck, I even sold 3D-printed fidget spinners for a course project, and my team raked in $1,500+ over a couple of weeks.

One company's profitable, back-end fix to a sustainability problem is not 100% transferable to your back-end fix to a sustainability problem—in my case, 4ocean bracelets versus my endeavor with Grad Gown Gifts.

– However, note that if you believe you have something worthwhile, you *must* put in all the ground work—including the very important step of asking your potential customers questions to find out if you're actually solving a meaningful pain point.
– You will learn a lot more by taking action and asking questions rather than simply stewing on a stagnant idea.

Failing at one thing can lead to your next BIG one; you truly never know what lies around the corner for you so always keep pushing forward

– But at the same time, be reflective and smart about choosing your next steps so you can be efficient with your time and energy—as famed author Neil Gaiman would say, "Does it bring you closer to your mountain?"[21]

A Note to the Reader

Through consuming all of the plant and cell-based meaty content in the upcoming chapters, my hope is that you will learn and become truly inspired to get involved in this magical space in whatever way you choose.

Whether simply by talking more about biotech and sustainability with friends and family, writing a paper, article, or book, joining a lab or club, helping out on the financial side of these endeavors, or pursuing one of your own inspired ideas, please know that no matter your background, no matter your age, you can join the cause and help drive the development of our bio-based future.

We're all in this together, and your part can be as little or big as you want to make it.

The rest of the chapters are structured similarly to this introduction in that we'll mostly deep-dive into the sustainability challenges followed by a discussion of the amazing Gene-trepreneurs and start-ups rising to meet them.

And now that your feet are wet, let's do one giant cannonball into the pool of STEM and sustainability; off to chapter 1!

21 Gaiman, Neil. "Neil Gaiman: Keynote Address 2012." University of the Arts. May 17, 2012.