LIFE FORMED: EVOLUTIONARY DESIGN AND THE FUTURES OF A POLITICAL BIOLOGY

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ABSTRACT

With the advent of CRISPR and gene drive gene editing technologies, synthetic biology is paving the way towards a world where humans have the capacity to rapidly design and re-design lifeforms. With little oversight and agreed upon governance structures, how will we ensure that these technologies are used for the greatest good? As we begin to actively design evolution, how might we decolonize this science? Privileging alternative forms of knowledge production and ethical frameworks from Indigenous peoples and spiritual ecologists in order to shape a preferred future for the planet in the era of synthetic life.

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INTRODUCTION

SYNTHETIC BIOLOGY AND THE MEANING MACHINE

"That assumption is that there exists some fundamental equivalency between genetic 'codes' and computer 'codes,' or between the biological and digital domains, such that they can be rendered interchangeable in terms of materials and functions."

~ Eugene Thacker

"Cyborgs are not reverent; they do not remember the cosmos."

~ Donna Haraway

"We'll design every human on a computer and make poop smell like bananas."

~ Austen Heinz, Cambrian Genomics CEO

This research is, at best, a work of what Jared Lanier calls 'speculative advocacy.' (Lanier, 2013) We have entered an era of humanity where it has become possible to intentionally design evolution at the genetic scale using rapidly advancing technologies in the biosciences, namely synthetic biology. This is also an era of rapid and unpredictable climate change, species extinction and overpopulation that is stretching the limits of Earth's resources. This research grapples with the challenges and opportunities of this particular historical moment - to understand the systemic roots of current trends in order to glimpse the emerging futures and what they hold in store for humans, non-humans and Earth. Christopher Preston calls this the 'Synthetic Age,' a time in which "Earth's formative processes themselves become open for redesign," so that the changes humans are capable of making are deeply "metabolic, impacting not just how the planet looks but how the planet works" (Preston, 2018). I embark on this

exploration so that we may better advocate for practices and ontologies in the field of synthetic biology that support equity, peace and flourishing rather than inequality, violence and suffering. In an era where humans may have the rampant capacity to engineer, and therefore govern, evolution at hyperspeed, this work will advocate strongly for a place-based politics that engages a whole planet. In doing so, it will rely upon unearthing the genealogy of the science, for we cannot know where we might go unless we know first how we got to where we are now. It will rely upon engaging practitioners of Indigenous sciences as powerful and critical alternatives to the dominant Western-European science that is the core basis of synthetic biology's genealogy. It will argue that the leadership of Indigenous science and scientists are necessary to chart a path forward that honors past and futures while ensuring that we don't repeat the mistakes that have brought our planet to the brink of multiple systems collapse. It will not make claims to any perfect worldview or ontological grounding, but it will advocate that Indigenous and animist practices of knowledge formation hold critical aspects to assist in the way out and the way towards a preferred future of planetary flourishing. Indigenous peoples make up less than 5% of the total human population and yet hold tenure over approximately 25% of the world's land surface in areas which support some 80% of the planet's total biodiversity (Garnett et al, 2018). Empowering the leadership of Indigenous science and scientists represents an extraordinary opportunity in the quest to manage runaway climate change. This research will argue that Indigenous methods of knowledge formation and ontologies must be privileged in the field of synthetic biology in order to move into a future of general human and planetary flourishing.

The assemblages involved in this analysis will run the gamut from flows of capital and spaces of knowledge production to spiritual values and plastic petri dishes run by robots. All play a part in the complex web of interactions that have led to this compelling moment in time when human embryos are beginning to be engineered for certain traits under the watchful gaze of corporate and patentable interests, with little to no policy oversight or overt ethical boundary agreements. It would be easy to write this off as a desire to return to some mythically perfect past before these technologies existed. That is not what this work advocates. Rather, it attempts to bring to light the engrained, entrenched, complex and interdependent forces that cannot be simplified or parsed out if we want to ensure that this powerful capacity to rewrite and permanently alter genetic coding is used for the general good and not simply to advance and further entrench the rapidly expanding inequality of access and privilege that defines the first part of the 21st century.

Like all genealogies, the birth story of synthetic biology is a map, outlining the particular circumstances that had to exist for this very unique set of practices to come into existence at a certain time and in a certain space in the annals of history. It is a tale that merges capital flows, reductionist science, mechanistic worldviews and burgeoning techno-optimism to bring into being a new vision of life as readable, writeable code, similar to software code, with the ability to precisely engineer genetics to solve the world's most pressing problems. While the very beginning of this story is in some ways difficult to pinpoint, it clearly hit stride in the early 2000's, in the Bay Area of California, when a confluence of specific, converging factors formed the conditions of possibility for this new way of imagining and practicing genetic engineering. But before we jump to

that point, for the purposes of this genealogical story, we'll begin in the year 1980. This year marks a crucial moment in the emergence of the prospect of synthetic biology, during a time when the broader field of biotechnology was itself still emerging. In 1980, the U.S. Supreme Court ruled in a landmark case, *Diamond v. Chakrabarty,* that "the question of whether or not an invention embraces living matter is irrelevant to the issue of patentability, as long as the invention is the result of human intervention." (Office of Technology Assessment 1988, p 49) Prior to this ruling, living organisms and importantly cells and genetic material were considered 'products of nature'; not patentable, not part of the capital flows of industrial production. Capitalism and the capitalist ontology is foundationally based on the belief that all things can be ascribed a monetary value that can and should be released into the international flows of capital exchange. In systems dictated by flows of capital, perceptions of worth come from the capacity to engage a thing, in this case a being, in systems of ownership and financial trade.

The *Diamond v. Chakrabarty* ruling was a novel and critical move that would legally, and in practice, more closely merge university based biotech labs with biotech industry and venture capital. This new imaginary of patentable life produced an opening whereby something known as a *biotechnology industry* could be born. The newly expanded collaboration between knowledge, produced in the university lab, and capital, circulated by rapidly growing biotechnology companies, produced a situation whereby it became financially lucrative for university scientists to both accept funding for research from industry and to leave the university to work in biotech corporations. From 1980 to 1984, patent applications from universities doing research in areas relevant to

biotechnology rose 300%. (Rabinow, 1999, p 22) Massive amounts of capital began to flow into the biosciences, and large biotechnology corporations like Cetus and Genentech merged scientific practice with an entrepreneurial culture resulting in organizations that lacked hierarchy and allowed the ascent of younger scientists to positions of power and profit without having to navigate the tedious ladder of time and tenure demanded by the university. Simultaneously, scientists who remained in the university began to see increased demands on their time to seek federally funded grants and continuously prove the innovative nature of their research, a daunting and tireless cycle that sent many more scientists in search of coveted positions as 'scientific advisors' in the big biotech firms.

The next factor at play in the birth of synthetic biology is the core concept of a unitary gene as the 'building block' of life. The science of genetics is founded in the idea that genes can be understood apart from the overall organism, and that an organism is constituted of a series of genes which are coded into DNA strands that comprise the genetic material to dictate all the attributes of that lifeform. Genetic engineering has taken this study of genetics and applied to it the conceptual foundations of engineering practices and disciplines. It is premised on the notion that single pieces of DNA can be removed from their context, isolated for certain predictable attributes and engineered to do certain predictable things in the future. To understand the roots and soul of synthetic biology as a scientific discipline, we first need to understand the origins of engineering as a discipline in the United States and how it came to be applied to biology.

While human beings have been creating useful tools through a process we might call engineering for many millennia, the actual etymology of the word dates back to

1325 when an engine'er literally referred to a person who constructed military engines. (Oxford English Dictionary) In the 18th, 19th and 20th centuries, a series of innovative inventions sprung from what is now known as the Industrial Revolution, thereby cementing engineering of various kinds, civil, electrical, mechanical, etc, as a respected scientific discipline. This foundation in both military and industrial production is central to engineering as a discipline. It is formed from a mechanistic worldview. One in which exact answers to complicated problems can be both divined and executed in predictable ways. Engineering works within a linear understanding of complexity. One that is manageable with a rigorous set of consistent practices and procedures. The realities of biological complexity are non-linear and often unpredictable. The complexities of a biological entity cannot be captured or engineered in the same way that a machine can be. There are as many examples of the complexity of biological organisms as there are organisms. It seems almost silly to have to place such a stake in the proverbial ground of this argument. But the premise of synthetic biology requires that we clearly delineate the messy and complex realities of biological beings. Take the concept of *saltations*, sudden and large mutational changes that don't follow a lineal or expected pattern of speciation. Or the research showing that trauma experienced by previous generations has material effects on future generations - just some of the many interdependencies and unexpected dynamics within biology that we are so far from fully understanding let alone managing.

How *did* biology come to be perceived as manageable with practices of engineering? Biology, is the study of life. Messy, contingent, unpredictable life. Typically, it is a discipline that embraces the concepts of complexity, entanglement,

ecosystems and interdependencies. For most of its history, biology was not a scientific pursuit where it was thought possible to do any sort of meaningful 'engineering.' It wasn't until the latter half of the 20th century that the idea to meld biological disciplines with engineering disciplines really took hold. Synthetic biology's embrace of engineering is dependent upon the belief that complex entities can be understood and replicated when they are broken down into their constituent parts and the belief that those parts can be understood discreetly. These practices enable scientists to create new subjects and new situations that didn't exist before. Reductionism as a means to gain access to 'truth' has been merged with a mechanistic view of biology in the world of biotechnology. The mechanistic view of biology argues that living beings are like complicated machines which can be understood in a way that is repeatable and thus programmable: that the whole can be understood by parsing out its constituent parts. It is the intent of this research to pay attention to the particular "forms of life" which are made possible by these new configurations of practice and the discursive claims that something like synthetic biology has the potential to create objects which will solve all of our most pressing problems. (Rabinow, 1996)

In the 1950's James Watson set out to understand how genetic traits were passed on to future generations. Buoyed by Linus Pauling's discovery of proteins that take the shape of a spiraling helix and the concurrent work of fellow scientist Francis Crick, the first cataloged discovery of the ubiquitous DNA double helix structure came about in 1953. In 1961, a seminal publication by Francois Jacob and Jacques Monod suggested that some sorts of consistent regulatory circuits existed which regulated the response of a cell to its environment. This, then radical, supposition became the

foundation upon which a vision of programming genetic expression began to take form. (Cameron et al, 2014, 381) In the 1970s and 80s, the developments of molecular cloning and PCR, the Polymerase Chain Reaction, both precursors to mapping the human genome and genetic engineering, created the sense that there was finally a potential way to purposefully engineer genetic traits. In his anthropological analysis of PCR (Polymerase Chain Reaction), Paul Rabinow explains “the truly astonishing thing about PCR is precisely that it wasn’t designed to solve a problem; once it existed, problems began to emerge to which it could be applied.” (Rabinow, 1996, 7)

At the same time, cybernetics and early computer science were emerging as another set of potentially transformational technologies. This led to the field of computational biology where biologists and computer scientists suddenly saw themselves as unusual allies. This unique convergence of biology as capital, genetics that could be engineered, DNA code that could be reduced to its component parts and rewritten and the necessary technology to begin thinking about DNA code as algorithmic peaked in the early 2000s as the Internet-fueled information revolution boomed across Silicon Valley in the Bay Area of California. Where biotechnology was birthed among venture capitalists and start-up companies, the newly entrenched understanding of software code and coding language met with the de-coding of the human genome to produce an epistemological breeding ground for the concept of ‘life as software code.’

From this chance genealogy, synthetic biology as a field was born. The first international conference for the field was held in 2004 at MIT and brought together researchers from across the scientific spectrum, building a new community and the

shared goal of whole genome engineering. From the very beginning, despite concerted efforts to create methodical processes, genetic parts when removed from their context often failed to function in a predictable manner. These sorts of context dependency issues have been a consistent roadblock in the field, challenging the myth of genetic precision and the myth of a unitary gene – concepts we will return to in later chapters.

In 2012, a lab at Berkeley under the guidance of scientist Jennifer Doudna published a landmark paper about a new gene editing technology called CRISPR Cas-9. CRISPR is an acronym that stands for “clustered regularly interspaced short palindromic repeat.” Discovered within bacteria, CRISPR is a series of repetitive, uniformly spaced DNA sequences.

Numerous, diverse CRISPR series were found within the bacteria and they matched perfectly the DNA sequences of known bacterial viruses. What Doudna had discovered is that the CRISPR sequences had evolved to help bacteria fight off the invading viruses. They do this using a cut mechanism whereby the CRISPR DNA can disable the invading virus rendering it harmless. Using the CRISPR technology paired with a protein called Cas-9, Doudna proved that it was possible to create a strand of genetic code and transport it into a living cell using Cas-9 as the transport vehicle. CRISPR would then act as the scissors, targeting a specific piece of the DNA code predetermined by the geneticist, cutting out the old code and inserting the new code into the living cell. This discovery rocked the world of gene editing with its perceived precision, speed and relatively low cost. Suddenly it seemed that gene editing could be rapid, wide spread and available to all. Since 2012, numerous other labs have advanced the understanding and use of CRISPR at lightning speed. International

conferences on Synthetic Biology, do it yourself wet-ware labs, bio-hacking undergrounds, genetically altered human embryos and human-pig chimeras are just a few of the incredible developments that have happened in the relatively short period of a few years time.

The visions of synthetic biology are grand and absolute. We will solve the energy crisis, print vaccines and medicines at home, bring extinct species back to life and design away all rare genetic diseases. The field is rife with a pervasive attitude of techno-optimism, one that is admittedly not confined to this field alone. In a recent lecture at MIT, famed synthetic biologist George Church posited, "What if you could engineer a cell resistant to all viruses, even the ones it hadn't yet encountered? What if you could grow your own liver in a pig to replace the faulty one you were born with? What if you could grow an entire brain in a dish?" (http://news.mit.edu/2018/reading-and-writing-dna-George-Church-0131) If you're experiencing a strange sense of déjà vu, you're not alone. The communications technology and information technology boom of the late 20th and 21st century exemplifies a form of techno-optimism that is now forcibly coming into question in the public sphere. Where social media once held the promise of toppling autocratic governments and making knowledge accessible to all, we are beginning to realize the ways in which social media can become the tool of autocracy and a means for distorting, privatizing and containing vital knowledge from the public. Based in a deeply held belief that technology alone can solve the problems we face, that all we need is the right technology to make things better, techno-optimism is blind to the complexities of politics, numb to the notion of unintended consequences. This political backdrop is what Jim Dator refers to as 'orgware.' Orgware "designates the

humans (and/or artilects) who envision, create and maintain the hardware and software, and, very importantly, for whom the hardware and software provides a job and personal identity." (Dator, Sweeney & Yee, 2015, 10) Orgware is the who does what with or to whom when and where. And it is the domain where most of the conflict and disagreement about new technologies resides. In the case of synthetic biology, as software coders began to collaborate with biotechnologists and the DNA code was mapped for a wide variety of organisms including humans, it is easy to see how the very simple A-T-C-G combinatory sequence came to be conflated with the 0s and 1s of software coding such that we could begin to imagine life itself as code and life itself as therefore programmable.

We are awakening to a powerful new era of managing evolution on a planetary scale. Where biology is an organic, messy and evolving set of processes, engineering is saturated in a sense of human agency and control, predictable, repeatable results of manageable processes. An engineer sees the world as mechanism which can be discreetly understood and controlled for responses that will not change when parts are removed from their context. This grounding is antithetical to our understanding of organisms and living systems. The complexity of living systems demands that we pay attention to dynamics that exist between and among parts within the system. Those parts cannot be parsed from the whole without potentially changing the way that they interact and operate in the world. With that understanding, what does it mean to create a 'biological toolbox' from which to pull resources in the creation of new and novel biological-technological combinations? When we embrace an understanding of biological complexity, the idea of engineering consistent genetic responses begins to

seem radically naive. The thing-power, to quote political theorist Jane Bennett, of these new novel creations is borderless and transcends traditional efforts at boundary making that inform our existing governance structures.

This milieu of capital, reductionism, mechanism and techno-optimism allows the birth of synthetic biology to feel almost predestined. That it was simply a matter of time before someone would bring together these diverse forces to create this particular configuration of scientific practices. In contrast, this research would like to question the usefulness of a bio-science based on these particular forces and their combination. Would it be possible to instead imagine a way of working-with life rather than doing-to life that would be both more productive and more just? A new set of practices based in a different set of ontological underpinnings and governed by a different set of ethical foundations? Instead of capital driven science that believes life is programmable and re-writable, might we find a way towards a decolonized biotechnology that imagines life as outside of the grasp of human ownership, that embraces a humility which exposes the myth of 'miracle technology'? Divorced from market pressures and capital driven flows, these scientific practices would demand open source information and an end to politically neutral techno-optimism. This path would support a velocity of governance that intentionally tempers the arguably reckless velocity of robot driven, artificial intelligence powered wet-ware labs where speed and competition drive innovation in unsustainable ways. Could we find a way to 'love our monsters,' and support responsible innovation whereby an inventor is responsible for the success, failure and unintended consequences of their invention over their lifetime? Bruno Latour's call to love the 'monsters' of our technological invention is one radical response to the rapid

and largely hubristic nature of modern-day biotechnology. As Latour argues, “Dr. Frankenstein's crime was not that he invented a creature through some combination of hubris and high technology, but rather that he *abandoned the creature to itself*.” (Latour, 2012) For Latour, the critical failure is not that we have failed to care for the world itself but that we have failed to care for our very own technological creations and the havoc they have subsequently wreaked upon the world. Like the monster in Frankenstein, we abandon our creations with the velocity of a capital driven fury, determined by the pressures of markets to continually produce and capitalize upon innovation. There is no reciprocity, there is no accountability built into this system of governance. In a world where we are rapidly approaching the capacity to ‘design evolution,’ this situation presents a number of inherent and real dangers for future generations. Rather than seeing ourselves as separate from or superior to Nature, a new political ecology would embrace the human as an always becoming process “ever-more attached to, and intimate with, a panoply of nonhuman natures.” (Latour, 2012)

Political theorist Eugene Thacker argues, “The situation is complex enough that it invites a perspective that sees not the machine opposed to the human, and not the artificial opposed to the natural, but a particular instance in which the ‘bio’ is transformatively mediated by the ‘tech,’ so that the ‘bio’ reemerges more fully biological.” (Thacker, 2004, 6) Synthetic biology is a field of research that expands the reach of private property to biological life, effectively allowing biology to be captured, synthetically reproduced and commodified. What responses and structures are necessary to manage the radical and inherently unknowable possibilities of the futures of gene editing? (Zhang et al, 2011, 5) This research will argue that we need to engage

with practitioners of Indigenous sciences and to begin the decolonization of synthetic biology, so that it can be a science that decenters the human and sees the capacity to design evolution as a responsibility, not a right. The ethics of such a scientific practice would embrace the foundational principles of immersive knowledge production, reciprocity, humility and open-source knowledge sharing. The decolonization of synthetic biology requires stringent attention to language as the source of a values driven science that takes seriously the agency of non-human actors in a system. The words we choose create the world we experience, and a decolonized science will consider who is involved in the production of knowledge, who is left out and how decisions are made to ensure that those who have been historically marginalized, non-humans and humans alike, have a stake in the futures.

At present, both the experimental and the aesthetic nature of synthetic biological research play a part in the evolution of newly formed and living things. There is a palpable excitement and mystique around the notion of mythical beings, chimeras made from parts of other beings, and extinct animals resurrected from history. There is a natural aesthetic tendency to embrace the fantastical visions of science fiction and mask the political realities of a world governed by capital flows and their entrenched inequalities. The problems we face in the 21st century will never be solved by technology alone. And the efforts and attempts to control, own, manage and commodify these new forms of life are likely be ultimately undermined by the self-replicating nature of the creations themselves. If we are not prepared and committed to love and care for our creations, the effects of their insistent agency have the potential to be catastrophic.

In concert with the call to ‘love your monsters,’ Latour’s call to slowness as a tool

for navigating this new world asks us to profoundly reinterpret our relationship to innovation. Imagine a world where, “the production of hybrids, by becoming explicit and collective, becomes the object of an enlarged democracy that regulates or slows down its cadence.” (Latour, 1993, 141) How would investment in a paradigm rooted in slowness, and careful, considerate, constant selection of bio-technological hybrids reform our relationship to scientific practices? I would argue for the necessity of a generous and radically just politics to temper the potential of governing evolution. When we envision the capacity for these technologies to make our lives and the world ‘better’ we have to immediately demand, ‘better’ for whom? Engaging with indigenous scholars and scientists to decolonize the practices and discourse of synthetic biology would offer a pathway embedded with the foundational values of equity, justice and genealogical responsibility (past and future) that are necessary to attempt a future that is better for more people and non-human life.

Within the practice of synthetic biology today, there already exists a distinct tension between on one side, calls for open source science, particularly when it comes to the controversial nature of heritable gene drives, and on the other side the emerging and booming bioeconomy, which is anchored in a state-sponsored effort to translate all aspects of life all the way down through ideologies and logics of capital. If we counter the mechanistic worldview with one of a new animism where non-human beings have real power and agency, we will see that these relationships and entanglements demand a different kind of respect and reciprocity. One that sees the human as one part of a much larger inter-species project that is known as carbon-based, biological life.

Trends and emerging issues in the realm of biotechnology are rapidly evolving and difficult to pin down in any static document. Every day there are new stories of the breakthroughs happening in editing technologies, gene sequencing technologies, and the swiftly dropping price of gene coding done ever faster by robotics and algorithms. This research aims to nail down a deeper ontological discussion of the practices of the science. To bring into focus the ways in which current political and economic systems are not capable of ensuring that synthetic biology will be used to the benefit of humanity and the planet. It aims to expose and look honestly at the type of world-building that exists at the confluence of capital and mechanism that will only serve to more deeply entrench and amplify the inequalities and injustice that are becoming hallmark of the 21st century. And it endeavors to explore the potential futures that exist when we combine multiple emerging disruptive technologies like CRISPR Cas-9 with the simultaneous rise of machine learning and big data and place these technologies within existing political power structures, increasing environmental unraveling, rapacious capitalism and social inequality. It also attempts to open conversations around other ways of knowing, other epistemologies, that may offer modes of interacting with non-humans and the nonliving matter of the world that shift the current imbalance of power, which is unsustainably concentrated in the hands of an elite few, and instead enable greater flourishing and greater equality for more of the planet and more of humanity. Within this exploration, it is my hope that we may find an inherently just and productive path forward for synthetic biology. One that truly embraces the flourishing of both human and non-human as its core mission. Pandora's box has been opened. Now we

must learn to talk to the spirits we have already unleashed and do our best to make fast friends.

Redefining the 'natural'

I want to begin to expand some previous notions of naturalness while also examining the nature-culture split that defines the 'modern' era. As Geographer Yi-Fu Tuan explains, it has always been the delineation between chaos and order that frame the nature-society divide: "the biological, the raw and the instinctive, the unconscious and the primordial are attributed to nature; and form and order, consciousness and deliberation, the developed and achieved ideal are attributed to culture." (Tuan, 1993, 8) For Bruno Latour, the manufactured nature-society split was paradoxically cause for greater relationality between the two spheres so that, "The less moderns think they are blended, the more they blend. The more science is absolutely pure, the more it is intimately bound up with the fabric of society." (Latour, 1993, 43) In his reading of Plato's *Allegory of the Cave*, Latour demonstrates the ways in which modern culture has rendered *S*cience and *N*ature unintelligible such that the average person is forced to rely upon the translations of experts in order to make the world around him/her intelligible. (Latour, 2004, 10) "Only experts are fully equipped to explore the world of nature, reporting their findings back to the political world in incontestable form." (Mitchell, 2011, 246) Denying everyday humans the ability to interpret their world and elevating *S*cience to the level of *T*ruth and *N*ature to the level of *L*aw has had profound consequences. Engaging with indigenous ways of knowing which embrace multiple paths to knowledge creation and relating more intentionally with the other-than-human

world, we may begin to craft a politics that de-centers the human and makes room for resilient and abundant life forms with an ethics of compassion and aesthetic inter-species conversations. When I say aesthetic inter-species conversations, I mean to propose that it is not outlandish to argue that the beauty or legibility of a non-human form is precisely its way of communicating ethical relationalities. Which is to say that there is an important and legible message being conveyed by a flower's color and scent, the patterns of a brightly colored fish, or a massive pile of plastic decomposing in the ocean. This idea expressly challenges the prevailing belief in the modern world that "The facts of nature speak only with the help of measuring devices and tools of calculation." (Mitchell, 2011, 233) Along with Mitchell, Latour and others I would argue that it is this belief in the cold, hard irrefutable 'facts of nature' that is greatly responsible for the mounting environmental catastrophes we face today.

Understanding the 'synthetic'

At the most basic level, the concept of 'synthetic' is grounded in the actual process of synthesis, a combination of objects/subjects that were not previously combined in that particular way. At this level of understanding, 'synthetic' can perhaps be best understood through the visage of Latour's 'hybrids,' precisely those creations that arise from the productions of the nature-society divide and which become 'monstrous' as they are unable to be traced, remaining elusive from the public sphere. (Latour, 1993, 42) Synthetic biology proposes the synthesis of new or revised genomic language at the level of cellular function, designed by and optimized for humans.

The meshing of counterproductive paradigms, precisely the organic and evolutionary aspects of nature with the static, controlled and designable aspects of

engineering potentially creates a new kind of hybrid that is ultimately capable of producing its own iterations beyond the scope and capacity of its original synthesis. With gene drive technologies, where heritable traits could be designed and edited using CRISPR technologies, the ramifications for future generations are both unknowable and potentially huge. We may discover that the utopian metaphor of a 'tool box' of biological components, which can be infinitely combined, synthesized and crafted to engineer new life forms is naïve at best and potentially catastrophic. Timothy Mitchell challenges us to acknowledge the messy nature of reality, the ultimate uncontrollability of hybrids that possess their own power and politics beyond the agency of human bodies; "our world is an entanglement of technical, technical, natural and human elements. Any technical apparatus or social process combines different kinds of materials and forces, involving various combinations of human cognition, mechanical power, chance, stored memory, self-acting mechanisms, organic matter and more." (Mitchell, 2011, 239) To understand the synthetic and the processes of synthesis we must first understand the cacophony of agents, human and non-human, living and nonliving, involved in the birth of every hybrid synthetic being.

The practices of synthetic biology must absorb and ingest a deep understanding of porosity, the power of the 'its' and the concepts of both "scientific uncertainty and cross borderness." (Zhang et al, 2011, 5) Bennett's ideas around porosity are especially useful when thinking of the relationalities and power of human and non-human objects. We know that the human body is porous. We pass massive amounts of material, chemicals, microbiotic organisms etc. through our skin alone. We can also consider activities like breathing, ingesting, excrement and the porosity of each cell down to the

very most micro of levels. This porosity does not know boundaries and is indifferent to the governance structures of the human political and in many cases indifferent to the human. There is a constant and consistent exchange of information and material between human and non-human bodies. We are never apart from the rest of the world, but instead *made of it*. The nature of this ubiquitous and relatively indifferent porosity is tied to what Bennett calls the 'power of the its.' Things have power, not least because of their porosity and incessant interaction with other bodies. (Bennett, 2011)

Indigenous Sciences

The prescient realities of thing-power have ramifications for humans and human agency that we are just beginning to uncover and understand, but which, it can be argued, have long been understood by Indigenous cultures. Indigenous scientific practices, while notably as diverse as the cultures from which they originate, hold certain core principles in common. There is a sacred connection to the other than human world that transcends anthropomorphism and embraces a lived experience of non-human forms as powerful and possessing tangible agency. Rocks, the wind, sharks and supernatural phenomenon all hold a significant place in the experience of knowledge formation. There is also a commitment to phenomenological knowledge creation; knowledge is gathered and carefully tended over long periods of time through lived experience and tangible interaction with the world. Knowledge is also reciprocal, the scientist is changed equally as the object of science is changed and altered in the encounters over time. And knowledge is both ancestral and futured. The knowledge of the ancestors is highly valued and the new knowledge produced is seen as a significant

responsibility to future generations. There is a commitment to care for and shepherd one's creations as if they were familial and thus treasured. This formation of science embodies an inherent resistance to technologies of extraction and an allergy towards practices of commodification. As Noenoe Silva and Jon Goldberg-Hiller explain, the Hawaiians have a concept called *kino lau* that addresses the interaction and relationality between and within human and non-human bodies. They specifically address the "cultural distinction between beings that have kino lau (which we translate as having many bodies—human and nonhuman) and beings that remain within a given body," such that a plant, rock or animal can actually hold genealogical ties and material significance to humans. (Goldberg-Hiller & Silva, 2011, 431) In Chapter 4, this research will explore the history and implications of what is known as biopiracy and biocolonialism. The practice of colonial technologies of erasure and capture applied to biological material and biological information such as DNA.

It will also explore the possibilities of decolonized biotechnology as a means to advance an ethics that is more capable of responsibly governing evolution. The decolonization of science is a participatory process deeply invested in values of responsibility to others in both time and space (past and future), intention and attention linguistically and practically to those who have been left out or behind and an attention to the multiplicity of sense-making possibilities employed in diverse forms of knowledge creation. Such that knowledge gained from a dream can be considered as important as knowledge gained from a repeated visual encounter of a thing/being or a physical measurement of material over time. A commitment to heterogeneous and diverse forms of knowledge production is necessary to ride the unpredictable tsunamis of systems collapse that are

guaranteed as our climate continues to change – increasing widespread resource scarcity, weather-driven disasters and ensuing political unrest.

The Meaning Machine

This research argues that we might begin to think about the forces at work in the field of synthetic biology as a newly found 21st century meaning machine. A process and set of practices by which we, in this case literally, make new meaning of constituent parts in order to help form new kinds of scientific subjects. In her essay *Teddy Bear Patriarchy*, Donna Haraway uses the deconstruction of a museum diorama to unpack the forces of colonialism, patriarchy, power and the relationships between man, science and the nonhuman other in the form of a socially constructed 'nature.' With the diorama positioned as it was: a "meaning-machine," she argues that "machines are maps of power, arrested moments of social relations that in turn threaten to govern the living." (Haraway, 1994, 54) Employing a 'literal reading' of scientific practices in the American museums of the early 1900's, Haraway demonstrates the opaque and ever present ironies of intention, realism, colonialism, patriarchy and control that were present in early 20th century science and that persist in the biosciences today. Using this methodology to expose the forces of scientific reductionism along with Haraway's vision of the *cyborg* that is "a hybrid of machine and organism, a creature of social reality as well as a creature of fiction," I want to propose a re-investment in human/nonhuman entanglement as a political intervention and I want to suggest that we can engage the thinking and methodologies of indigenous and animist sciences to achieve the necessary rebalancing with nonhuman intelligences. (Haraway, 1994, 3) This re-investment is critical to counter the ways that synthetic biology aims to decontextualize

and distance crucial relationships between humans and non-humans. When we begin to fully understand the entanglement of bodies, we are less likely to cause violence against a perceived other. We would be less likely to leave our creations to their own devices, abandoning them to the greater wilds without education and care – simply because in them we would now see true reflections of their complexity. To bring this discussion into focus, let's employ two useful metaphorical frames: Hunters, Collectors and Chimeras; and Synthetic Authorship and Cyborg Ironies.

Hunters, Collectors and Chimeras

"For example, the gene responsible for giving light to a firefly, that green luminescence, we know the software code of this particular gene, so you don't have to cut it out of a firefly anymore. You can just look that code up and order it from a specialized company."

~Rinie va Est (2013, 12)

"Taxidermy was made into the servant of the 'real.' Artifactual children, better than life, were birthed from dead matter."

~ Haraway (1989, 38)

The long history of collecting for the purpose of studying, understanding, capturing, rendering inanimate and then reproducing nature is intricately interwoven with the histories of colonialism, imperialism, ideologies of patriarchy and paternalism and the making of the modern world. Like Haraway's accounting of (in)famous taxidermist Carl Akeley's "dream of collecting gorillas" in order to protect and preserve them for posterity, the synthetic biologists of the 21st century dream of collecting, cataloging and preserving DNA code for the purposes of modernity. But synthetic biologists take this charge one crucial step further. While Akeley's vision was one of

isolating and freezing in time a perfect specimen, bioscientists today aim to understand life as a series of codes. Information that is readable, writable and revise-able. Once we understand and can transcribe these codes, technologies like CRISPR open the possibility to recombine codes of life. In this way, we suddenly have the capacity to create infinite chimeras, ideally in service of a 'better world'. Who wins and who loses in this estimation of 'better?' When we use CRISPR to engineer human/pig chimeras for growing human replacement organs, we place a moral value on what is better. When we use CRISPR to create life altering gene therapies that counteract rare and devastating genetic diseases, but place those therapies in an economic and political health care system that favors certain citizens over others, we place another moral value on what is better and who is given access.

The drives to collect and to design, are situated and grounded by a 'notion of perfection' that appears to transcend the materiality of the world. (Haraway, 1989, 40) When we render life inanimate through collection and taxidermy, or when we reshape life through human driven design we are ultimately aiming to remove the messy, contingent aspects of life. We aim to render life perfect. For Akeley and the collectors of his time, the perfect specimen was always an adult male. (Haraway, 1989, 40) Perfection too is not without its politics.

Where the taxidermist deals in representation of nonhumans made inanimate, the 21st century synthetic biologist has embraced the added challenge and desire to control, reshape and manage vitality. New materialist political theorist Jane Bennet argues that:

> "By 'vitality' I mean the capacity of things – edibles, commodities, storms, metals – not only to impede or block the will and designs of humans but also to act as quasi agents or forces with trajectories, propensities, or tendencies of their own." (Bennett, 2010, vii)

If James Beniger is right and "Purposive organization and control…define the tangible discontinuity that distinguishes life from the inorganic universe." (Beniger, 1989, 35) then how do we reconcile the unintended consequences of undeniable political realities when humans control and command vitality? And what is the role of non-life, entities that were never and will never be living but with which we are nonetheless enmeshed? One can think of rocks, the weather, chemicals and metals. All of which structurally and actually shape and inform both our world and our relations within and between species. For Povinelli, there is a distinct and important division between "those things that are saturated with actuality when they arrive in existence (Nonlife, inanimate things) and those defined by an inner dynamic potentiality at birth (Life, animated things)." (Povinelli, 2016, 47) What are the ramifications of synthetic life on both life and non-life with which it interacts and depends? One can imagine the confluence of geoengineering, the current technologies which aim to manage and control the earth's environment on a global scale, and synthetic biology. Where the weather becomes populated by human designed beings crisscrossing traditional political boundary lines of the nation state to create new forms of conflict and war through the control of weather. Politically induced droughts, floods or even locust swarms all become possible. What spaces do these technologies open for international relations and security studies?

Think of the image of the ‘hunter as collector’. Traditionally, the hunter, in order to meet with success, narrows their vision, tuning all senses to the hunt and the prey, creating a tunnel of experience that minimizes sight while metaphysically incorporating the whole - employing a perspective that on some level incorporates the consciousness of animal into one’s being. For the modern hunter turned collector, the goal is not sustenance of a physical kind and the reverence offered is not self-conscious. Rather, the aim is to kill in order to preserve, reconstitute, decontextualize, re-contextualize and ultimately reanimate in a controlled environment - and in that process let loose potentialities that amplify chosen and predetermined effects. For Akeley, the taxidermist and collector, “Perfection inhered in the animal itself, but the fullest meanings of perfection inhered in the meeting of animal and man, the moment of perfect vision, of rebirth.” (Haraway, 1989, 41) The hunter as collector is emboldened with dreams of coloniality, patriarchal duty and empire’s calling all in humble service of the public interest. He is lulled by visions of grandeur into somnabulence, unable to witness his ultimate irony. On his quest to sequence all the genomes of the world, Craig Venter set out on the *Sorcerer II* in 2008, a luxury yacht turned scientific vessel. “Bald, bearded and buck naked” on a remote island atoll, hunting and collecting species to extract their DNA, Venter the ‘maverick’ envisioned himself as a critical link in the long lineage of voyagers like Darwin musing that, “We will be able to extrapolate about all life from this survey, this will put everything Darwin missed into context." (http://archive.wired.com/wired/archive/12.08/venter.html) The violences of the hunter/collector’s quest are obscured for those involved. This figure cannot envision itself as anything other than heroic and necessary and is unable to see those left out or

left behind. Leaving trails of waste in his wake, the hunter/collector can only imagine his revered place in history and the duty to which he calls. A call that simply must be answered. The calloused nature of the collector is staged as bravery but often lived as cowardice. For Carl Akeley, the collector in Haraway's analysis, killing the gorilla who was running away from him became an act of courage and wisdom for "The animals must be wary of new hunters; collecting might be very difficult." (Haraway, 1989, 33) The laser focus on the heralded task of collecting obscures and masks the damage caused. Trajectories of preservation, reanimation in service of public good and progress become the only obsession. "Scientific knowledge canceled death; only death before knowledge was final, an abortive act in the natural history of progress." (Haraway, 1989, 34) Today we have multiple efforts rushing forth to collect and save the genetic print of life: from Russia's massive project dubbed *Noah's Ark*, to the US National Museum of Natural History's *Global Genome Initiative*, the *Millennium Seed Bank* project, San Diego Zoo's *Frozen Zoo*, to the British *Frozen Ark* project led by a consortium of museums zoos and other institutions. The fact that these initiatives are run by museums and zoos in the developed world is no coincidence. There is a complex political ecology at work that masks the ever-present reality of embedded colonial and imperial violences. What remains invisible and unaddressed is the cacophony of assemblages that conspired to create a world where preservation has become necessary for survival. "Once domination is complete, conservation is urgent. But perhaps preservation comes too late." (Haraway, 1989, 34) Today, the discourse in gene editing circles easily turns to de-extinction, a once radical concept whereby extinct species are 'brought back to life' via genetic replication of ancient DNA mixed with modern day cousin-species

utilizing CRISPR technologies. Whether to absolve human guilt about the conditions that led to a species' extinction, or to satisfy the novel curiosity of invention, or born of a true desire to repair relations with the nonhuman 'other' wronged by human doings, de-extinction is to the 21st century what taxidermy was to the 20th. We could one day witness a living museum populated by 'beasts' from the long extinct past in an excessive display of humanity's desire for mastery and restitution. (Church, 2012; Carlin 2014; Friese, 2014; Sandler, 2014)

Questioning the telos of the modern project, Bruno Latour argues, "The shaft is broken: on the left they have put knowledge of things; on the right, power and human politics." (Latour, 1993, 3) This separation has made modernity ultimately incomprehensible and obscured the political and economic nature of scientific discovery and scientific practice. It has brought us to a world where it would make sense to genetically engineer a more efficient cow to stuff into more densely packed CAFO's (Confined Animal Feeding Operations) despite all that we know about the horrific suffering these animals endure, the pollution created and the inherently unsustainable practice of every day meat eating culture. We now live in a world where we are actively destroying our capacity to survive because of an insane commitment to a rapacious form of capitalism. One which requires ceaseless extraction and consumption. Reductionist sciences argue for an apolitical stance: that 'facts' simply exist in a natural state of being and can be ultimately known if one is to look in the right ways and in the right places. The twin beliefs in the truth-finding power of the scientific gaze and in reality as 'ultimately knowable' have led to a world of multiple and cascading systems collapse. Inequality, climate change, food insecurity, overpopulation, species extinction

and water shortage are just some of the crises converging in our time. The Anthropocentric illusion is that we can manage *nature as capital* in a way that will still allow for human and nonhuman flourishing. Normative science retains this illusion without embracing its politics. Bonaventura de Sousa Santos calls this *orthopedic* thinking, where all things are measured through the epistemology of science such that certain aspects of cosmology (consciousness, spirit) that cannot conform to scientific inquiry are simply crippled and left out of the conversation. (Santos, 2014) The foundation of this ontology, the hunter/collector's ethos, rests in what Latour calls 'matters of fact' and 'matters of concern.' (Latour, 1993) The idea that we "know the nature of facts because we have developed them in circumstances that are under our complete control." (Latour, 1993, 18) The expert, the scientist, the taxidermist, the collector, these figures serve as translators bridging the semiotic divide between human and nonhuman with a language that is ultimately incomprehensible to both and legible only to the privileged. In such a world, we will eventually find that our technologies and innovations once seen as a panacea of solutions, in actuality and over time, serve to deepen inequalities, amplify the suffering of the poor and hasten the destruction of planetary systems.

By 'translating the silent behavior of objects,' the expert scientist becomes the intermediary between human and nonhuman such that:

> "The representation of nonhumans belongs to science, but science is not allowed to appeal to politics; the representation of citizens belongs to politics, but politics is not allowed to have any relation to the nonhumans produced and mobilized by science and technology." (Latour, 1993, 28)

When we relegate the practice of science to the scientific expert, the ability to translate the languages of objects is taken away from the average person. Where in many indigenous and animist cultures, critical observation, ancestral practice and access to various forms of knowledge is available to anyone, western science has obscured our relation to the rest of the world through the lens of inaccessible and privileged access to one form of normative, sanctioned knowledge.

This brings us to the character of the chimera, the 'necessary monsters' that figure largely in our time and into the futures. (Borges, 2006) These are Haraway's cyborgs, Latour's hybrid assemblages, the were-beings of human/nonhuman/technological complex entanglements. (Haraway, 1994; Latour 1993) For Haraway, the cyborg blurs distinctions between "natural and artificial, mind and body, self-developing and externally designed." (Haraway, 1994, 10) Our concern with the figure of the chimera is the issue of decontextualization. For synthetic biology, this decontextualization has manifested in extreme form as the 'engineering of biology.' Despite disagreements over the exact definition of synthetic biology, there are certain aspects that retain popular support - that it exists at the intersection of science, engineering and design and that it produces beings which exhibit functions not found in 'nature.' Here are two of the most oft cited definitions:

SynBio is the application of science, technology and engineering to facilitate and accelerate the design, manufacture and/or modification of genetic materials in living organisms. European Commission – Opinion on Synthetic Biology I, 2014

Synthetic biology is the engineering of biology: the synthesis of complex, biologically based (or inspired) systems which display functions that do not exist in nature. This engineering perspective may be applied at all levels of the hierarchy of biological structures – from individual molecules to whole cells, tissues and organisms. In essence, synthetic biology will enable the design of 'biological systems' in a rational and systematic way. NEST High Level Working Group, 2005

With the engineering of biology, genetic material is envisioned as the most basic and foundational component of life. DNA sequences are reduced to readable 'code,' a genetic language imagined as parts to be separated, removed from their wholes, disaggregated, standardized and distilled for recombination: plug and play. The metaphor of the readable code ignores the realities of gene expression. In many cases, the same gene will express itself differently or at different intensities across organisms and even across time. The assumption that genetic code can be consistently 'read', like a static book, is simply not reality.

At its foundation, this is an industrialist imaginary of 'living factories' – "the translation of the world into a problem of coding, a search for a common language in which all resistance to instrumental control disappears and all heterogeneity can be submitted to disassembly, reassembly, investment and exchange." (Haraway, 1994, 39) Just as the taxidermist is captivated by the quest for the 'perfect specimen,' synthetic biologists are motivated to design perfection and predictability into otherwise messy, highly contingent and unpredictable biological beings who exhibit agency. Synthetic biology holds as the ultimate goal, the engineering standards of standardization and replicability. Today, we can browse the Registry of Standard Biological Parts catalog to find: "Well documented parts; Frequently used parts; All the parts:" standards, codes, parts and pieces. (parts.igem.org)

Chapter 2, *Necromaterialism*, will examine the consequences of living in a world of media saturated with affects of both real and perceived precarity. When we perceive the world to be falling apart around us, to what lengths will we go to preserve what's

left? When we begin to design for death, how far can the weaponization of life forms take us?

The chimera born of synthetic biology is subject to a periscope logic whereby discreet parts can be unmade and remade into a new whole with a hybrid and programmed purpose. (Latour, 2103) Synthetic biologists "impose the logic of tiny machines upon the materiality of biological systems, they do not account for the non-equilibrium state of biology." (Armstrong, 2013) BioBricks and the Registry of Standard Biological Parts are the most visible organizations aiming to democratize this genetic decontextualization in an effort that they imagine will "ensure that the engineering of biology is conducted in an open and ethical manner to benefit all people and the planet." (http://biobricks.org/about-foundation/) Gregory Bateson and others saw the flaw in this category mistake, arguing that "children in school are still taught nonsense…That is, they are taught at a tender age that the way to define something is by what it supposedly *is* in itself, not by its relation to other things." (Bateson, 1979, 16-17) There is a sense that the chimera as engineered creation is the ultimate manifestation of capitalist destiny, such that "Modern production seems like a dream of cyborg colonization work," and the "new Leviathan signals an end to the illusion of technology as human beings exercising control over nature, rather than the other way around." (Haraway, 1994, 4; Dyson, 2013, 41) Chapter 3, *Who Owns Emergence?*, explores this question: What happens if all we get from these technologies is more efficient means of rapacious extraction and production, more efficient CAFO's (Confined Animal Feeding Operations) or massive pig organ farms with which to destroy resources and improve the lives of a privileged few with ever more reckless velocity? Is there a significant

difference or even distance between the design and the designer? How does the sovereignty of the synthetically produced being ultimately disrupt what we intend to do with it? Even Venter, a founder of the field, openly admits that there is at least 10% of any DNA sequence that defies understanding (SynBio Beta, 2014). What is to be done with that modicum of sovereignty that genes are unwilling to concede in an era that seeks to control biology through engineering? Might we be engaged in the greatest mistake of all: the search for a technological holy grail.

Synthetic Authorship and Cyborg Ironies

"At the center of my ironic faith, my blasphemy, is the image of the cyborg."
~ Haraway (1994)

"Taxidermy became the art most suited to the epistemological and aesthetic stance of realism. The power of this stance is in its magical effects: what is so painfully constructed appears effortlessly, spontaneously found, discovered, simply there if one will only look."
~ Haraway (1989)

For the synthetic biologist, vitalism is ever present and always futuring but that only heightens the stakes of control. The image of taxidermy is useful because of its investment in careful, precise artifice and controlled management as a measure of success. The replication and reproduction of 'realism' become the ultimate aim of the taxidermist. For the synthetic biologist, the precise artifice of taxidermy merges with the controlled cultivation and management of animal husbandry. Reproduction and replication become means towards an end whereby 'realism' is enhanced, made better through human control of myriad nonhuman entities. For both, artifice is the tool of precise creativity. Defined by its mode of cunning, where design and the designer's influence cease to be visible, perfected artifice is the aim of engineering biology.

Carl Akeley's accounts, from hunting/collecting in Africa through reproduction in the museum diorama, underscore the intensity of synthetic authorship. The painstaking work of artificial reproduction in the case of taxidermy, "requires a complex system of coordination and division of labor, beginning in the field during the hunting of the animals and culminating in a finished diorama." (Haraway, 1989, 39) In the field of synthetic biology and genetic engineering in general, the replication, reproduction and reprogramming of biological beings is beset with high failure rates, intense experimentation, massive amounts of energy expenditure (human and material), intense amounts of capital (again human and material), and a complex array of intersecting and contingent systems, forces and capacities that all form a variety of assemblages which hide their political natures behind a veil of scientific objectivity. One of the latest trends in synthetic biology is the 'cloud laboratory.' Companies like Teselagen, Transcriptic and DNA 2.0 employ algorithms and robotic machinery to accelerate genetic experimentation and synthetic DNA code sequencing in 'cloud laboratories.' These mythical spaces allow scientist to become purely designer: pulling DNA codes from massive shared databases, remixing sequences into new hybrids to be uploaded, sent over the Internet and tested in the remote 'wet-ware' lab with results returned online. Methodologically the idea is to stop trying to understand what you're doing (mechanistic thinking) and instead let the data (of big data) tell you what you're doing (machine learning). (speech by Claes Gustafsson of DNA 2.0, 2014) The illusion of the 'cloud' in this trend, mimicking the illusion of 'cloud computing,' makes the design and execution of synthetic authorship both opaque and invisible, in fact the hallmark of *good* design is precisely its ability to go unnoticed: "We're living in a time when design becomes

invisible. We're designing at the scale of atoms and genes." (Van Mensvoort, 2013, 107) When consumers purchased the 'green' product Ecover there was no way for them to be aware of the fact that the algae oil contained within was made using synthetic biology. In this case and many others, as a result of the complexity of modern production and mediation, design has been rendered invisible. (http://www.theguardian.com/science/political-science/2014/jul/08/what-syn-a-name) For Latour this is a dangerous proposition. "Technology, for its part, seeks to be forgotten. Definitely, it is about technology rather than nature that we can say, 'it likes to hide.'" (Latour 2013, 217) The invisibility hides experimentation on the nonhuman entities we place at our service. This disconnection is tied to fantasies of ultimate perfection at any cost and is driven by the engines of capital flows and the utilitarian use-value of nonhumans for human ends. What the opacity of process and the invisibility of design most dangerously obscure is the material reality of unintended consequence, "since technologies follow such twisted paths that they leave in their wake all sorts of other invisibles: danger, waste, pollution, a whole new labyrinth of unintended consequences." (Latour, 2013, 221) In search of technical answers to material problems we forget (at our peril) the "invisibles of technology – deviations, labyrinths, workarounds, serendipitous discoveries" and I would add to this list – politics! (Latour, 2013, 220) It takes numerous tries with manifold failures to produce a viable being in the process of genetic engineering. The ubiquitous myth of 'genetic engineering precision' is based in a flawed techno-optimism and an idealized view of nature, which proclaims existence of a genetic 'code' and a unitary 'gene' that can be translated and

transcribed. (McAfee, 2003) All of these myths are ultimately tied to the interests of transnational biotech corporations.

The process of making human/nonhuman assemblages 'invisible' is the dangerous proposition of 21st century synthetic authorship. This visceral disconnection of a being from its source amounts to a 21st century form of biopiracy and settler biocolonialism. In Chapter 4, *Decolonizing Synthetic Biology*, I will explore the history of these practices and the ways in which they have morphed and cemented themselves in the capitalist version of synthetic biology. How might other forms of knowledge and other ontologies, other forms of science, inform a different sort of genetic authorship? How can we attend to those who have been left behind in the race to a globalized world? And how might indigenous scientists lead the way towards a more robust ethics and participatory governance of evolution's design?

Build Life to Understand It is the title of a 2010 article that outlined the turn in biosciences from a focus on 'natural organisms' to 'potential organisms.' (Elowitz & Lim, 2010) The idea that it is *possible* to understand 'life' and then that it is equally as possible to recreate and reengineer nonhumans to do our bidding is at the very heart of synthetic biology as a scientific discipline. More information does not necessarily equal more knowledge. (Latour, 1993) And it most certainly does not equal greater ethical commitments. In Chapter 5, *A foundational ethics for designing evolution*, I will look at the ways in which fields like Spiritual Ecology and Indigenous Politics can help to inform robust ethical commitments for the field of synthetic biology. Commitments that offer a chance of using these disruptive technologies for the greater good and to amend the historical traumas of colonial erasure and extractive capitalism. The reductionist science

that has brought us to this historical moment stands in opposition to what I would term an animistic notion of 'becoming' and the commitment to this reductionism has blinded science to the realities of vitalism. I agree with Armstrong that, "Cells possess a 'will' of their own with unique qualities that cannot be encapsulated by mechanical systems, such as resilience, flexibility and the capacity to 'surprise.'" (Armstrong, 113, 2013) Synthetic authorship in the 21st century of biotechnology has predominately chosen to stand on the side of reductionist science; believing that nonhumans can be understood by dissecting, examining and deterritorializing their component parts at the most basic level of genetic function. In contrast, animism as defined by anthropologist Tim Ingold holds that "beings do not propel themselves across a ready-made world, but rather issue forth through a world-in-formation, along the lines of their relationships." (Ingold, 2006, 9) In the animist life-world, beings can never be fully understood as discreet objects as they are always already both contingent and becoming. This becoming-ness of being is critical as we think through the relationship of synthetic biology to nonhuman life forms. By removing context and isolating biological building blocks to be reassembled in novel forms, we assume that there is an essential formula to 'life' that can be deciphered, translated, transcribed and reinscribed.

Animism shows us otherwise; where animism is "the dynamic, transformative potential of the entire field of relations within which beings of all kinds, more or less person-like or thing-like, continually and reciprocally bring one another into existence." (Ingold, 2006, 10) The creative possibilities of co-creation and co-authorship with other modes of being are lost in a world that seeks to engineer life by removing context and parsing out its most basic components. The legibility of modern biotechnologies, notably

synthetic biology, is tied to the illusion of genetic control and precision referenced earlier. By turning nonhuman beings into component parts, we have created a mythology that in very real ways determines the types of beings synthetically authored. Paul Rabinow explains that, “How things come into existence – are named, sustained, distributed, and modified – is an issue of primary importance for many scientific disciplines, especially for synthetic biology, whose goal is precisely the creation of such objects.” (Rabinow, 2014, 4) And as Jane Calvert asserts, synthetic biologists would be wise to not underestimate their ability to “turn tropes into worlds.” (Calvert, 2012) In this way metaphors are incredibly performative of a certain micropolitics that through processes of synthetic biology is inscribed on nonhuman lifeforms. The micropolitics of synthetic authorship is currently informed by market forces that demand any new product be monetized and sent into transnational capital flows. There is no space held open for creations that don’t fit these parameters; creations that challenge existing power structures or which merely make life better for more people and the planet.

For social scientists, artists, futurists and visionaries the response to this reductionist trend must be to open new spaces of possibility and discussions of vitality. “If science is about closing down variables to find the truth, a role of fiction and narrative is to create many versions of the truth, to open up space to find new questions and ideas.” In the final Chapter, *Imagining Alternative Futures*, I will explore some of these future imaginaries and their consequences. (www.daisyginsberg.com/work/irrational-genome-design-contest)

The agency of creation…

In a conversation with John Glass from the J.Craig Venter Institute, a leading synthetic biology laboratory, Rachel Armstrong, who views her work as an extension of synthetic chemistry, outlines the bifurcation between gene centric and biosynthetic science in the field of synthetic biology. Where gene centric synthetic biologists adhere to the notion of precision engineering of discreet genes which lack agency, proponents of biosynthesis work with powers of self-assembly and "processes such as 'metabolisms' that form 'agents,' which possess forces that work independently from human intent." (Armstrong, 2013, 115) Messier, contingent and unpredictable, this arm of synthetic biology embraces process and agency in novel ways. This type of creation is hard to quantify and thus difficult to commodify, leaving it often beyond the purview of industry. For Armstrong, it is critical that we invest in an "alternative model for life than a machine." Perhaps, she posits, life is instead more like the weather, unpredictable, non-linear and dynamic. (Armstrong, 2017) 'Agentized matter', matter with agency, which can form assemblages and imbue the natural world with creativity offer us a new way to imagine the world. (Armstrong, 2013, 115) These philosophical standpoints require a way of being *with* nonhumans and non-life forms rather than merely doing *to* them. An ethos of reciprocity, interconnectedness and vibrancy is possible. The nonhuman world in this way is found to embody a hopeful 'politics of heterarchy' rather than hierarchy, but to engage in these ways we must be willing to turn our shared ontology upside down. (Kohn, 2013, 19) I would argue that the crises of our moment demand nothing less than this commitment to dialogue between human and nonhuman actants.

One of the ways we might begin to actively engage with nonhuman vitalism is through an aesthetic semiotics that functions by means of affect – assuming that affects are the 'currency for the intensity of becoming.' (Grove, conversation, 2015) Said another way, affects are always already virtual, momentarily made actual through aesthetics, the semiotics of which are intelligible to humans and nonhumans alike - should we attune ourselves properly. This affective form of communication for Eduardo Kohn rests in *indicies*: bricolaged messages composed of a cacophony of signs - material, visual, audial, tactile and otherwise: "to the extent that indicies are noticed they impel their interpreters to make connections between some event and another potential one that has not yet occurred." Indicies thereby "encourage us to make a connection between what is happening and what might potentially happen." (Kohn, 32-33) In this animistic understanding, we can see ethics as a series of aesthetic judgments formed through moments of affective experience. Many Indigenous cultures and peoples who live in close proximity to the natural world understand indicies intrinsically. They are the movement of an animal in the bush (not to be mistaken for the wind) or the way the water ripples when a certain fish is near. These are some of the moments when 'things,' nonhumans, talk back.

The illusion of separation may someday be finally understood as our greatest mistake as an intelligent species. The insanity that has resulted from humankind's desire to control that which is perceived to be 'not us', has manifested in deeply suicidal tendencies. Perhaps the realism of Haraway's diorama and the histories held within, the synthetic stories layered with politics of meaning-making and being in the world, hold a

powerful method for distancing ourselves far enough to understand our own madness as such.

> "Within minutes of his first glimpse of the features of the face of an animal he longed more than anything to see, Akeley had killed him, not in the face of a charge, but through a dense forest screen within which the animal hid, rushed, and shook branches. Surely the taxidermist did not want to risk losing his specimen, for perhaps there would be no more." (Haraway, 1989, 33)

Blinded to the indicies all around him, Akeley's commitment to a patriarchal heroism is testament to the hubristic nature of our collective unraveling. Perhaps this is the greatest irony of all, that to preserve what we think we love, we must first forget what we always already are. The danger of unchecked techno-optimism is that it ignores both politics and the ramifications of material inputs. We do not produce something from nothing. The current practices of synthetic biology leave the most important perennial questions unasked, let alone unanswered. In a world invested in the productive capacity of interspecies semiotics, developing heightened capacities for affectability may become a dominant practice of flourishing. What politics remain when we finally take seriously the fact that we are merely 'evolved animals?' (Singer, 6, 2000)

CHAPTER 1

NECROMATERIALISM AND THE AFFECTS OF PRECARITY

Ontopower: “It is a power-to: a power to **incite and orient emergence** that insinuates itself into the pores of the world where life is just stirring, on the verge of being what it will become, as yet barely there. It is a **positive power for bringing into being** (hence the prefix "onto").”

~ Massumi p.viii

“If we want to attain a living understanding of nature, we must become as flexible and mobile as nature herself.” ~ Goethe

“So we have to rethink the human in light of precarity, showing that there is no human without those networks of life within which human life is but one sort of life.” ~ Butler

Necro-materialism and designing for death

What makes an animal or insect a pest? A plant a weed? A bacterium a germ? At the center, driving these designations sits the human. The human that will be harmed or inconvenienced by that animal, plant or bacterium. The human that determines a need to eradicate those beings that don’t supply humans with perceived value or benefit. We’ve been working diligently on solutions to these bothersome creatures since we’ve been, well, humans. With the advent of new biotechnologies, specifically CRISPR and Gene Drives, we now have a spectacular velocity with which to design and redesign life forms for a variety of purposes. Including the ability to design lifeforms that are meant to die. Today, there is a movement afoot to genetically engineer animals that are vectors of disease such as mosquitoes, rats and cats, to sterilize their own populations as a new method of disease eradication. In Hawai‘i, scientists and policy makers are looking at engineering mosquitoes in order to combat deadly diseases like Zika, dengue and chikungunya. These virus-borne diseases are spreading into new

territory as a result of human-induced climate change. We are experiencing a profound moment of convergence in Western bio-science between: our capacity to design species extinctions; our growing appreciation of nonhuman vitality; and the perpetual states of emergency found in discourses of climate-change-induced disease and species extinctions. This moment opens up important new spaces of political potential. We will decide which species die and which are saved. Whether to treat engineered species as independent lifeforms or commodities to be exchanged and profited from. And when lifeforms become commodity, we will decide who or what owns them. We determine what counts as a moral imperative and we prioritize whether species are engineered to do things that help human and nonhuman life and which human or nonhuman lives will be bettered. Responses to this movement from the field of synthetic biology are currently anchored in an assumption that genetic parts added up are equivalent to functioning organismal wholes. This research argues against that assumption and says instead that organisms must be understood as complex, interdependent assemblages that cannot be parsed out without losing their original function, that organisms hold an agency at the level of organism that is lost and misunderstood at the level of genetics. The potential danger of these technologies is increased by the velocity with which we are being pushed to find solutions. Climate change is increasing both the prevalence of diseases and our sense of urgency around solutions. The engineering of mosquitoes and other lifeforms to save us from disease can just as easily be used to deliver disease and death. This constitutes a new form of biological weaponization at the genetic scale that needs to be considered carefully. As a result, this research argues for a new commitment to open-source science combined

with an understanding of the *organism* as the basic functioning *assemblage* of life. This scientific grounding needs to supplant our current commitment to competitive, commodified forms of science which rely on the assertion that DNA or genetic material is the foundational unit of biology.

In 1826, so the story goes, a Reverend William Richards was walking home from the mission in Lahaina, on the island of Maui in the Kingdom of Hawai‘i when he “met a native who informed him that there was a new ‘fly’ in the place. The native described the insect as being a very peculiar ‘fly’ that made its presence known by ‘a singing in the ear.’” (Van Dine, 1904) This encounter would mark the arrival of one of the world’s most infamous insects to these isolated islands in the middle of the Pacific. Held responsible for some 438,000 deaths in 2015, the measly mosquito is considered the world’s deadliest animal. (http://www.who.int/mediacentre/factsheets/fs094/en/) In September of 2016, a diverse group of mosquito scientists, avian conservationists, genetic researchers, social scientists and policy makers met on the island of Hawaii to launch discussions aimed at returning Hawaii to its ‘mosquito free’ past.

From the meeting, emerged a foundational paper intended to establish a shared understanding of the possible technologies used for eradicating mosquitoes as well as the mission of what would come to be known as *Mosquito Free Hawaii*:

> *The presence of mosquitoes in Hawai‘i represents a persistent and serious threat to public health as well as to the economy and ecosystems. Diseases such as chikungunya, dengue, and yellow fever infect hundreds of millions of people worldwide, causing debilitating symptoms and sometimes death. More*

recently, the Zika virus began to spread through the Americas, causing birth defects and neurological disorders.

These human diseases are transmitted by two mosquitoes, the yellow fever mosquito (Aedes aegypti) and the Asian tiger mosquito (Aedes albopictus), natives of Africa and Asia respectively. Both species have invaded Hawai‘i, are responsible for sporadic outbreaks of dengue fever, and could sustain a Zika virus outbreak sparked by arrival of an infected traveler.

Additionally, the Southern house mosquito (Culex quinquefasciatus) transmits avian malaria and avian pox virus, major factors in the extinction of more than half of Hawai‘i's honeycreepers. This mosquito and the pathogens it carries threaten imminent extinction of most of the remaining 17 species of these unique birds that are found nowhere else on Earth.

Among the various methods of population control discussed in the paper, the most experimental and most controversial is a genetic engineering technology known as gene-drive.

***Gene drive systems** are capable of altering the traits of wild populations and associated ecosystems.*

Named for the ability to "drive" themselves and nearby genes through populations of organisms over many generations, these genetic elements can

spread even if they reduce the fitness of individual organisms. They do this by ensuring that they will be inherited by most - rather than only half - of offspring. (http://www.sculptingevolution.org/genedrives)

Combined with the CRISPR Cas9 genetic engineering technology, which allows the accelerated alteration and manipulation of specific genes in an organism, gene drives could potentially be designed to ensure that all mosquito offspring are born male or that females would be made infertile when both parents carry the drive system, thereby crashing the population to extinction. The extension of human control over organism death and species extinctions is not new. We are living through what some call the sixth mass species extinction, this one brought about by a confluence of diverse global forces as wide ranging as climate change, plastic pollution, population growth, palm oil plantations, carnivorous humans, new diseases and appetites for exotic foods and folk medicines. What *is* new in this unfolding future is the conscious intention, mechanization, efficiency and velocity of potential genetic- and species-level management and control. The capacity to purposefully extinct certain life forms deemed unsavory to human and or nonhuman life *is* a form of necropolitics. (Mbembe, 2003) Which Mbembe defines as the "subjugation of life to the power of death." (Mbembe, 39, 2003) In the case of gene drives and engineered mosquitoes, humans have begun generating sovereignty over synthetically produced life whose death is already pre-programmed into its very existence. So, when Mbembe asks, "What is the relationship between politics and death in those systems that can function only in a state of emergency?" we need to consider this question in relation to the mosquito that has

become politicized as an enemy for its role as vector of human and nonhuman disease. (Mbembe, 16)

Affects of Precarity

Climate change and species extinctions are contextualized in popular discourse as persistent states of emergency rife with both uncertainty and complexity beyond human control. Images of disaster, suffering, and apocalypse bombard us every day. The affective nature of these visual images along with the written and audio narratives that accompany them builds up a persistent experience of constant low-level anxiety. We feel both helpless to do anything while consistently charged to *do something* to abate the onslaught which has no foreseeable end in sight. At this same moment, emerging technologies like gene drive offer the promise of greater control, a chance to mitigate the dire circumstances that we face. The premise of engineering biology is based on a belief that life can be understood through the basic code of genetic material, DNA, and that reading and writing this biological code the same way we read and write software code allows us to program and reprogram the genetic material to do whatever it is we want it to do. Theoretically this is a flawed assumption because the complexity of organisms escape the boundaries of readable/writable DNA code, and politically this is a dangerous assumption that leads towards the commodification, patenting and corporate control of lifeforms.

When we engineer mosquitoes to deliver their own species death through heritable sterility, the mosquito becomes weaponized. We have to carefully consider both the vitality of the mosquito, its political agency and the potential uses of its

weaponization. Current discourse of mosquito gene editing focuses on the potential life-saving capacities and these are significant. But it is equally true that "innovations in the technologies of murder aim not only at 'civilizing' the ways of killing. They also aim at disposing of a large number of victims in a relatively short span of time." (Mbembe, 2003, 19) Systematic eradication of mosquitoes construed as pest poses little moral challenge. But how do we ensure that these technologies are not used in the future against other nonhuman and eventually human 'enemies'? We are being pushed to increasing the velocity of our interventions as a result of the perpetual state of emergency. Pressures like climate change and the mass migrations, food insecurity, water insecurity and war are now characteristic of the 21st century. A persistent and pervasive anxiety of extinction and apocalypse create the conditions of possibility to accept once radical solutions to seemingly insurmountable problems. Where the capacity for programmed death meets the agency of synthetically designed life, we are entering a new moment of necro-materialism with significant political and ethical ramifications. If we are to consciously design evolution in pursuit of greater good, these technologies must remain open-source, collaborative and out of corporate control.

Vector Politics: Biotechnology in a permanent state of emergency

"Change can be accommodated by any system depending on its rate" Crake used to say. "Touch your head to a wall, nothing happens, but if the same head hits the same wall at ninety miles an hour, it's red paint. We're in a speed tunnel, Jimmy. When the water's moving faster than the boat, you can't control a thing." I listened, thought Jimmy, but I didn't hear."

~ Margaret Atwood (2012)

New materialists argue for the vitality of nonhuman life and matter. Indigenous

peoples have understood this vitality and the agency that accompanies it for generations. Now, scientists have taken huge leaps into better understandings of bacterial and other non-human consciousness. We can posit that cognition, when understood as “the reorganization of sensory input toward the emergence of meaning,” may have begun with bacteria. (Margulis, 2011, 9) We humans do not live alone. We are instead composed of billions of bacteria, viral, chemical parts that together make an organismic whole which we identify as ‘self.’ It‘s been found that Mother‘s breastmilk contains an abundance of oligosaccharides, a carbohydrate that babies cannot digest. These carbohydrates feed a crucial bacteria in the baby‘s gut, B. infantis. We quite literally feed the bacteria that in turn feed us. (https://www.nytimes.com/2018/06/17/opinion/babies-bacteria-breastfeeding-formula.html) The I is inherently a we and the we is itself informed by relational assemblages and interdependencies with which it communicates and is constantly reinscribed. This context of ubiquitous material vitality combined with a politics of affect where sense-making itself is imbued with political meaning, all depend upon a notion of vitalism that is at the center of my argument. (Margulis, 2011; Bennet, 2010) If we take seriously the vibrancy of nonhuman lifeforms as I’m proposing to do here, what can be said about the ethics of a research platform that supports pre-programmed death? In the case of the mosquito, their incidental involvement in the deaths of others provides a moral scapegoat for extinction. An unwitting victim of entanglements and assemblages, the mosquito unto itself is little more than a nuisance. Viruses without a vector are essentially harmless. When the two come together to form an assemblage of mosquito plus viruses like malaria, dengue, chikungunya, West Nile virus or Zika, the mosquito is

transformed into an effective biological weapon against a variety of life forms including humans. The political ecology of this biological entanglement leaves mosquitos in the lurch. Old English law contained the notion of the 'deodand,' "the nonhuman actant, for example the carving knife that fell into human flesh." The 'deodand' bore some agential responsibility for the harm done and would be surrendered to absolve its inherent complicity. (Bennett, 2010, 9) Themselves vibrant and endowed with biological purpose and agency, mosquitos are similarly the unlucky co-conspirators in a relationship with viruses that transforms them into 'killer' despite the unintentional nature of their involvement in spreading death and disease. The mosquito then, becomes the focus of a new sort of necropolitics, where humans seek to control the vitality of the mosquito as a species vector of multiple and as-yet-unknown deadly diseases. Morphing mosquitoes into deadly villains and targeting their capacity to reproduce enables us to justify weaponizing biology in service of an ostensibly greater good. Mbembe cites that his "concern is those figures of sovereignty whose central project is not the struggle for autonomy but the generalized instrumentalization of human existence and the material destruction of human bodies and populations." (Mbembe, 2003, p 14) I state here that my concern is those figures of sovereignty whose central project is not the struggle for collaboration with non-human agency but the generalized instrumentalization of non-human existence and the reconstruction of non-human bodies and populations for human ends. Rather than working with, we are doing to. Which is to say that when we stretch the necropolitical beyond the human we open up new spaces for instrumentalizing vitality in service of all kinds of ends. This means that we are openly willing to sacrifice one species, the mosquito, as an instrument or weapon in the fight

against other emergencies, here climate change and disease. And this is not to say that there is no upside to elimination of mosquitoes, but rather it is to say that we should not go lightly into this new necropolitical velocity without some serious introspection. What are the limits to our ability to justify extinction of one species in service of saving another? In light of the mounting pressures of real and perceived emergency in a world of political, economic and environmental uncertainty, we must assume that the limits could be quite broadly stretched.

Thacker argues for the notion of 'whatever-life' "in which biology and sovereignty, or medicine and politics, continually inflect and fold onto each other. Whatever-life is the pervasive potential for life to be specified as that which must be protected, that which must be protected against, and as those forms of nonhuman life that are the agents of attack." (Thacker, Clough & Craig, eds. 2011, p.159) Whatever-life helps us to understand how and why we are willing to extinct the mosquito to save other species, in this case endangered Hawaiian birds, from their own extinction. This logic is supported and justified by the fact that the mosquito threatens human health and offers no apparent upside for human or nonhuman life while the endangered birds are aesthetically beautiful, ostensibly harmless and represent the innocent fallout of human induced climate change. This concept of 'whatever-life' also helps us to situate the extinction of the mosquito in a longer political tradition of assigning agency to non-human life when it serves our ends while denying non-human agency when it is inconvenient to the goals of a neoliberal world order. With the notion of biological sovereignty seriously in question in a synthetic biological era, any lifeform, human and non-human, is at risk of becoming an undesirable 'vector' of whatever-life. The

combination of vibrant, complex human/non-human entanglements, a divisive political climate, institutionalized inequality and rapidly changing climate guarantees a drastic increase in both affective and material pressures as well a generalized and disconcerting awareness of pervasive uncertainty. The implications for security and for human health posed by synthetic biology are exciting and terrifying at the same time. And the assemblages of colonial prospecting, non-native species introductions, imperialism and the reverberations of colonial guilt that inform and enliven discussions of endangered species and native species protections are all part of this unfolding narrative. The history of the conservation movement itself is entangled with colonial guilt and imperial plunder. As Donna Harraway argues, “Conservation was a policy to preserve resources, not only for industry but also for moral formation, for the achievement of manhood.” (Harraway, 1989, 55) As our technological capacities evolve in the biotechnological era we are being challenged to consider what we conserve and why we conserve it. Additionally, we are being challenged to consider, if life can be made or remade from scratch what life forms might we bring back or create anew and for what purpose?

With its origin in the experience of 15th century plague, the word pest is generally defined as “A destructive insect or other animal that attacks crops, food, livestock, etc.” (https://en.oxforddictionaries.com/definition/pest) And yet we know, for example, that pesticides ostensibly created to eliminate pests and ergo make life better for humans have been implicated in numerous neurological and physical diseases that shorten or limit human life. We also know that pest is a relative term and highly relational. Bees are a pest in one’s home or a school and yet without bees we wouldn’t have pollination of

crops. Bats are a nuisance unless they're eating mosquitoes, and cockroaches are considered dirty and disgusting, despite the fact that they fastidiously clean themselves like cats. What we today consider a pest may tomorrow be embraced for the value of its previously misunderstood entanglements. Oversimplification of the interspecies meshwork is full of unknown risk. We have to learn to speak across perceived species boundaries and intuit complex entanglements before we start building worlds from scratch. Technology is never without unintended consequences and the uses of technology are always entangled with moral and ethical choices. Articulating these ethical foundations and determining their moral validity is critical before we begin any sort of biological being-building.

All of that said, the diseases harbored by mosquitoes, rats and tics among other such pests are serious and cause significant harm to people and wildlife, some of them our most vulnerable. Additionally, the endangered species and current extinction crises combined with our foggy understanding of the true consequences of human induced climate change are converging to create a sustained sense of environmental anxiety and grief. In this current perceived state of persistent emergency with human health and environmental collapse at stake, once radical technologies can become rapidly normalized. These technologies are situated within an economic and political paradigm of neoliberal capitalism which demands constant iteration and innovation to reach ultimate commodification. We also operate in a paradigm that says technology is inherently neutral, it is the way any technology is used that lends it a moral imperative. When velocity and technology amplify each other, we can often find good people doing unintentionally bad things. Careful and intentional engagement in active anticipation of

the systemic ripple effects is needed to truly harness the power of emerging technologies for the greater good. In the case of the mosquitoes in Hawai'i, it is both human health and the endangered endemic Hawaiian honeycreepers that are at stake. The entanglements that have created this crisis – colonialism, climate change, globalization – constitute a virtually unstoppable web of forces that reinforce one another to create the state of emergency. At the December meeting of the United Nations Biodiversity Conference, the 13th Conference of Parties to the Convention on Biological Diversity (CBD) ratified the use of Gene Drive technology and synthetic biology for the conservation of nature. (https://leadership.ng/news/564414/developing-countries-kick-as-un-ratifies-gene-drives-synthetic-biology) This was surprising to many in the conservation community as these emerging technologies are just barely beginning to be understood and tested. But the pressures of this moment of species apocalypse will continue to push the boundaries of what is acceptable and require particularly rapid attention to ethics and active foresight.

Parts and Wholes

"Like other animals, and indeed all other life forms, we humans do not live alone. We have always been embedded in communities that include our viral, bacterial, protoctistological, fungal and plant travelling companions. We continue to ignore them at our own peril."

~ Margulis, 2011, 9

The necromaterialism of designed death is dependent upon a complex assemblage of biological forces and premised on the assumption that the parts can be parsed out and engineered to operate in a predictable and repeatable collaboration. This concept of engineering biology for predictable and repeatable ends is at the

foundation of CRISPR technology and the entire field of synthetic biology. The other foundational concept is that biology is nothing more than genetic information, code that can be transcribed, edited and re-transcribed ad infinitum. In a neoliberal age of information technology this paradigm supports the unmooring and re-inscription of genetic material in order to make it mobile in the service of capital. Among the incredibly complex entanglements at play in the CRISPR process, there are genes and genetic material, bacteria, proteins, viruses, glass, gene guns, humans, electricity, lab coats, robotics, air conditioning and fluorescent lighting. Designed by nature as a bacterial defense mechanism, CRISPR, —clustered regularly interspaced palindromic repeats, refers to the process by which a bacteria nuclease called Cas9 cuts up the RNA of an invading virus and transcribes it onto the bacterial DNA to block the invasion. As explained by Carl Zimmer:

> *"When a virus invades a microbe, the host cell grabs a little of the virus's genetic material, cuts open its own DNA, and inserts the piece of virus DNA into a spacer. As the CRISPR region fills with virus DNA, it becomes a molecular most-wanted gallery, representing the enemies the microbe has encountered. The microbe can then use this viral DNA to turn Cas enzymes into precision-guided weapons. The microbe copies the genetic material in each spacer into an RNA molecule. Cas enzymes then take up one of the RNA molecules and cradle it. Together, the viral RNA and the Cas enzymes drift through the cell. If they encounter genetic material from a virus that matches the CRISPR RNA,*

the RNA latches on tightly. The Cas enzymes then chop the DNA in two, preventing the virus from replicating." (Zimmer, 2015, para 25-26).

CRISPR technology relies foundationally upon the precision and power of 'the cut.' If we consider this idea of 'the cut' as an ultimately creative act (Kember and Zylinska, 2015, xvi), then we can see the novelty of co-creation between the scientist who selects the genetic trait and the bacteria that delivers the cut to its destination as an incredible moment of interspecies communication. (Zylinska, 2015, 89) In discourse that mirrors the realities of commercial laboratory environments, metaphors of imperialism are strewn throughout this process of translation. Based on a human need and human centered design, a genetic trait is selected. Using a process of biological colonization of genetic material, a gene gun blasts the genetic material into the organism to be carried on the back of bacteria. With CRISPR, we are effectively imposing human will upon biological beings as a radical new form of mediation. And as Kember and Zylinska argue, "we have to bear in mind that the process of mediation is also a process of differentiation; it is a historically and culturally significant process of the temporal stabilization of mediation into discreet objects and formations." (Kember & Zylinska, 2012, xvi) I would argue that our basic assumption may be flawed and that biological beings as organisms can never be stabilized into discreet objects and formations. That the mosquito with a CRISPR edited gene is an organism enlivened by complex and interdependent interactions that cannot be selected out and stabilized without losing integrity and that therefore the principle of precision and control embedded in the notion of engineering biology may be inconsistent at its core. In thinking about the interspecies

translations and forms of knowledge at play, we can imagine that there is a good way and a bad way to communicate. If CRISPR is based on the cut, then what does it mean to 'cut well'? Can we embrace a sort of 'good violence' in this violent process so that something greater is born of the moment of violence, the cut and the gun? The notion of genetic precision and the idea of precisely and predictably engineering biology is itself borne of a need to fit within the flow of commodification and privatization of resources. And the privileging of precision science over its 'primitive' ancestors is a logic that "helps to rationalize the privatization of science, the treatment of genetic information, organisms, bio-techniques, and research findings as proprietary commodities, the valuation of genetic resources in terms of the prices they can fetch in international markets." (McAfee, 2003, 212) Oxitec, a British Biotechnology corporation, has designed several strains of genetically engineered mosquitoes for sale to governments hoping to battle mosquito borne illnesses. The latest, set to be released in India pending government approval is trademarked: Oxitec's Friendly™ Aedes mosquito. In a pattern that mirrors the functions of agricultural biotechnology giants, Oxitec sells the engineered mosquitoes to the host government but maintains control of the engineering patents. Biology becomes commodity, ostensibly in service of the greater good. Ethically, it remains to be seen if this is the direction most aligned with goodness in service of all.

We must consider that the futures will bear out the unintended consequences of technologies. There is a need for velocity in the face of real emergency. A danger in moving too slowly to stop the natural systems that are crashing all around us. But when we move too fast, what else is lost, what else is unleashed. "Will the major technological

revolutions of our time—in the life sciences, information and communication technologies, computers and weaponry, and most recently nanotechnology—favor emancipation or recolonization?" (Jasanoff, 2006, 275) Any technology is merely as good as the ontologies that birthed it and the society that embraces it. If we rush forward into emerging technological terrain without addressing the inequality and injustice of our modern politics there are likely to be very dangerous unintended consequences.

An open source science meets an organismal cosmology

"I say, beware of all enterprises that require new clothes, and not rather a new wearer of clothes." ~ Henry David Thoreau, Walden

When we embrace the vitality of nonhuman life and the foundational assumption that organisms are assemblages irreducible to independent parts, then the debate between patented and open source science becomes central to imagining a future of biological flourishing. Kathleen McAfee in her essay *Neoliberalism on the Molecular Scale* argues that U.S. patent policy has been "framed by a neoliberal approach to biotechnology regulation. This approach…depends upon two forms of reductionist discursive practices: molecular-genetic reductionism and economic reductionism." (McAfee, 2003, 203) Economic reductionism tells us that all things are ultimately reducible to a commodity form. That objects can be made 'lively,' disconnected from their context in order to circulate as objects of capital. (Sunder-Rajan, 2012) Genetic reductionism is founded on the pervasive metaphors of a deterministic 'gene' and a readable/writable 'genetic code.' And while these metaphors may seem logical at first,

as McAfee and others point out, they are way too simplistic. (McAfee, 2003; Calvert, 2012, Rossi, 2014) The average person is not privy to the workings of a biotech wet-ware laboratory where genetic experimentation is messy, failure rates are high and certain aspects of genetic expression remain ultimately unknowable – this is what McAfee calls the 'myth of genetic engineering precision.' (McAfee, 2003) Rather than representing reality, these dominant metaphors are born of neoliberal desires to commodify and capitalize upon genetic resources. The metaphor itself thus "provides conceptual support for treating genetic constructs as tradable commodities which are subject to market exchange." (McAfee, 2003, 204) Genes are in fact highly context dependent and the results we see from genetic expression are due to dynamic, complex interactions between genes themselves and between those genes and their environment. It has been shown that two identical genes in two different places will evolve differently, but neoliberal discourse tends to ignore these instances of difference because, "they do not lend themselves to easy solutions, much less to the production of patents, profitable commodities or research funding or fame." (McAfee, 2003, 206) The reality of genetic expression is illegible to the market and is therefore suppressed and re-inscribed in ways that more easily render life as commodity.

This trend towards a double-reductionism in biotechnology rests upon the history of patent law and the dualistic metaphysics of nature and culture that have defined the modern neoliberal era where techno-optimistic and industry driven arguments "draw upon the vague notions of a post-industrial 'new economy' which, almost miraculously, creates value from information with relatively little need for mundane material inputs or labor." (McAfee, 2003, 204)

In this way, Jane Calvert argues that nature is being redesigned to fit the commodity form. She calls this a process of 'disentanglement:' "for something to be a 'thing' it must be fragmented… reduced to a format that makes it possible to make an exclusive package or artifact for which an exchange value may be established." (Calvert, 2008, 384) Today you can buy a genetic base pair from a company like Twist Bioscience for as little as $0.07. Fragments of genetic code cheap, fast and rapidly accessible to the whims of market logics. The reality that is obscured by this process is that biological systems are by their very nature 'open' – they exchange information and matter with each other and with the environment. To imagine that this can ultimately be controlled, as synthetic biology aims to do, is highly suspect reasoning. Calvert's concern with the "regulatory and the epistemic" demonstrates the ways in which ontologies, politics, economics and culture effect science in visceral, material ways. (Calvert, 208, 383) We imagine and create certain innovations because they easily fit into the dominant socio-cultural paradigm, not necessarily because they are the innovations most needed for human and nonhuman flourishing.

Sheila Jasanoff writes about 'lively capital,' the processes by which nature is transformed into culture so that it can be made mobile and put into economic circulation for profit. (Jasanoff, 2012) The logics that allow biology to become capital rely upon an ethics grounded in competition, ownership, control, inequality and structural violence. They are also dependent upon the myth that progress is made through discovery, taking and development. (Jasanoff, 2012)

Context dependency, interdependence and biological emergence all sit at the found of organism theory. And so, the theory of the organism, what Steve Talbott calls

organisms of meaning, holds a similar but even more radical philosophical space for synthetic biology. Pushing in direct resistance to dominant tropes of a mechanistic, deterministic, engineer-able biological world, organism theory asks us to acknowledge that wholes have a meaning that is not divisible to parts and that the interdependencies of wholes cannot be meaningfully modulated or parsed without losing critical and complex functions. (http://natureinstitute.org) This directly challenges the trope of biology as information that can be transcribed and re-inscribed in linear fashion and instead sees organisms as a living symphony of enmeshed components in which removing one piece changes the overall dynamics in important and often unpredictable ways. The 'cut' disrupts the meshwork in ways that may unravel meaning and purpose. We simply don't know enough. This organismal biology ascribes critical agency to the matter of life all the way down and challenges the idea that DNA alone contains all the information needed to form an organism. Animism and indigenous sciences echo a similar cosmological foundation in organism and complexity. Tim Ingold explains that in Animist cosmology, the environment is a meshwork of entanglements which beings actively inhabit in a complex web of relationship that cannot be bound such that "beings grow or issue forth along the lines of their relationships." Organisms are part of a relational field building increasingly complex interwoven lines of relationality that are enmeshed and indivisible. (Ingold, 2006, 13) Similarly, Manulani Aluli Meyer explains that for Native Hawaiians, there are no boundaries between human and non-human worlds and "thus the natural world was not separate from a moral one." (Meyer, 2003, 100) And for Hawaiians, like many other Indigenous peoples, knowledge takes many forms including insight, supersensory intelligence, knowledge gained through

experience and knowledge by artistic endeavor. These vastly different forms of knowing and ways of understanding the non-human other and non-human agency inform a very different politics for the future of synthetic biology, especially in the realm of conservation. Phillippe Descola challenges us to build an ecology of relationships that pulls philosophically from all the various sciences in order to "recompose nature and society, humans and non-humans, individuals and collectives, in a new assemblage in which they would no longer present themselves as distributed between substances, processes and representations, but as the instituted expression of relationships between multiple entities…" (Descola, 2013, 5) These cosmologies challenge the discourse of biology as information. Combined with a push for transparency and caution in the pursuit of synthetic biology, these perspectives present a significant challenge to the normalized intellectual property-commodification paradigm.

Among some geneticists, there is a movement to make CRISPR science and gene drive technology open source, bucking the dominant trend of competition, patents and privacy in scientific discourse and practice in order to protect the public good and ensure that these technologies are used for a greater purpose than circulation of profit and creation of wealth. Kevin Esvelt is an Assistant Professor at the MIT Media Lab and part of the Sculpting Evolution Group whose mission is to "understand and engineer complex living systems." This group holds firm to a philosophy that includes the following statements:

> *To humanity, we owe transparency and responsiveness. As scientists, we have a professional responsibility to share the possible consequences of our research with the public in an understandable manner. If our research will not*

have any such consequences, we're clearly doing something wrong. More generally, we must invite, listen, and respond to concerns as best we can.

*We are morally responsible for **all** consequences of our work. It does not matter whether our research is approved by an institutional biosafety committee, regulators, potentially affected communities, the International Association of Bioethics, or the National Academies. Moral responsibility cannot be outsourced: as we are likely the ones with the greatest knowledge of what might go right or wrong, the burden is ultimately upon our shoulders.*

To the natural world, we owe a sense of wonder, our gratitude, and our caution. As we seek to understand the systems that gave us life and support our civilization, we must be careful to respect their complexity and intervene only when we are confident that it is for the best. (www.sculptingevolution.org)

Dr. Esvelt is also part of the *Mosquito Free Hawai'i* collaboration. Explaining that gene drive is a technology found in nature and comparing the use of gene drive and CRISPR to insecticides, Dr. Esvelt makes the case that a careful and open source exploration of these technologies has important potential for public and environmental good. His lab is working on an experimental new type of gene drive that they have dubbed the 'Daisy Drive' (a playful nod to the movie *Driving Miss Daisy*) Addressing head on the legitimate fears of letting loose heritable traits into the environment, the daisy drive takes the idea of a global gene drive, and limits the capacity for the trait to be heritable. So, rather than

a gene drive that can spread globally and in perpetuity, the ‘daisy drive’ peters out after a set number of generations. CRISPR scatters its cuts in the genome so that no one genetic script can operate on its own. “In daisy drive systems, the CRISPR components are split up and scattered throughout the genome so that none of them can drive on its own. Though physically separated, they're functionally arranged in a linear daisy-chain: element C causes element B to drive, and element B causes element A to drive.” In effect, “the elements of a daisy drive system are like booster stages of a genetic rocket: those at the base of the daisy-chain help lift the payload until they run out of fuel and are successively lost. Adding more links to the daisy chain will spread the payload to more organisms.” And critically for matters of politics and bio-sovereignty, with a ‘daisy drive,’ decisions about the genetic engineering of wildlife could be localized and highly context specific. (Noble et al, 2019)

Esvelt himself admits this is currently hypothetical, but working with George Church at the Harvard Lab and using rapidly reproducing nematode worms to quickly test and innovate, they aim to see this technology become reality soon. At the root of these efforts is the philosophical belief that disruptive science with the capacity to help or harm the planet must be transparent, open source and geared towards the greater good. The ‘daisy drive’s’ emphasis on localized and limited control of natural resources emerges from a cosmological grounding that is antithetical to lively capital and the commodification of nature that has dominated the biotechnology industry to date.

Walter Anderson argues that the project of this coming era “requires a shift from evolutionary meddling to evolutionary governance, informed by an ethic of responsibility – an evolutionary ethic, not merely an environmental ethic – and it requires appropriate

ways of thinking about new issues and making decisions." (Anderson, 1987, 9) Cellular consciousness, epigenetics, Indigenous cosmologies, ethics and mosquitoes are all conspiring to bring us to a new biological politics. These entanglements press and challenge the promise of necro-materialism to cure human and environmental ills. Designing in death cannot be based on a politics of either efficiency or precision. The autonomous creativity of non-humans, from the level of organism, demands a different approach, one that privileges conversation across perceived species boundaries in profound new ways.

CHAPTER 2

WHO OWNS EMERGENCE?

"The boundary is permeable between tool and myth, instrument and concept, historical systems of social relations and historical anatomies of possible bodies, including objects of knowledge. Indeed myth and tool mutually constitute each other."

~ Donna Haraway (1989)

"Synbio's multiple protagonists promise to engineer life into a state of functional order. No gray space here; just black and white promise. We can save the world: through limitless diesel pumped out by safely lab-locked bacteria fed a syrupy diet of Brazilian sugarcane, or by their engineered cousins, just as safe, released into the great oil slicks of dirty technologies to digest their failures. Or so it is claimed. These stories are the myths manufactured to help us get closer to the scientific truth."

~ Alexandra Daisy Ginsberg
(http://www.daisyginsberg.com)

Hornless cows and Moldless mushrooms…

The biotechnological era is upon us. Intellectual property has played a major role in setting this stage, in creating the conditions of possibility for this genetic revolution. In broad strokes, we can see that the advent of Intellectual Property as both a legal and cultural phenomenon in the world has shaped the way we understand innovation, private property and public goods in foundational ways. Beginning in the West, the practice of protecting intellectual property for private gain has spread worldwide as a result of globalization. Pockets of resistance remain, and contested cases are always being heard that push or contract the rules in different directions. The collusion of neoliberal ideologies, globalization and the 'information society' have created a perfect storm where intellectual property can flourish. The complexity of the current global

situation means that it is important to resist the temptation to isolate the 'nation-state' as the sole source of this situation. As Debbie Halbert explains in *The State of Copyright*:

> "Given the complexities of alliances, resistances, and advocacy positions that tend towards maximizing or limiting protection, the global debate over intellectual property can be better understood through examining the complex networks of states, industry actors, NGOs, and of course the flow of culture itself rather than focusing solely on the agency of the state." (Halbert, 2010, 9)

It is with an eye towards this understanding of political economies and complex cultural/economic assemblages that I analyze the past, present and futures of intellectual property as it is related to the biotechnological era and in particular to the field of synthetic biology. In some ways, the definition of synthetic biology is still under debate. It is an emerging field with many different players vying for dominance. But the general idea is that it is a meeting ground of engineering and biology, where technology and biology merge, and is concerned with the creation of novel life forms, which display functions not otherwise found in nature. In thinking about the relation of intellectual property to this emerging field, it is important to note that "Current copyright law protects culture as a commodity – it protects culture like it protects shoes or pots and pans…To use Habermasian terms – it allows for capitalism to invade yet another aspect of the lifeworld." (Halbert, 2010, 19) The importance of this statement cannot be stressed enough as we move into the futures of intellectual property and synthetic biology. The metaphor of genes as 'information' or 'code' allows the gene to be removed from its context and inscribed with capital value thereby becoming a site of capital accumulation rather than a natural object with certain non-human agency.

Past – Setting the Stage for The Biotech Era

"A new organism was every bit as novel as a new machine."
~ Pottage (2007, 325)

Intellectual property laws emerged at a time when biotechnology was not yet realized. But there was already a concern in the early 20th century about property rights over biological material, specifically related to agriculture. Both the U.S. Plant Protection Act of 1930 and the Plant Variety Protection Act of 1970 sought to protect the rights of plant breeders who developed novel varieties. There was a general consensus that these varietals were novel enough, useful enough and reproducible enough (all hallmarks of patentable material) that they should qualify for patents. (Sunder-Rajan ed., 2012, 166) The U.S has led the world in plant-related patents since that time with an explosion in patents as we have moved into the era of industrial agriculture and the genetic engineering of plants. By 1988 there were 40 U.S. patents of crop plants and by September 2001 there were more than 1800 U.S. patents on plants, seeds and other parts of plants or plant tissue. (Dutfield, 2004, 23)

The most commonly cited case related to the patenting of biological life forms would come in 1980 when the Supreme Court of the United States heard a case called Diamond v. Chakrabarty. At issue was the question of whether a bacterium for breaking down oil spills, created by Ananda Mohan Chakrabarty while he worked for General Electric, could be patented. Initially the patent application was rejected with the patent office citing the historical understanding that living things were not patentable. Taken to appeal, the US Court of Customs and Patent Appeals overturned the ruling in favor of Charkrabarty. When Sidney A. Diamond, then Commissioner of Patents and Trademarks took the case to the Supreme Court, a 5-4 ruling determined that the

bacterium had been created through human innovation and could thus be patented. The bacterium was clearly alive, but was nonetheless considered by the court to be manufactured and thus worthy of patent protection. (Walsh, 1981) Sheila Jasanoff explains that for a thing of nature to move from the 'commons' into the realm of 'private property,' it must be moved from the domain of nature to culture. One way to do this is to reframe the actions of researchers as "a project in mining nature for extractable entities that can freely circulate." (Sunder-Rajan ed., 2012, 169) In this way a being of nature is extracted, isolated, altered and turned into cultural property. After the 1980 Chakrabarty ruling, a slate of court cases and patents for living, genetically modified beings ensued and since then companies like agribusiness giant Monsanto have gained dubious fame for their copious lawsuits typically aimed at small farmers accused of patent infringement (http://www.vanityfair.com/news/2008/05/monsanto200805). The dominant logic became that: "The invention (the modified trait) and the product in which it found expression (the seed) became in this way a single, indissoluble package, part of culture not nature." (Sunder-Rajan, 2012, 171) After Chakrabarty, DNA sequences, isolated from their organism context and 'purified' as sequences of genetic code, began to regularly appear in patents. The argument remained that it requires great ingenuity and a human hand to do this work and that the purified DNA would never exist in nature. (Dutfield, 2004; Sunder-Rajan, 2012) Then in 1995, the Opposition Division of the European Patent Office (EPO) officially "declared DNA to be 'not 'life,' but a chemical substance which carries genetic information', and therefore patentable just like any other chemicals are." (Dutfield, 2004, 21) This declaration would be seminal for biotechnology and would persist until 2013.

The history of U.S. Patent Law has clearly erred on the side of expanding private property rights. Halbert calls proponents of this trend *maximalists* and demonstrates the ways in which the private rights maximizing ideology is not only tied to deeply held neoliberal ideologies but also results in the strange situation where "access to knowledge becomes an activist stance" such that protection of commodities and the extension of commodification deeper into the realms of 'nature' and 'culture' become viewed as means for protecting the public good. (Halbert, 2010, 6) Advancing the reach of IP into the realm of more complex 'life forms,' the first patent granted to a multicellular transgenic mammal was for Harvard's Oncomouse in 1987. (http://www.wipo.int/wipo_magazine/en/2006/03/article_0006.html) These mice had been genetically engineered to be more susceptible to cancer (an ethical conundrum for a different conversation) and thus useful for cancer research. While most countries agreed with the U.S. decision, to patent Harvard's mouse, the Canadian Supreme Court disagreed and ruled that these mice could not be viewed as patentable material. Jasanoff argues that where "The U.S. debate centered on an imaginary of progress…The Canadian decision, by contract occupied itself with the difference between life and matter." (Sunder-Rajan ed., 2012, 173) A later case with a different outcome shows us the nuances of the Supreme Court's decisions. This case in 1992 involved the Upjohn pharmaceutical company. They had genetically engineered mice to lose their hair so that the company could test products for treating baldness. The U.S. Supreme Court in this case ruled that the benefit to the public did not overshadow the suffering to the mice, thus overturning the patent on moral grounds. (http://www.wipo.int/wipo_magazine/en/2006/03/article_0006.html) This subtle

distinction between morality and progress will be important when we visit the potential futures of IP and emerging biotechnologies.

The final critical turn in the road towards a biotechnological boom was the Bayh-Dole Act - brought into being in 1980 and made into law in 1984. This act dealt with the transfer of technology from research universities to the private sector. Previously, any research conducted with government funds by a university had to remain the property of the government. Now, this research could be transferred to the private sector and subject to patent laws, commodification, etc. The dominant ideologies at this time held that the public would benefit if innovations from public universities were released into the market for commodification, manufacture and sale. (Mowery et al, 2001) Paul Rabinow argues that this act then paved the way for the invention of the polymerase chain reaction (PCR), a founding hallmark of biotechnology, because the new method of technology transfer would "encourage cooperative relationships between universities and industry, and ultimately take government sponsored inventions off the shelf and into the marketplace," thus making R&D for PCR, an unproven technology, economically viable. (Rabinow, 1996, 22) Biotech in many ways has always persisted as a fictional science:

> "a projected application that is considered to be scientifically plausible and technologically feasible when subjected to further research and investment. These fictions are often made real by the momentum of economic process; speculative biotechnological projects are embodied as corporate forms that serve as vehicles for the attraction of venture capital and as legal enclosures for such proprietary technology as might eventuate from research. The role of law – and

patent law in particular – is reinforcing these fictions and has itself become a productive theme in research." (Pottage, 2007, 322)

The Bayh-Dole act required universities taking government funding for research to report any potentially patentable inventions that came out of their work. The connection between universities and the private sector was enlivened with a 300% rise in patents related to human biological research granted between 1980 and 1984. (Rabinow, 1996, 22)

Rabinow's ethnographic account of the creation of the polymerase chain reaction (PCR) is a crucial lesson in the workings of neoliberal bioscience. As capital began to flow to the biosciences in the 1970's and even more aggressively in the 1980's after Bayh-Dole, the central players became venture capitalists and start-up companies. This trend continues today. (Rabinow, 1996) Well-known scientists were recruited as advisors to start-up companies and a Nobel Prize for research began to signal not just fame but also fortune. The invention of PCR was hotly contested among a few major corporations and some prominent scientists. But what is more important for our purposes is: the trend towards an ever increasing corporate/academic merger; what PCR could actually do; and the ways that it profoundly opened the doors for today's biotechnological revolution. In sum, PCR "facilitates the identification of precise segments of DNA and accurately reproduces millions of copies of the given segment in a short period of time." (Rabinow, 1996, 1) And perhaps most interesting, as Rabinow explains, PCR was not designed to solve any particular problem, rather, "once it existed, problems began to emerge to which it could be applied…PCR is a tool that has

the power to create new situations for its use and new subjects to use it." (Rabinow, 1996, 7) Synthetic biology would not have been possible without it.

Present – Welcome to the Wild West

"When everything can be made or remade, there is no world of external regularities at all, only a world that exists through human action or in default of human action."

~ Pottage (2007, 324)

"Anyone in the world that has a few dollars can make a creature, and that changes the game," Heinz said. "And that creates a whole new world."

~ Austen Heinz, CEO Cambrian Genomics (http://www.sfgate.com, 2014)

This current chapter in the unfolding biotech boom might one day be known as its *wild west*. The technology is moving so quickly that regulatory and social norms are struggling to keep up, and we can see how certain people are using this chaos to their advantage. Glowing Plant was a project started by Antony Evans in the Bay Area. He was able to make the Arabidopsis thaliana plant glow using a gene gun to insert DNA identical to the sequence that makes a firefly glow. It was the first ever synthetic biology project funded by Kickstarter - they raised over $400,000 by promising to mail seeds to their backers. Kickstarter pulled the project from their site and prohibited any future projects that provided genetically engineered products as a reward to funders. There was no existing way to regulate the sale or distribution of the seeds. Operating in a new, weird gray zone in between the jurisdiction of various governmental agencies, Glowing plant was able to escape any formal oversight. As Evans explained in a 2015 blog post:

> Part of what makes our business possible in the U.S. is the regulatory environment. The Coordinated Framework for Biotechnology was developed

around the principle that the product, not the process, should be regulated. This principle is robust and based on solid scientific evidence. As a result, plants are regulated under the existing USDA plant regulations that prevent the introduction of noxious weeds or plant pests. If there is no reason to suspect a new plant to be either of those things, then the product will not be regulated by the Animal and Plant Health Inspection Service (APHIS)—a confirmation we recently received from APHIS for our first version of the Glowing Plant. (http://techonomy.com/2015/03/a-glowing-plant-the-first-fruit-of-digitized-genetic-engineering/)

Another genetic engineering firm, AquaBounty, was caught for years in a different sort of regulatory grey zone, this one not as productive for the company's bottom line. AquaBounty created a genetically modified salmon that the FDA determined is also classified as a drug. As a result, they worked to get FDA approval for over a decade. Meanwhile salmon fisheries mobilized to make it illegal to transport, sell or purchase genetically modified fish. Caught in a regulatory no man's land, AquaBounty was finally approved for sale in both the U.S. and Canada in 2015. (http://www.npr.org/2012/01/02/144330629/biotech-firms-caught-in-regulatory-no-mans-land; https://www.washingtonpost.com/news/speaking-of-science/wp/2017/08/04/gmo-salmon-caught-in-u-s-regulatory-net-but-canadians-have-eaten-5-tons/) But as of late 2017, only Canadians had actually eaten the engineered fish. In America, labeling regulations were a major hurdle to the sale of AquaBounty's salmon. Now with an aquaculture plant built in rural Indiana, nowhere near any natural

body of water, AquaBounty hopes to finally see its genetically modified salmon in U.S. grocery stores in 2019.

Kathleen McAfee in her essay *Neoliberalism on the Molecular Scale* argues that U.S. patent policy has been "framed by a neoliberal approach to biotechnology regulation. This approach…depends upon two forms of reductionist discursive practices: molecular-genetic reductionism and economic reductionism." (McAfee, 2003, 203) Economic reductionism tells us that all things are ultimately reducible to a commodity form. That objects can be made 'lively,' disconnected from their context in order to circulate as objects of capital. (Sunder-Rajan, 2012) Genetic reductionism is founded on the pervasive metaphors of a deterministic 'gene' and a readable/writable 'genetic code.' And while these metaphors may seem logical at first, as McAfee and others point out, they are way too simplistic. (McAfee, 2003; Calvert, 2012, Rossi, 2014) This is the problem of design rendered invisible. (Latour, 2013) The average person is not privy to the workings of a biotech wet-ware laboratory where genetic experimentation is messy, failure rates are high and certain aspects of genetic expression remain ultimately unknowable – this is what McAfee calls the 'myth of genetic engineering precision.' (McAfee, 2003) Rather than representing reality, the dominant metaphors are born of neoliberal desires to commodify and capitalize upon genetic resources. The metaphor itself thus "provides conceptual support for treating genetic constructs as tradable commodities which are subject to market exchange." (McAfee, 2003, 204) Genes are in fact highly context dependent and the results we see from genetic expression are due to dynamic, complex interactions between genes and their environment. It has been shown that two identical genes in two different places will

evolve differently, but neoliberal discourse tends to ignore these instances of difference because, “they do not lend themselves to easy solutions, much less to the production of patents, profitable commodities or research funding or fame.” (McAfee, 2003, 206) The reality of genetic expression is illegible to the market and is therefore suppressed and re-inscribed in ways that more easily render life as commodity.

This trend towards a double-reductionism in biotechnology rests upon the history of patent law and the dualistic metaphysics of nature and culture that have defined the modern neoliberal era where techno-optimistic and industry driven arguments “draw upon the vague notions of a post-industrial ‘new economy’ which, almost miraculously, creates value from information with relatively little need for mundane material inputs or labor.” (McAfee, 2003, 204)

In this way, Jane Calvert argues that nature is being redesigned to fit the commodity form. She calls this a process of ‘disentanglement:’ “for something to be a ‘thing’ it must be fragmented… reduced to a format that makes it possible to make an exclusive package or artifact for which an exchange value may be established.” (Calvert, 2008, 384) The reality that is obscured by this process is that biological systems are by their very nature ‘open’ – they exchange information and matter with each other and with the environment. To imagine that this can ultimately be controlled, as synthetic biology aims to do, is highly suspect reasoning. Calvert’s concern with the “regulatory and the epistemic” demonstrates the ways in which ontologies, politics, economics and culture effect science in visceral, material ways. (Calvert, 208, 383) We imagine and create certain innovations because they easily fit into the dominant socio-cultural paradigm, not

necessarily because they are the innovations most needed for human and nonhuman flourishing.

In relation to intellectual property and biotechnology, a few of the crucial trends and events of the more recent present/past include: the Myriad Genetics ruling of 2013; the recently resolved fight for patent control over the CRISPR Cas9 technology; the open source movement; the tragedy of the 'anti-commons;' and indigenous and other resistances to what is seen as biocolonialism and neoliberal monopolization of technologies.

The Myriad Genetics ruling of 2013, which overturned the 1995 EPO declaration that DNA is patentable, can be situated in a larger philosophical move towards treating both software and biotechnology as objects rather than texts. Bonaccorsi et al argue that "legislation on intellectual property is shaped by ontological considerations" and that the introduction of patenting in both software and biotechnology caused a radical shift in the way these inventions were understood and protected by IP laws. (Bonaccorsi et al, 2011, 2) Where a text is protected as a whole by copyright with individual elements considered part of the greater whole work, objects are protected "based on the model of mechanical inventions that assumes a narrow relationship between the structure of an object and the function it performs." (Bonaccorsi et al, 2011, 2) As discussed earlier, prior to the recognition of biological forms as patentable material (Chakrabarty case), biological material was protected by the plant breeder's right 1930 & 1970. These were based on protection of the *whole* organism, not its constituent parts or its genetic makeup. After 1995 when DNA is declared a patentable chemical, the notion of patenting particular gene sequences is popularized. This led to a huge consolidation of

patents and market control in the hands of a few large agribusiness corporations that were able to rush their products to patent while small farmers lacked such capital for research and development on any scale. Today there is a clear monopoly in the realm of industrial agriculture with corporations like Monsanto, Dow and Syngenta being some of the largest worldwide. (Bonaccorsi, 2011; Scharper, 2006; Kumar & Rai, 2007) It can be argued that all of this previous legal and ontological groundwork led up to the 2013 decision in Association for Molecular Pathology v. Myriad Genetics Inc., a decision that seemed to limit the patenting of DNA, but when understood in the context of synthetic biology, has in reality opened the way for a proliferation of biotechnology patents. Where Myriad Genetics had been patenting isolated and purified DNA sequences, as had many others, the U.S. Supreme Court now ruled that isolated DNA could not be patented. But, and this is the critical but, the court simultaneously ruled that synthetically produced DNA *can* be patented. The ramifications of this ruling are yet to be fully understood, but for scientists and venture capitalists involved in synthetic biology, it is certainly a boon.

Another major event that has played out in the last several years, is the fight over the patent to control the CRISPR-cas9 technology. CRISPR-cas9 is a powerful but general technology for editing genomes hailed as a breakthrough that will be used in numerous and untold ways. It is a building block technology for synthetic biology so the group that controls this patent wields significant commercial power in the field. Based on a function found in certain bacteria that are able to identify and carve up the DNA of invading viruses, CRISPR allows scientists to cut up DNA strands and rapidly replace code. It is said that this technology may bring the cures for a variety of deadly and

debilitating diseases. At issue is who invented it first and the contenders are Jennifer Doudna of UC Berkeley and Feng Zhang of MIT's Broad Institute. Doudna's patent application was filed before Zhang's, making her the first to invent, but Zhang received a patent first, in April of 2014, after paying for an expedited patent review process. UC Berkeley then filed what is known as a patent interference, arguing that the two patents were identical and that Berkeley had invented the CRISPR process first. Broad, alternatively, argued that the processes were different. UC Berkeley's technology only worked on bacteria and prokaryotic organisms while their technology was for applications on eukaryotic organisms. In 2016 the US Patent and Technology Office (USPTO) ruled that Broad had invented a nonobvious invention and would hold the patent. Berkeley appealed and just this September 2018, the US Court of Appeals upheld USPTO's decision. (Sherkow, 2015; https://cen.acs.org/policy) Meanwhile, Berkeley has been more successful in obtaining foundational CRISPR patents in other countries such as China and parts of Europe. The IP control of these foundational technologies is a serious financial make or break for the labs and the race is on.

This brings us to what some call the 'tragedy of the anti-commons.' A riff on Garrett Hardin's *Tragedy of the Commons*, which argues that resources held in common will be exhausted as all parties competitively vie for their portion, the 'tragedy of the anti-commons' is particular to technologies where certain broad foundational processes are needed to do anything higher up in function and where individual parts are also needed to create novel innovations. This double bind, broad patents on foundational processes and a plethora of narrower patents on individual parts, creates a bottleneck for innovation – the very thing intellectual property is supposed to protect and

encourage. (Kumar & Rai, 2007; Calvert 2008) Part of the problem is that in many cases, the patent IS the product and all who come after must pay the original patent holder to do anything that will advance innovation in that particular area of science. (Dutfield, 2004)

One potential answer to these conundrums for synthetic biology is the open-source movement. Its foundations are in the BioBricks organization, which founded the IGEM (International Genetic Machine) competition and the Registry of Standard Biological Parts. But as some theorists demonstrate, this sort of 'open-source' is in many ways a misnomer. Users must still pay certain licensing fees to the databases making it more a 'mosaic of private property' regimes than truly free and open. (Calvert, 2008, 2012; Kumar & Rai, 2007) Another aspect of open-source biotech, also called DIY-bio, is the biohacking movement. Composed of a variety of loose groups that share open lab space or operate out of their kitchens and garages, biohackers often claim to be keeping biotech democratized for the future. (http://www.davidson.edu/news/news-stories/150330-mac-cowell-06-profile) Biohacking is pretty true to the open-source claim, with proponents purposefully keeping their research independent and apart from the market or politics. Construction plans, test logs and findings are all shared openly for collaborative learning and experimentation. There is currently no law regulating this type of science in the U.S., where anyone can buy a do-it-yourself CRISPR kit for $159. In Cameroon, biohackers are organizing a do-it-yourself bio-lab with the aim to address immediate concerns like water filtration, medicines for diarrhea and natural pesticides. (https://www.dw.com/en/biohacking-genetic-engineering-from-your-garage)

Indigenous and other resistance to biotechnology is another trend that has gained momentum in recent years. Often dubbed 'biocolonialism' and tied to historical forms of colonial violence, the movement of IP into the realm of biology is contextualized as the next form of 'accumulation by dispossession' (Harvey, 2009). In Hawai'i, Kānaka Maoli activist Walter Ritte has named this new colonialism the 'Mana Māhele'. With reference to the first Great Māhele of 1848 whereby the islands of Hawai'i were divided up and land was privatized for the first time, the 'Mana Māhele' is biocolonialism's move to divide up and privatize 'mana' - spiritual power, life essence. (Kanehe, 2014) Stephen Scharper writes of *The Genetic Commons* as a way to name the movements that resist neo-liberal enclosure of life. Questioning the benevolent claims of biotechnology advocates, what I have classified as 'the myth of better', Scharper, Kanehe and others bring into clear focus the questionable intent of a field that is primarily fueled by massive accumulation of wealth through the control and manipulation of biology. (Scharper, 2006; Anderson 2009, Kanehe, 2014; Cunha, 2009)

Futures – The Next Nature?

"We must no longer see ourselves as the anti-natural species that merely threatens and eliminates nature, but rather as catalysts of evolution. With our urge to design our environment we create a 'next nature' which is unpredictable as ever: wild software, genetic surprises, autonomous machinery and splendidly beautiful black flowers. Nature changes along with us!"

~ Nextnature.net

In 1999, Arturo Escobar wrote in his essay *After Nature* that biotechnology is leading us towards a "new view of nature as artificially produced. This entails an unprecedented ontological and epistemological transformation which we have hardly

begun to understand. What new combinations of nature and culture will become permissible and practicable?" (Escobar, 1999, 2) What type of futures do current intellectual property laws make possible? How might those futures unfold in the 21st century? In thinking about these questions, I see three dominant trajectories based on extrapolations of current trends, the Continued Growth paradigm: Monopolized and multiple 'tragedies of the anti-commons'; De-extinction and beyond; Weaponization of Synthetic Biology; and Biohacking Undergrounds. Exploration of these alternative images of the future may open up spaces of possibility beyond current trajectories and help us to envision potentially useful alternatives.

Continued Growth paradigm: Monopolized and multiple 'tragedies of the anti-commons'

The monopolies over biotechnology innovations and their patents are only concentrating as time goes on with corporate wealth and power accumulating as the market system has intended. In 2006, 90% of all global biotech patents were held by institutions in the North. (Scharper, 2006, 197) In 2011, a single company, Monsanto, accounted for a full half of all genetically engineered crop trials in the U.S. (Bonaccorsi et al, 2011, 8) These monopolies are transferring to the synthetic biology sector as the very same corporations now acquire promising start-up companies in the synthetic biology space along with their patents. In addition to the agribusiness giants in this space, tech giants are also getting into the game. A recent article in The Motley Fool explained that Autodesk, Intel and Microsoft are quietly investing huge sums of money in synthetic biology. As just one example of what may be in store, Autodesk's "Project

Cyborg" would enable users of a CAD-like program to design virtual organisms, test their behavior and model changes to biological systems - without ever having to enter a laboratory. (http://www.fool.com/investing/general/2015/01/07/3-tech-giants-quietly-investing-in-synthetic-biolo.aspx) Neoliberalism concentrates wealth and power. Patents and intellectual property protect that wealth and power. As we move into the biosynthetic era we may see immense monopolies and thickets of patents that stifle innovation for anyone but the patent holders and the other corporations wealthy enough to purchase their way through research and development.

De-extinction and beyond

De-extinction is currently a novelty. Proponents include the Long Now Foundation who in 2013 started a non-profit called Revive & Restore. Their aim is to bring back extinct species using ancient DNA and synthetic biology techniques. Some of the species they are currently working on include the Passenger Pigeon, the Wooly Mammoth and the Heath Hen. An article in the MIT Technology Review in 2013 profiled the synthetic biology pioneers, Robert Lanza and George Church who claimed to be starting a de-extinction company called The Ark. While they remained fairly opaque about their ultimate intentions, they were clear that they see de-extinction as just the beginning. Once the technique is perfected, "the company's real aim is to combine cutting-edge cell biology and genome engineering in order to breed livestock and maybe even create DNA-altered pets that live much longer than usual." Beyond these goals may be the desire to one-day engineer humans for infertile couples. Major IVF-clinics are backing the scientists and they use a technology that can ostensibly make

functional eggs and sperm from a person's skin among other things. (http://www.technologyreview.com/view/512671/a-stealthy-de-extinction-startup/) One can imagine that the day depicted in this HSBC ad, where every being is patented, owned and accounted for is not very far away:

In a 2013 interview for Volume magazine, Liam Young asked scientist Adam Rutherford, "Are we going to see a scenario where a pharmaceutical multinational patents a particular kind of plant and forests become a copyright infringement, gardening an act of piracy?" To which Rutherford replied, "We are not there yet, but it is not unimaginable." (Rutherford, 2013, 17)

Weaponization of Synthetic Biology

At the 2014 SynBio Beta conference in San Francisco, a representative from DARPA briefly took the stage to announce their *Living Foundries* program, aimed at harnessing the power of innovative, world changing synthetic biology inventions. With just a 2-page abstract explaining the world-changing idea, scientists and start-ups can be eligible for $700,000 in government funding for R&D. DARPA's stated goal:

> The goal of the Living Foundries program is to leverage the unparalleled synthetic and functional capabilities of biology to create a revolutionary, biologically-based manufacturing platform to provide access to new materials, capabilities and manufacturing paradigms for the DoD and the Nation. (http://www.darpa.mil/our_work/bto/programs/living_foundries.aspx)

Though the website, somewhat conspicuously, makes no mention of weaponization, it is no far stretch of the imagination to imagine DARPA, the DoD and the US government

taking the innovations they fund and own into the theatres of war. One can easily imagine synthetically controlled beings being the next line in our national security defense of the futures.

Biohacking Undergrounds

Today, the group of hackers and activists known as Anonymous has captivated the popular imagination with their Guy Fawkes masks and bold audacious hacks in cyberspace. Biohacking today is by contrast fairly benign and above ground. Groups like GenSpace, BioCurious and Grindhouse Wetware operate in garage laboratories and host meet-ups with like-minded individuals to make bacteria glow while they drink microbrews on a Friday night. The innocuous nature of these organizations could change as patent infringement and corporate strongholds force their work to go underground. Should this be the case, we may see an Anonymous style hacker group emerge. Perhaps something like the *New Weathermen*, a biohacker group of the future imagined by artist and designer David Benque:

> The New Weathermen is a fictional group of activists who embrace Synthetic Biology to push for radical environmental change. Challenging the borders between activism and crime, their actions aim to disrupt the status quo and propagate an ambitious vision for the greater good. (http://www.davidbenque.com/projects/the-new-weathermen/)

Infusing rainforest destructing palm oil with lipase inhibitors that make people sick when they consume the oil is just one of the fictional possibilities Benque has dreamed up for the future activist group.

Alternatives – Genes are not information

"Once you have the Next Nature perspective you know that altering our environment is inevitable. The question isn't whether we should do it, but rather how do we do it and for what purpose. I'm not against genetic modification of species, but I am against companies like Monsanto engineering seeds so that farmers can only use them for one season, making farmers completely dependent upon the corporation. With Next Nature you get a more nuanced discussion."

~ Koert van Mensvoort, founder of Next Nature

It has been shown time and again that "Genes do not willingly conform to researchers' and investors' expectations." (Rossi, 2013, 1128) So while synthetic biology conspires with intellectual property to foreclose public ownership of a genetic commons, what alternative spaces might be possible to imagine other futures? Artists and designers today inhabit and enliven this space of possibility in interesting ways. Artist and social scientist Alexandra Daisy Ginsberg writes that "Navigating the space between the mundane visions of chemicals, tethered in the technologically possible, and dreams unconstrained by existing science can help us test what we might want from a future." (Ginsberg, 2013, 51) There are a few areas where I see possibilities for an opening, a potential way out of the continued growth paradigms: Natural computing gains traction over synthetic biology making patents in many arenas obsolete; The Supreme Court rules that synthetic life is the same as natural life and therefore not subject to patents; Indigenous and other forms of resistance gain traction and the idea of a genetic commons is recognized at the UN.

There is an ongoing debate between those who believe in biosynthesis/natural computing vs. those who adhere to gene-centric/synthetic biology. While both facets of the biosynthetic spectrum have grandiose visions of techno optimistic futures, their

differences could have profound effects on the futures of intellectual property and biotechnology. Rachel Armstrong describes how natural computing is based in new materialist philosophies of agentized matter:

> "where comparatively weak microscale forces possessed by 'agents' can amplify their effects by forming 'assemblages'…Viewed from this philosophical lens biosynthetic technologies can potentially help us explore a new world of co-authorship, creativity and empowerment, in which humans and nonhumans can bring forth new kinds of living systems, not all of which may be truly biological." (Armstrong, 2013, 115)

Armstrong's vision, while admittedly utopic in nature, is based in a more egalitarian ethic of shared design and co-creation between human and nonhuman forces. This sort of an ethic is much more resistant to commodification and may open up spaces for creation that resist the dominant neoliberal trajectories. It's a similar debate to the one between systems biology and synthetic biology that Calvert documents. Systems biology looks at wholes and embraces complexity, a practice that is particularly difficult to commodify. Synthetic biology on the other hand focuses on standardized, interchangeable components, reduced complexity and disaggregated biological parts – all of which are infinitely easier to commodify and therefore patent. (Calvert, 2008) If we see a trend towards systems biology and natural computing in the future, we may find spaces for productive resistance against the enclosure of life forms.

In another scenario, one could imagine that the Myriad Genetics ruling of 2013 is challenged and overturned with a ruling that synthetically produced life is the same as natural life and *neither* can be subject to patent. Perhaps too many synthetic organisms

are patented, and we do see future trends like the forests being considered a patent infringement or a subsistence fisherman being taken to court for not paying use fees on a genetically modified fish that he caught. Perhaps we realize that patenting life forms does not actually lead to or support more innovation, that it is in fact a detriment. The trends in IP and biotechnology privilege venture capital and neoliberal market logics. To truly unleash the power of the emerging biotechnologies, we may need to realize the limits of these trajectories. Neoliberalism and the myth of the free market claim that human creativity is primarily driven by capital gain. I'd like to argue that while this is sometimes the case, human ingenuity is often driven by deeper more altruistic desires. And that if we can focus on these drives and ways to support the people who work for greater good, we will find ourselves in a much more resilient future. "As engineers, synthetic biologists ask: 'How do we make algae fuel?' We also need to challenge what is being asked. This means not only designing ways to use less fuel, but also imagining systems that don't need fuel." (Ginsberg, 2013, 51) Take Modern Meadows for example: a start-up company with the ethically charged mission to create cow's milk without cows. The production of milk in modern industrial agriculture is resource intensive, environmentally destructive and causes great suffering for the animals. If Modern Meadows is successful, they will produce milk from bacteria and yeast without any animals involved. Logically they would want to patent this technology and own the right to producing milk in this way. But if we take a step back and think for a moment about the supermarket shelf – packed with different brands of milk to choose from. The cow that produces milk the natural way was never patented, that didn't stop innovation or competition from happening on the market. I believe that the founders of Modern

Meadows and similar ventures with ethical underpinnings are driven by something deeper than pure profit. Current economic and cultural systems push them in the direction of profit motives and the promise of great wealth is certainly alluring. But I don't believe that the lack of patents would bring an end to these types of innovation. Perhaps we will find that a variety of factors drive the human desire to innovate and will realize that patenting and privatization are not always the only way.

In a final scenario, we might see that pressures from the side of resistance against patents and enclosures on life forms mount and become an international force. Eventually the UN responds with an international treaty that defines all forms of DNA, synthetic and natural, to be part of a genetic commons for use by all of humanity without the ability to be patented for commercial gain. This ultimate resistance to biocolonialism is a foreseeable possibility for the futures.

21st Century Narratives

Let's return to this original thought - current copyright law protects culture as a commodity and allows capitalism to invade all different aspects of the Habermasian 'lifeworld.' (Halbert, 2010) This may have worked for a time, and certainly some people have profited greatly, but it seems that the biotechnological revolution and the collapse of nature and culture as binary domains requires a new way of thinking about the world. Moral arguments against biotechnology patents often cite the way that these products of law illegitimately treat natural products as artifacts of man, "thereby undoing the prestige of the grown and sanctioning the appropriation of resources that should remain common or uncommodified." (Pottage, 2007, 326) What we need to remember is that our

normalized visions of the moment are always peculiar when understood through the lens of macro history. We have a choice about how to proceed. Nothing is set in stone, even despite our current collective inertia. Our choices matter and we shouldn't take them lightly. Biotechnology is just finding its feet, and it is moving at a pace that defies comprehension. We will need to find collective understandings of life, nature and culture that fit our new reality. When biology is at the behest of technology, new narratives, new norms and new economies must be imagined that have at their root the ethic of human and nonhuman flourishing as a basic right. In the next two chapters, we will explore possibilities for this reframing and the curation of an ethics that has some chance of responsibly governing evolution at the pace of synthetic biology.

CHAPTER 3

DECOLONIZING SYNTHETIC BIOLOGY

"Botany was energized through the transplantation of tropical plants (along with slaves and prisoners), becoming a science tightly integrated into the structure of empire and colonialism. Transplantation and a climate-based anthropology both signaled the variable possibility of rootedness that settler colonials desire/d."

~ Hiller & Silva (2014,15)

"The mosquito, on the other hand, is said to belong to nature. It cannot speak."

~ Morton (2002, 25)

In April of 2015, genetic researchers from China published a highly controversial paper in the open access online journal Protein & Cell. In it, they outlined the work they had done editing the genes of human embryos with the, then, relatively new CRISPR gene splicing technology. Using some 86 human embryos obtained from a fertility clinic, the researchers attempted to repair a gene that causes the hereditary blood disease known as beta-thalessemia. Most of the embryos died during the research and even those few that survived did not successfully repair the gene. In the name of science, this was hailed as a productive experiment, a learning experience (http://www.wsj.com/articles/new-advance-in-gene-editing-reported-1429804820). And while ethical questions and calls to alarm have mounted in the U.S. and Europe, there is no global agreement or governing body capable of tempering researchers like this team in China or privately funded research teams that are not subject to government oversight. Politics and science eternally collide in the quest for greater knowledge and control over the forces of nature. Might we posit that authenticity is so irrevocably

entangled with sovereignty, that we need to embrace and entangle ourselves with mystery more than ever? Synthetic biology attempts to conflate organism and mechanism, despite the fact that an organism *"*cannot be taken apart and put together again without damage," cannot be analyzed as its component parts out of context, out of time. (Deutsch, 2008, 111) In an era of ruling neoliberal logics, the political implications of this conflation include a trade-off of authenticity for managerial control. Authenticity is the sovereignty to be genuine, to be self-evolving, to be beyond control and management. It is the embrace of a heterogeneous diversity that defies ever being fully captured because of its complex dynamics and ultimate mystery. When we can accept that "any sufficiently advanced technology is indistinguishable from magic" might we also accept that spirituality and science are indistinguishable? (Arthur C. Clarke, 1962) I argue that we must move in this direction if we want to have a planet that is diverse, filled with the richness of non-human life forms and vibrant with the humility of humans who understand dying as inextricably tied to really living. Indigenous political theory is the bridge to carry critical political theory into this next evolution. This research argues that Indigenous political scholarship and rigorous acts of decolonizing scientific practice is required if we hope to arrive at a place where synthetic biology *might* be capable of responsibly governing evolution.

We live in a time when power is the "ability to afford not to learn," and power is the persistent insistence upon one's right to experiment on and profit from those less powerful. (Deutsch, 2008, 111) Synthetic biology is aiming to capture and control the forces of vitality, the stuff of life, the complexity that is being and becoming, that vital force that can never be fully captured and Indigenous political theory represents an

opportunity to assert and claim the sovereignty that has always existed at the foundation of biological life. The technologies of settler colonialism aim to erase to replace and we can argue that these same logics are now being applied at the level of genetics. Patrick Wolfe explains that the settler-colonial will is “a historical force that ultimately derives from the primal drive to expansion that is generally glossed as capitalism” (Wolfe, 1999, 167). This marriage of settler-colonial will and capitalist drives is very clearly playing out in the development and push to spread synthetic biology into the depths of heritable genetics where it not only erases the present but also the possible futures. Bridging from critical political theory, which is still inherently invested in the Western world order that created the systemic problems we now seek to solve, Indigenous theorists and scholars are openly challenging the imposition of colonialism into the realm of biology. Engaging with these voices and research allows myself and other non-indigenous scholars to become allies in driving forward the crucial project of decolonization of research and scientific knowledge production. This chapter will examine how Indigenous scholars track colonialism in the biosciences and how we can support their ability to disrupt and dismantle the power structures that have created the current inequitable distribution of wealth and privilege.

Synthetic biology as a response to human desire for control over nature is at its essence nothing new. Humans have been aiming to control unpredictable, complex and fearful natural phenomenon for as long as we have been humans. And yet the work of techno-politics in the industrial era through to the current century has represented a movement towards a prevailing belief that technical expertise inhabits a privileged arena of knowledge. Techno-political responses to biological forces entail a “certain way of

organizing the amalgam of human and nonhuman, things and ideas, so that the human, the intellectual, the realm of intentions and ideas seems to come first and to control and organize the nonhuman." (Morton, 2002, 18) This privileging of technical expertise and western forms of science is a reorganization of knowledge where other forms of expertise existed before rather than an introduction of expertise where none existed. The erasure of indigenous and traditional forms of knowledge, in this way, follows along the same lines of colonial erasures of peoples, lands and genealogies. Synthetic biology in its current technical iteration is one more process in a long history of processes that purport radical discovery in order to enable the concentration of power and capital. Indigenous sciences directly challenge the duality of techno-politics and the distancing of human and non-human that has characterized western sciences. This ontological challenge is a critical force in boundary setting as we navigate the ethical limits of our human capacity and moral responsibility in the governance of evolution. How might a decolonized synthetic biology approach the governance of life differently, in ways that integrate human and non-human agency more realistically and with greater equity? What would it mean to enable a sovereignty that allowed certain beings and peoples the right to be left to evolve on their own terms or simply be left alone?

To begin a process of decolonizing something like Synthetic Biology, we need to dig into the genealogy of colonial technologies as they are applied to the building blocks of biology - biocolonialism. Lea Kanehe defines biocolonialism as "the extension of the process of colonization to genetic material and traditional knowledge of Indigenous peoples." (Kanehe, 2014, 331) Extreme forms of biocolonialism have been called biopiracy. An apparently modern problem, the roots of biocolonialism actually run deep

into the shared histories of violence and oppression experienced by Indigenous peoples worldwide as a result of colonialism, settler colonialism, imperialism, empire, white supremacy and paternalism. So in fact, biocolonialism at its foundation is not so new at all. Indigenous scholars argue for a framing of this modern technological issue as a socio/political one, and a continuation of the colonialist practices that have shaped and defined the project of modernity. (Goodyear-Ka'opua, 2014; Hiller & Silva, 2014; Kanehe, 2014; Salazar, 2014) Settler-colonialism is an enduring structure deeply woven into the fabric of the project of modernity - we have never ceased to be the colonial and the colonized. The modern world would not exist as it is and could not persist as it is without the sustained attention and energy towards hegemonic practices of settler colonialism and imperialism. What is new is only that with biocolonialism the reach of these practices has now extended into the genetic building blocks and spiritual being-ness of life itself. The danger of this degree of colonization over those traditionally experienced in the 20th century, is its near total invisibility, the velocity of change that is possible and its automatic perpetuity over time. Gene drive technologies have the capacity to render new genetic information that is heritable over future generations. We look at plastics accumulating in the oceans and wonder how could we have not known this would be a problem with trash that persists in the environment for hundreds to thousands of years. What will we say several generations from now when we realize that heritable genetic mutations were designed to support and increase consolidation of power and privilege? Intentional or not, this research argues that this is the future we face if we do not quickly embed Synthetic Biology with a set of ethics and values tied to radical notions of equity and the inclusion of previously marginalized voices – human

and non-human. The only way to truly decolonize this science is to privilege and lift into authentic leadership Indigenous practitioners and ethicists. And only through a rigorous decolonization of the science do we stand a chance of crafting a diverse and vibrant future where more people and the planet can thrive.

Patrick Wolfe famously wrote of settler colonialism that, “The colonizers come to stay - invasion is a structure, not an event.” (Wolfe, 1999, 2) Biocolonialism, particularly in Hawai’i, a settler-colonial state, is a manifested experience of invasion. The logics that maintain the morality of biocolonialism are the same logics that maintain the morality of occupation. The indigenous critiques of biocolonialism are therefore framed as impediments to scientific and economic progress, a progress that is assumed to be necessarily for the greater public good. I would like to interrogate these assumptions directly; by bringing into question the practice of maintaining histories of oppression and the practice of invalidating Indigenous epistemologies as inferior to western science. I would also like to highlight the unique epistemologies of Indigenous peoples, particularly Kānaka Maoli, as sites of productive resistance and alterity where alternative futures of greater equality and actual abundance (material as well as spiritual) might be imagined and realized. Manulani Meyer argues that our current foundational epistemological assumptions take on transformational new meaning when viewed through a Hawaiian cosmology, representing an opportunity “to reassert the things of value and reconnect the twin areas of ontology/cosmology with epistemology. The split between rationalism and empiricism, reason and experience will be healed with emic tools that reclaim these images in a more appropriate and Hawaiian cultural light” (Meyer, 2003, 81). I am interested in the specific histories of nonhuman others, plants animals and other

biological life forms, as the unwitting handmaidens of empire, and genetic engineering as a method of severing genealogies in order to create capital flows for neoliberalism's expansive growth. And I would like to question the validity of all these logics for a future of justice and human/nonhuman flourishing.

Histories and Ideologies of Biocolonialism

"Kew's mission is: 'to be the global resource in plant and fungal knowledge, and the world's leading botanic garden'." ~ kew.org

"Decisions taken at Kew Gardens or implemented with the help of Kew Gardens had far-reaching effects on colonial expansion: if the botanists could suggest where to find a plant that would fill a current demand; how to improve this plant through species selection, hybridization, and new methods of cultivation; where to cultivate this plant with cheap colonial labor; how to process this product for the world market; then the botanists may be said to have had a major role in making a colony a viable and profitable part of the Empire."

~ Goldberg-Hiller & Silva (2014,17)

The deep roots of biocolonialism reach down into the twin projects of colonialism and imperialism, what Makere Stewart-Harawira calls "the twin capitalist logics of accumulation and expansion." (Stewart-Harawira, 2005, 1) Particularly in Hawai'i, these histories remain manifest today as settler colonialism, what Iokepa Salazar defines as "a regime of hegemonic power whose influence runs throughout society, but is never guaranteed, entirely coherent, or wholly complete and without rupture or contradiction." (Salazar, 2014, 32) Where ethnobotany and bioprospecting were the original technologies of this colonial desire, in the late 20th and early 21st centuries the drive towards imperial conquest has moved into the realm of genetics and biology itself. The

history of collecting goes back to the early explorers who justified their expensive journeys as journeys of discovery, as if the lands they invaded and the materials and peoples they found were wholly new, without sovereignty and available for conquest. In the 'post-colonial' world, this practice of collecting morphed into one of bioprospecting. The World Health Organization defines bioprospecting as "the systematic search for and development of new sources of chemical compounds, genes, micro-organisms, macro-organisms, and other valuable products from nature. It entails the search for economically valuable genetic and biochemical resources from nature." (http://apps.who.int/medicinedocs/en/d/Jh2996e/6.3.html) The connection between nature and capital circulation is critical and what is left out of this definition is the fact that the majority of the biological diversity of the world exists in areas with predominantly Indigenous populations. The logic behind bioprospecting as a practice is that raw materials (natural resources) of their own right represent little in the way of commercial value. Their real value comes from the process of extraction, relocation to arenas of scientific production, and their re-production as altered materiality that is primed for commercial exploitation. Kathleen McAfee situates this logic within the framework of mythologies of the 'gene' and 'genetic precision' that permeate the biotechnological era. These mythologies of control reinforce power structures that privilege Western scientific knowledge over ancestral sciences and so exist in tension with the Indigenous peoples who have stewarded and cultivated the natural resources that make up the biopropector's raw material.

> "This logic helps to rationalize the privatization of science, the treatment of genetic information, organisms, bio-techniques, and research findings as

> proprietary commodities, and the valuation of genetic resources in terms of the prices they can fetch in international markets." (McAfee, 2003, 212)

What is silenced and erased by this logic is the fact that many of the 'raw materials' collected and re-scripted have been stewarded for generations by Indigenous peoples, often through careful genetic selection for preferred traits via traditional means. The traditional ways of knowing are consigned to a 'pre-genomics scientific dark age' with the assumption that "farmers practicing so-called informal methods of crop improvement have been toiling in ignorance and superstition." (McAfee 2003, 212) Such paternalisms are rampant in the practice of ethnobotany and bioprospecting, perpetuating the misnomer of 'discovery,' this time not on lands and peoples, but on biological matter and genetic material. Natural resources are seen as a commons going into the scientific pipeline and a private commodity coming out the back end. Touched by the magic of western science, the raw materiality of biology is thus inscribed with capitalist morality that enables beings to become commodities for exchange and wealth accumulation. Even the Convention on Biological Diversity's Nagoya Protocol is immersed in this contradiction. The *Access and Benefits Sharing* agreement is premised on the notion that local peoples offer their natural genetic resources to the realm of western science with remuneration coming after the issuance of patents on commercial products is complete. It is a scheme rife with inconsistencies and unrealistic expectations of cooperative governance and another example of poorly executed good intentions. (http://www.cbd.int/abs/)

All of these logics fall under the banner of *big science*, namely the "nexus of labor, expenditures, international coordination, geographical space, and resource

consumption." (Salazar, 2014, 41) Big science is particularly adept at forgetting the myriad practices, ontologies, cosmologies and epistemologies of the rest of the world. This forgetting is not only convenient for capitalism, but it is baked into heart and soul of the western scientific 'revolution.' Big science hands to biocolonialism a lineage of ideologies of oppression: scientific reductionism and objectivity, commodification, and neoliberalism. Scientific reductionism is premised on a notion of objectivity, knowable reality; scientist as the archaeologist or 'discoverer of truth.' Bruno Latour calls it a category mistake "to believe that the world before the invention of knowledge was already made of 'objective knowledge.'" (Latour, 2013, 89-90) Assuming that knowledge IS and truth IS, the scientist is then an objectively attuned truth-seeker, a-political, non-judgmental, merely the vessel and the expert translator through which the world is able to make itself known. Hawaiians on the other hand access knowledge from a diverse array of sources including close relationships with people "in the pō (the realm from which we come and to which we return at death; therefore the realm where our deceased kūpuna (ancestors) continue to exist)" (Silva, 2017, 8). For Kānaka Maoli, this rich tapestry of diverse knowledge is intertwined with the ideological commitment to moʻoʻkūʻauhau (genealogical) consciousness which necessarily imagines one's knowledge and purpose in the present extending far into the future with all the responsibility that entails (Silva, 2017, 6). The thin empiricism of western science pales in comparison to the rich practices of Kānaka ontologies.

The lineage of commodification is linked with the history of colonialism, the scientific revolution and the simultaneous project of empire. As I've argued, the discourses of commodification are woven throughout the history of collecting and

colonial conquest. They cannot be separated out of the project of empire. Where empire sought to disconnect colonized peoples from their genealogies through practices of displacement and enslavement, simultaneously 'nature' became the raw material for science and the basis of circulating commodities on the world stage. Jodi Byrd calls this the experience of 'transit' where "to be in transit, then, is to be in motion, to exist liminally in the ungrievable spaces of suspicion and unintelligibility. To be in transit is to be made to move." (Byrd, 2011, xv) For Indigenous peoples for whom place-based genealogies are a connection to the lifeworld, this is a significant violence. On the other side of this neoliberal process, is what Sheila Jasanoff identifies as 'lively capital:' the nonhuman actants that are likewise loosed from their moorings, decontextualized and made to move in circulations of capital for the purposes of wealth production. (Sunder-Rajan ed., 2012)

What is critical for the purposes of my project is the linkages between all of these historical and ever present forces. What I am seeing in the outset of the new synthetic biology boom is that colonialism plus capitalism plus reductionist science have together perfectly laid the conditions of possibility for the science of synthetic biology to emerge and expand at this time in history. The question to ask in the face of this field that beneficently purports to 'create a better world' through technological solutions to some of the planet's impending crises, is whether or not these foundations are the right ones for building a preferred, just and resilient future for the planet.

Western and Indigenous Science

"rather than being limited to a 'codified canon', traditional or indigenous knowledge is an expression of life itself, of how to live, and of the connection between all living

things…knowledge is also understood as sacred."

~ Makere Stewart-Harawira

"The crisis of reason is not so much a crisis for Hawaiians as a window of opportunity to reassert the things of value and reconnect the twin areas of ontology/cosmology with epistemology. The split between rationalism and empiricism, reason and experience will be healed with emic tools that reclaim those images in a more appropriate and Hawaiian cultural light."

~ Manulani Aluli Meyer (2003, 81)

At the outset, I think it is important to qualify that not all western science is reductionist, and not all indigenous science is holistic. For the critique of biocolonialism, however, it *is* the case that genetic engineering technologies are based on reductionist science and it is the case that indigenous relationships to nature and nonhuman life forms emit from a holistic cosmology – these distinctions form a critical frame of analysis. In contrast to western reductionist science, which embraces objectivity and a privileged distance from the object of inquiry, indigenous science engages with the world in a participatory embrace that encompasses generational knowledge, attunement to nonhumans through sensory and super sensory perception and a recognition of the spiritual realm of existence as parallel to, and in fact often primary to, the physical realm. (Cajete, 2000; Meyer, 2003) Katrina-Ann Oliviera explains how the Hawaiian belief in human nonhuman entanglement manifests through the practice of mele ko'ihonua (cosmogonic genealogies): "all living and nonliving elements are believed to be interrelated and possess a spirit, many Kanaka likewise value mele ko'ihonua as the framework by which all things in the natural environment, including people, are genealogically linked and ordered." (Oliviera, 2014, 2) Manulani Meyer similarly

delineates an inclusive Hawaiian cosmology that embraces the vitality of a variety of nonhumans and the participatory nature of an epistemology that is interwoven with spirituality so that spirituality becomes “a way of discussing the organic and cultural mediation of experience, and hence knowledge, and should not be expected to conform to religious structure” (Meyer, 2003, 93). Knowledge, ‘ike, is not alienated from supernatural understandings of the cosmos. Spiritual and physical realms weave throughout each other, often without clear demarcations: “‘Ike makes it clear that knowledge was gained from a large variety of sources, both spiritual and temporal, both sensory and extrasensory” (Meyer, 2003, 97). This same epistemological foundation is resonant with other Indigenous peoples. In the theory of Tsawalk, “The physical universe is like an insubstantial shadow of the actual, substantial Creator. In this worldview, the highest form of cognition, of consciousness, does not occur in the insubstantial shadowlike physical realm, but in the realm of the creation’s spiritual source.” (Atleo, 2005, xvi) In stark contrast to dominant western scientific materialist notions of reality, this paradigm offers different spaces for creative ways of co-producing *with* the world that decenter the primacy of the human and the primacy of knowledge as a one-way act of translation. Instead the human comes alive in a vibrant world of becoming, co-creator alongside the rest of the nonhuman multitude, ripe with a sense of astonishment that Ingold describes as the “sense of wonder that comes from riding the crest of the world’s continued birth” (Ingold, 2006, 18). For the Indigenous scientist, the materiality of the world is a ‘system of signs’ that communicate the more multivalent realities of the universe. (Stewart-Harawira, 2005, 39) Contingent, enmeshed,

interrelated and reverent, the science of Indigenous peoples expands rather than contracts the meaning of the material other-than-human world.

Despite western reductionist science's claim to objectified rationality, mythical narratives inform and shape its course. We've already discussed the myth of precision and the unitary gene with respect to genetic engineering, but there are also much broader and more pervasive myths that underscore the entire modern scientific worldview. The myth of Darwinism is of particular interest to a study of biocolonialism – narrowing down the sum of life's creative process to a 'survival of the fittest' whereby genes compete for their genealogies. We know now of the varied effects of epigenetics, the effect of environment, context and even consciousness on genes and their expressions. In so many ways, science is "a story of the world and a practiced way of living it." (Cajete, 2000, 14) A major story of creation for Kānaka Maoli is the story of Hāloa, the first born son of Wākea (sky father). Born premature and buried in the ground, Hāloa emerged from the ground as the kalo (taro) plant, a staple food of the Hawaiian people and literally their ancestor. From this understanding, Meyer explains that taro is both a member of one's 'ohana (family) and a 'spiritual food': "This is why taro is an aspect of epistemology; it has shaped how Hawaiians experience the world." (Meyer, 2003, 78) The myths that comprise our practices of science and ways of knowing the world constitute the worlds we create. As we decolonize the futures, it is critical to support a more egalitarian understanding of the mythical origins of western science alongside those of indigenous epistemologies.

The general mistake made of those seeking to understand the cosmology of indigenous science is that it is purely subjective and merely based on non-rational links

between materiality and an unseen supernatural cosmos. In practice, systems of traditional knowledge embrace both quantitative and qualitative forms of knowledge without necessarily privileging one over the other. Instead, the different ways of understanding the world become part of an evolving continuum that holds the different data in tension and continuously evaluates reality based on shifting and contingent, but measurable, variables. (Cajete, 2000; Meyer, 2003; Stewart-Harawira, 2005) This can be seen in the practices of mental modeling common to many practitioners of traditional knowledge. In her study of numerous cultures practicing traditional knowledge around the world, Fikret Berkes has come to define this as a practice of 'fuzzy logic.' Hardly a derogatory term or one that denotes lack of rigor, the idea of fuzzy logic is that large numbers of qualitative variables can be held and understood as a holistic set. For environmental science in particular, this dynamic and nuanced understanding of reality is extremely useful. We are faced with highly complex environmental crises today entangled in the context of an unpredictable and rapidly changing climate. These complex crises benefit from the ability of indigenous science to focus "on a large number of less specific (and probably multicausal) indicators used simultaneously as a suite." (Berkes, 2009, 10) The skill to hold wide ranges of variables as a 'suite of knowledge' is not possible with reductionist science and it requires intimate, specific and multi-generational knowledge of place, a variable I will discuss in more detail a little later. These experience-based epistemologies are linked to what Stewart-Harawira, Meyer, Atleo, Cajete and other Indigenous thinkers define as 'inner technologies.' Highly participatory, non-hierarchical and linked with the material and spiritual worlds, Stewart-Harawira points out that:

> "whereas Western peoples' explorations of technology took an outward direction, indigenous peoples' prioritizing of 'inner technologies' enabled the advancement of particular ways of knowing centered around the interconnections between the molecules of existence and the nature of the energy that binds them." (Stewart-Harawira, 2005, 39)

For ancient Hawaiians and cultural practitioners of traditional Hawaiian knowledge today, these inner technologies often take the form of mental models – complex and nuanced mental maps of ecological systems that capture multiple levels of qualitative data and system dynamics. (Poepoe et al, 2007) This discussion of western scientific epistemologies and indigenous scientific epistemologies is meant to demonstrate that colonization has conditioned the modern consciousness to privilege certain ways of knowing over others. From the western world, emerging disciplines such as quantum physics are likewise demonstrating that the world is contingent, probable and ultimately unknowable. Indigenous science provides a way to move within these uncertainties, understanding our place as humans within the flow of becoming. Rather than awkwardly trying to grasp the world and control domains, we can instead enter into conversation with life and become co-creators of an emergent reality. (Atleo, 2005; Ingold, 2006) If we are to work our way out of the current converging crises of the 21st century, the need for this sort of re-framing feels urgent. Any process of re-framing will necessitate leadership from Indigenous and marginalized voices, the voices of the oppressed and vulnerable who have been most decimated by the project of modernity; the voices and collective will of those who need most the possibilities of 'better' purported to arise from these new technological saviors.

The Myth of 'Better'

Synthetic biology is premised on a vision of 'better.' Better, more efficient fuels, more abundant and better food supply, better medicine, better living, better humans and a better, generally more abundant life for the future. The discourse surrounding the discipline is replete with visions of a utopian 'better' where all our problems are solved through harnessing the powers of technology. Ruth Panelli asks us to consider "How are hegemonic human/nonhuman binaries sustained and for whose advantage?" (Panelli, 2009, 85) There is a distinct political economy to this pervasive myth of better, a myth tied to the narrative of progress in a quest for 'modernity'. These myths are enmeshed within systems that depend upon capital flows of raw materials and production apparatuses which require an overpopulated planet of consumers to support their continuation. What about synthetic biology could possibly erase these political realities and how can we possibly imagine that it won't be shuffled along the same trajectories towards the production of more suffering? To think about these questions I find McKenzie Wark's concept of metabolic rift and Jussi Parikka's concept of the future fossil especially useful. Tracing the extractionist bent of human history along lines of new animistic ontology, the metabolic rift that defines our time is bound in the irreversibly intricate flows of material through processes of financialization. "Labor pounds and wheedles rocks and soil, plants and animals, extracting the molecular flows out of which our shared life is made and remade. But those molecular flows do not return from whence they came...agriculture is a maker of deserts." (Wark, 2015, xiii) A thing loosed from its origins, its context is no longer ever to be what it once was. Irreversibly changed by the rupture we find parts of old wholes becoming entirely new

wholes like the microplastic clogging a fish's gills and then absorbing into a human body or the liberated carbon divested from fossil fuels and joining its relatives to collectively alter the atmosphere. Better medicine is only helpful if you have access to decent health care. Better, healthier food becomes a priority when you are not starving. Efficient fuels and mobility represent better only if you first have a peaceful society within which to raise a family and move about. We are told time and again that our capacity to accumulate more things is equivalent to wealth. And the fallout of our destruction is relegated to the less powerful, the invisible parts of the human and nonhuman world who bear most of the burden of modernity's excess and extraction. As Alexandra Daisy Ginsberg premises, "Establishing what we want from 'better' is essential, otherwise we may end up replicating existing, troubled systems of production with 'biosimilars.'" (Ginsberg, 2013, 51) A recent iGEM competition winner proposes to use synthetic biology to engineer bacteria that would be released into the oceans to cause microplastics to stick to each other "solving the scourge of microplastic pollution." (Quaglia, 2017) This is a scaled solution to a nasty problem, but it does not solve the problem of plastics in the ocean. This way of thinking is not new. We repeatedly mistake the band-aid for the disease diagnosis. But to engage such faulty logic with highly experimental, risky science is irresponsible. Long term, multi-generational thinking and deeply reverential forms of knowledge production are necessary to get at the root of the issues we seek to solve.

The gravitational pull of the status quo is cemented in deeply entrenched systems of capital flows and power structures which are not willing to shift without significant, radical disruption. And while technologies like synthetic biology purport to

offer miraculous solutions to all our ills, they still remain ensconced in the systems that got us to this point in the first place. New technologies land in the midst of the same power dynamics that drive inequality. No matter how great our medicines may become, they will do us no good on a sick planet full of suffering. If synthetic biology allows us to do more of what we have been doing, it will be a tragically failed project in line with the other tragically failed projects of modern life. Numerous studies have shown that your zip code may be more important than your genetic code when determining health and well-being over the course of your life. (https://wire.ama-assn.org/delivering-care/death-zip-code-investigating-root-causes-health-inequity) Before we can make claims to 'better' we have to acknowledge that the cards are already stacked in favor of a privileged few and that many will be not only be left out, but the unintended consequences of making life better for those who already have it so good will leave the most vulnerable even more vulnerable. Swimming in the water that is the industrial era with industrial era thinking driving our technologies, we may not even be asking the right questions to transition out of this era into a new one. It is foolish to think that a technology deployed from within a powerful social system like capitalism will be anything other than a vehicle for enhanced capitalistic endeavors.

William Connolly calls our attention to the inherent *fragility of things* explaining the danger that "Much of life is organized around daily routines and struggles that draw attention from the attachment to humanity and the world typically woven into the undercurrents of living." (Connolly, 2013, 48) To really address the crises we face, we have to reengage with the nonhuman world and embrace our interdependencies with the vitalism all around us. We have to start asking different questions and solving for

truly novel, different ways of being on the planet. “To be human, again, is also to be organized by a host of nonhuman processes and to be entangled with others.” (Connolly, 2013, 49) On the invention of the polymerase chain reaction (PCR), a precursor to all things genetic engineering, Paul Rabinow writes that the “truly astonishing thing about PCR is precisely that it *wasn’t* designed to solve a problem; once it existed, problems began to emerge to which it could be applied.” (Rabinow, 1996, 7) Might we acknowledge that our commonly held vision of ‘better’ is more inherently premised and informed by drives for accumulation than amelioration.

The metaphor of the ‘living factory’ of synthetic beings arises from the drive to commodification that pervades the modern biosciences. Sheila Jasanoff calls this a move towards ‘lively capital’ where nonhuman entities are unmoored from their contextual environments in order to circulate as capital on the world stage. (Jasanoff, 2012) Again, the visions of groups like BioBricks, the IGEM competition and the Registry of Standard Biological Parts fall directly in line with this reasoning; for while these groups are ostensibly open source, the creations that spring from them are decidedly not. By many accounts the revolution in synthetic biology is a continuation of the industrial revolution with synthetic biological beings replacing chemical ones fulfilling many of the same functions that chemicals historically occupied. Timothy Morton argues that there is nothing new in the science of synthetic biology, that it is a repetition of the same ‘thought-virus’ that has infected humankind throughout the Anthropocene era. Ultimately this “assertion of radical newness is called *modernity*;” we have been here before. (Morton, 2013, 21) Using the ‘blunt technics’ of engineering applied to biological beings, scientists proceed unfettered in a state of ‘happy nihilism’ when “*What is really*

disturbing is precisely the lack of disturbance." (Morton, 2013, 22) Lulled into complacency by the myth of 'better' we collectively engage in a barely veiled pursuit of simply 'more and faster.' The collaborating forces of scientific reductionism and neoliberalism have lulled us into the somnabulence of the modern movement to rush through knowledge production on the backs of technical experts and invisible design. Our only recourse to counter this trend is an ethical investment to "slow down the movement." (Latour, 2004, 3) The assertion of radical newness around emerging biotechnology is deeply linked to politics of control. This discourse silences the agentic capacities of the nonhuman while purporting to defend an ethos invested in human freedom. The truth could not be farther afield. "As neoliberalism proceeds, it diverts attention away from multiple connections between capitalism and a variety of nonhuman force fields with differential powers of self organization. It also obscures how it itself requires a very large state to support and protect its preconditions of being." (Connolly, 2013, 7)

Resistance to Biocolonialism

"any time Hawaiians—or any other native people, for that matter—come out in force to push for more respect for our culture and language or to protect our places from this kind of destruction, we are dismissed as relics of the past, unable to hack it in the modern world with our antiquated traditions and practices. Though the very things that people say they love most about Hawai'i are actually what Hawaiians and their allies have been trying to protect for decades, we are still considered nothing more than speedbumps slowing everyone down on the road to progress."

~Brian Kamaoli Kuwada (hehiale.wordpress.com, 2015)

"DNA, as digitized information, is not only accumulating in computer databases, but can now be transmitted as an electromagnetic wave at or near the speed of light…With this new

understanding of life, and the recent advances in our ability to manipulate it, the door cracks open to reveal exciting new possibilities. As the Industrial Age is drawing to a close, we are witnessing the dawn of an era of biological design. Humankind is about to enter a new phase of evolution."

~ J Craig Venter (2013)

In a speech to the crowd at SynBio Beta, the major conference for the synthetic biology industry, in November 2014, J Craig Venter explained the capacity of synthetic biology to re-program life using DNA as 'software code.' And yet, he stressed the fact that even with all the modern technology and iterative process of engineering the genome, there remain areas of DNA that simply cannot be understood. (Venter, speech, 2014) I like to think of these as spaces of genetic sovereignty, to me these are spaces of hope. For Kānaka Maoli, the word ea means life but it also means sovereignty; I take this to mean that to be fully alive is also to be sovereign. (Goodyear-Ka'opua, 2014, 6) Indigenous resistance to biocolonialism rests on deeply held epistemologies and cosmologies that simply do not hold space for understanding a world where nonhumans are re-inscripted and enslaved according to their use value. And it is not just the subject of knowledge that needs to be decolonized but also the agency and power involved in knowledge production, who decides what is considered scientific knowledge and how it is implemented. In Hawai'i the taro patenting controversy and the on-going debate surrounding GMO crop production are two examples of Kānaka Maoli resistance to biocolonial practices. Likewise, the concepts of kino lau, aloha 'āina (and mālama 'āina), kuleana and kū'ē emerge from Native Hawaiian ontologies and support the resistance to biocolonialism as anathema to a Hawaiian cosmology. And finally, the current resurgence of biocultural restoration projects underway across the Hawaiian islands is a

testament to lived resistance. Noenoe Silva writes, “what I mean by resurgence is our creation of a world in which we speak, write and compose in our native language; take care of our ‘āina (land) and waters; reinvoke and appreciate our native deities; and live (at least mentally) free from the destructive settler colonialism in which we now find ourselves” (Silva, 2017, 2). Through an ethics that embraces self-imposed limits, process-based temporality and place-based specificity, community-based projects of aloha ‘āina and malama ‘āina comprise a demonstrable attempt to counter balance the dominant trend toward scientific control of genetic and biological resources.

The Paoakalani declaration, authored during the Native Hawaiian Intellectual Property Rights conference of 2003, states that:

> Kānaka Maoli traditional knowledge encompasses our cultural information, knowledge, uses, practices, expressions and artforms unique to our way of life maintained and established across Ka Pae 'Āina Hawai‘i since time immemorial…The expression of traditional knowledge is dynamic and cannot be fixed in time, place or form and therefore, cannot be relegated to western structures or regulated by western intellectual property laws. We retain rights to our traditional knowledge consistent with our Kānaka Maoli worldview, including but not limited to ownership, control, and access. We also retain the right to protect our traditional knowledge from misuse and exploitation by individuals or entities who act in derogation of and inconsistent with our worldview, customs, traditions, and laws. (Paoakalani Declaration, 2003, 6)

Long time Kānaka activist Walter Ritte has dubbed the Hawaiian experience of biocolonialism a ‘Mana Māhele’. The great Māhele of 1848 signified the division of the Hawaiian islands into parcels of privately owned property for the first time in history. The reverberations of that first Māhele are still keenly felt today. Mana refers to life force and as Kanehe explains, “An aspect of mana is the spiritual force Hawaiians have, stemming from our familial relationship with nature.” (Kanehe, 2014, 334) So the ‘Mana Māhele’ is meant to signify the move of colonialism into the realm of mana, spirit or life force. In 2005 it was discovered that the University of Hawai’i had both patented and genetically engineered strains of kalo (taro). For Kānaka Maoli to whom kalo is Hāloa, the original ancestor, this was akin to both slavery and rape. (Kanehe, 2014) Activists protested and the University eventually acquiesced. First offering the patents to the Hawaiian people, University officials were met with consternation. It was not the goal to own the patents, rather for Hāloa to remain free. When the University agreed to put a moratorium on the genetic engineering of kalo and turned the patents over to the activists, they immediately tore the patents up.

Today, at issue is GMO propagation across the Hawaiian island chain. Under a thinly veiled mask of market logics, lies a complicated history of settler colonialism and corporate land ownership. After the great Māhele of 1848, big agricultural corporations were able to move into Hawai’i and take over large tracts of land for plantation agriculture. The erasure and subsuming of kuleana lands (those lands given to the common Kānaka Maoli people during the Great Māhele) were integral to this process of settler colonial land appropriation. (Perkins, 2013) As the ‘big 5’ agricultural barons have left the islands and either closed up shop or moved overseas where land and labor are

cheaper, the lands they once cultivated have in large part moved to agribusiness giants Monsanto, Dow, Pioneer and Syngenta. (Kanehe, 2014; Goldberg-Hiller & Silva, 2014) Identical to Salazar's appraisal of big science, big ag "as a product of Western modernity, is dependent on the inherited wealth, land, and resources secured by these earlier colonial practices." (Salazar, 2015, 44) Today, propagating primarily GMO seeds for test trials, these corporations benefit from a year-round growing season and, until recently, little public scrutiny. But as Kānaka Maoli and other activists have come to realize the extent of destruction being wrought on the environment and human health from copious pesticide use on the GMO fields, there has been ever increasing pressure for the corporations to submit to public disclosure and stricter regulation. In response, the multinationals rely upon generalized discourses of 'food security,' "Yet where this security was once seen as the responsibility of the state that promoted corn production for the local ranching industry, today this security is depicted in global terms." (Goldberg-Hiller & Silva, 2014, 35) All this despite the fact that in many cases these corporations are not growing food for human consumption.

Certain Hawaiian concepts emerging from commonly held ontologies are foundational to the practices of resistance. Kino lau denotes beings that have many bodies both human and nonhuman and the ability to 'change forms.' (Golberg-Hiller & Silva 2011; Meyer, 2003) 'Aumākua refers to the ancestral deities of a family, kino lau beings, that take shape in the body of a certain animal or plant or in an inanimate being such as rocks, the wind or a volcano. Thus the practice of honoring these 'aumākua was a physical embodiment of pono (or right) behavior, one that could bring Kānaka in close relationship to the natural world. (Meyer, 2003) These concepts also relate to the

notion of moʻokūʻauhau (genealogies) and show that for Native Hawaiians, and for many Indigenous peoples, there is a deep and intrinsic connection to nonhuman entities that is understood as a familial relationship - based on reverence and reciprocity. With this in mind, one can begin to understand how Kānaka Maoli relate to kalo as a sibling, a familial relation to be respected and protected. This spiritual connection to nonhuman beings extends to the supernatural. In his research on the thirty-meter telescope slated for construction on the sacred Mauna a Wākea, Salazar documented an instance where the Flores-Case family filed a petition against the telescope on behalf of Moʻoinanea, a guardian spirit of the mountain, who had appeared to their daughter in human form to plead for help in stopping the construction. While Flores argued that Moʻoinanea is "part human, has a genealogy, can manifest herself as a person or a moʻo – a giant reptile," the general public treated the assertions as absurd. In this way, Salazar argues, "Settler law remains vexed by its own limits to adequately absorb Kānaka ʻŌiwi, whose otherness and distinct ontologies disrupt legal and scientific determinations that seek to contain indigenous differentiation." (Salazar, 2015, 60)

Aloha ʻāina and mālama ʻāina are two concepts often used in the discussion of biocolonialism. The definition of ʻāina is 'land' but also 'that which feeds' and can refer to both a literal and spiritual form of sustenance. To aloha the ʻāina is an active practice – "it is important to think of aloha ʻāina as a practice rather than merely a feeling or belief." (Goodyear-Kaʻopua, 2013, 32) In order to aloha ʻāina, one must engage with the land, enacting certain protocols and acknowledging the place of the human within a greater chain of being. Acts of aloha ʻāina are forms of resistance to commodification and decimation of land and natural resources. Mālama ʻāina is more subtly a call to nurture

and care for the land. As it was explained to me by Malia Akutagawa, humans are the highest expression of mālama ʻāina, that in fact ʻāina only comes into being with the presence of humans and that it is the kuleana (responsibility) of humans to make a place better, to aloha and mālama the ʻāina. (Akutagawa, conversation, 2014) Kuleana and kūʾē are often translated to mean responsibility and resistance, although these are thin translations of very rich and political concepts. As a non-indigenous scholar, I do not attempt to adequately represent the complexities of these Hawaiian words, rather to offer them as an opening to understand Kānaka Maoli perspectives on genetic alteration. For many Kānaka Maoli and other Indigenous peoples today, it is clear that it is important to resist biocolonialism and the enclosure of genetic resources. As Kanehe explains, "To kū'ē biocolonialism in all of its forms is aloha ʻāina. To love the land includes protecting that which feeds us from genetic manipulation." (Kanehe, 2014, 350)

The myriad projects of biocultural restoration occurring across Hawai'i today are a form of resistance to biocolonialism manifested through practice. The understanding of limits, the investments in temporality through process and in specificity through place all directly counter the hegemony of neoliberal, biocolonial practices. These projects include lo'i kalo (taro field) restorations, ʻauwai (water ways/irrigation) restorations, loko ʻia (fishpond) restorations and in some cases highly collaborative, coordinated efforts to restore entire ahupuaʾa (ancient divisions of land based on subsistence needs and watershed boundaries). In an interview with Kevin Chang of Kuaʻāina Ulu ʻAuamo (KUA), an organization dedicated to "advancing community-based natural resources management in Hawaiʻi, working together with government agencies and communities towards restoring Hawaiʻi communities' traditional role as caretakers of their lands and

waters." (www.kua.org) KUA is home to a network of biocultural restoration practitioners called E Alu Pū. My interest in interviewing Kevin was to discern the nature of his work, what drives him and the groups that work with him to do what they do and whether there are any shared ethics or values among the diverse 30+ groups that make up the E Alu Pū network. In reference to shared values, Kevin articulated the idea of limits:

> "main thing where they come from is like limiting yourself… they were talking about limiting themselves…and some of it is the older folks who, they've been through that… they had to make a living on fishing, whatever… and they participated in, people call overcatch - people say they participated in that wasteful catch, but then at some point they turned on differently…I think the common thing is that *limiting*." (Chang 2014)

The idea that limits are not antithetical to abundance runs directly counter to the claims of synthetic biology, a discipline premised on engineering biology for the purpose of surpassing the current limits of nature and achieving a utopian techno-abundance. The temporality of these projects is a second aspect of their capacity for kū'ē (resistance). Embracing the often slow temporality of proper protocol and culturally appropriate process, they resist the push of neoliberalism to do more, with less, faster every time. The venture capital adage "fail fast, fail smart," is antithetical to the cultural practitioner whose genealogical tie to a place stretches many generations into the past and many generations into the future. As explained in the *Kūkulu ke ea a Kanaloa*, the culture plan for Kanaloa Kaho'olawe, "To understand the practice fully is to have an eye open to the many possible relationships of the practice because of the multiple components that constitute it. The independent reality of a practice can only be understood through its

many components." (Kūkulu, 2009, 17) As Escobar contends, knowledge of the world is "a process of enskillment in practical engagement with the environment," and "every act of knowledge brings forth a world." (Escobar, 1999, 10) In addition to a distinct temporality, biocultural restoration projects privilege the specificity of place. Place-based knowledge is paramount in almost all Indigenous cultures. There is an attention to the very specific knowledge about a place and it's particular nonhuman entities and environmental attributes. This specificity resists the globalization of knowledge that is central to the discourses of genetic engineering and synthetic biology; disciplines which treat all biological material as 'lively capital,' capable of decontextualization, dislocation and re-inscription for capitalist purposes. Place-based, attentive to process, science rooted in Native Hawaiian epistemology takes a stand against the neoliberal fantasies of the biocolonial vision.

The failed project of modernity

"Humanity is divided into two parts. One faces the challenge of complexity, the other that ancient and terrible challenge of its own survival. This is perhaps the most important aspect of the failure of the modern project."

~ Jean Francois Lyotard (1984)

The discourses and practices of biocolonialism are thus embedded in deep, historical practices of colonialism and imperialism. While the biosciences would like to imbue public discourse around synthetic biology with visions of new-ness, abundance and techno-optimism, there is nothing new about the twin projects of colonialism and imperialism – biocolonialism is the latest form. And we can not deny that this project of 'modernity' is failed. Equality, justice, peace, material abundance, spiritual fulfillment

have not manifested for the majority of humanity as a result of the neoliberal quest for control. Grounding resistance in indigenous epistemologies offers a way through. But as Makere Stewart-Harawira argues, the challenge is to go beyond simply resisting empire, to ultimately "effect transformation of the ontological underpinnings of the terms in which world order is conceived and the meaning of existence is articulated." (Stewart-Harawira, 2005, 3) Indigenous epistemologies and ontologies can provide the texture and grounding for this new articulation, a new world order to replace the failed one that is our 21st century inheritance. Leadership from Indigenous scientists, theorists and scholars who are grounded in multiple ways of producing knowledge, deep connection with and respect for the non-human others and a commitment to multigenerational pasts and futures must drive this conversation and the ensuing governance. It is the only way that a foundational ethics strong enough and deep enough to carry the kuleana of synthetic biology can take root. This new leadership will be critical to crafting a path forward for synthetic biology that enables greater human and non-human flourishing for more people and the planet.

CHAPTER 4
A FOUNDATIONAL ETHICS FOR GOVERNING EVOLUTION

"My desire for knowledge is intermittent, but my desire to bathe my head in atmospheres unknown to my feet is perennial and constant."

~ Thoreau

"The creative fire within the human venture now focuses on bringing forth something entirely new, a form of human life that envisions itself within the interconnected dynamics of the unfolding Earth reality. The tribe will not be the center of the human world, nor will the civilization, the culture, nor the nation-state. It will the Earth community as a whole that will be understood as our home, our womb of creativity and life."

~ Brian Swimme

What set of values and ethics will inform the limits to which we will go in the pursuit of knowledge? When Synthetic Biology is widely available across political boundaries and capable of staggering velocity with heritable genetic permanence, how do we craft a shared governance of evolution and emergence that can withstand the powerful political and financial pressures of the 21st century? Pressures which naturally bend towards the reproduction of existing power and serve to more deeply entrench inequality. When you add to these the pressures of climate change as context: resource scarcity, species collapse and increasing environmental disasters, it seems crucial to ask: How might an embrace of radical accountability and inherently unpredictable complexity change the way we approach a scientific practice of engineering life forms?

In November of 2018 it was revealed to the world that a Chinese researcher, He Jiankui, had altered the genetics of twin baby girls in order to make them resistant to HIV. He admitted to altering the genes of seven sets of embryos, all of which had an

HIV- infected father and an HIV-negative mother. So far this is the only pregnancy from the seven altered sets of embryos known to have resulted in live birth. He altered the girl's brains by suppressing a gene known as CCR5, making it more difficult for HIV to infect white blood cells. (https://www.sciencemag.org/news/2018/11/crispr-bombshell-chinese-researcher-claims-have-created-gene-edited-twins) More recent research in 2019 has shown that suppression of the CCR5 gene may also lead to an increase in capacity for memory and the brain's ability to form new connections, for example after a stroke. (https://www.technologyreview.com/s/612997/the-crispr-twins-had-their-brains-altered/) Whether increasing intelligence or avoiding disease was He's intention, the scientific world has been rocked with the realization that there is no critical ethical infrastructure or governance mechanism adequate to contain the possibilities of using CRISPR technology in any way a genetic designer sees fit. In the previous chapter, I examined the ways in which Indigenous peoples and Native Hawaiian's in particular have responded to experiences of biocolonialism and how Indigenous forms of knowledge production and Indigenous critical theory have the potential to unlock more productive spaces of science geared towards the greater flourishing of historically marginalized peoples and non-human life forms. This chapter will engage in a deeper look at the potential contours of an ethical framework that would draw from diverse sources including Indigenous and animist frameworks and the traditions of Spiritual Ecology, which share a few crucial commonalities:

1) they embrace a connection between **spirituality and science**;
2) they value and hold themselves accountable to **intergenerational equity**;

3) they explicitly understand the **ultimate entanglement** between human and the other-than-human worlds;
4) they embrace **values of empathy, humility and altruism**;
5) they engage and lift up the voices that have been marginalized in western scientific tradition – **empowering new voices of leadership** to craft a different type of future for the practices of governing evolution through synthetic biology.

This chapter will explore each of these five intersection points in an attempt to build the rough scaffolding of a framework for the preferred futures of synthetic biology. It will also review several other attempts at ethical frameworks that will be useful in clearing the space to have this seminal conversation. But what must be imminently evident is that I will not be the one to determine or suggest a certain framework as the one to adopt. Nor should a group of scientists trained in western practices, however esteemed, be the leading collective to develop and implement an ethical framework for synthetic biology. If there is one central argument to this thesis, I want to be clear it is this: Indigenous scientists, Indigenous ethics and Indigenous ontologies must be at the helm of this discussion and in crucial leadership roles for any international framework that we develop collectively. We will not be able to responsibly govern evolution with the velocity and capacities of synthetic biology unless Indigenous peoples lead. Even then, thriving is not guaranteed. And at the heart of anything we do or develop *must* be aloha. Manulani Meyer writes about this too often misused and misunderstood concept of aloha. So much greater, deeper and more powerful than its Hallmark card usage, cultivating aloha is intimately linked with multiple visions of ‘mind‘: “1) Mana‘o: thought,

idea, belief, intention, meaning; and 2) Waihona noʻonoʻo: depository of reflections, thought and meditations, and finally, 3) Naʻau: our seat of intelligence, wisdom, heart and emotion – our stomach" (Meyer, 2003, 14). To cultivate aloha from this understanding offers the opportunity to mend the "rift between mind and body, understanding your role in the world, and finally with disciplining your mind. They all lead to one end, and that is that *we get along better, we help each other more, we have the energy to do what is right*" (Meyer, 2003, 14). Far from an idealistic dream, this is in fact the necessary and possible work that we must do to approach the task of governing evolution.

To create some grounding, let's dig a little into the genealogy of our modern ecological crisis and the environmentalist responses it has inspired.

The Way In – Roots of the Modern Ecological Crises & Environmentalism

"Every aspect of life has been absorbed into the commercial-industrial context. We seem not to know how to live in any other way. In the industrialized nations the automobile, the highways, the parking lots, shopping malls, all seem to be necessary for survival at any acceptable level of human well-being."

~ Thomas Berry (1999,109)

"Today the species of Man is facing a question of the very survival of the species. The way of life known as Western Civilization is on a death path for which their own culture has no viable answers."

~ Haudenosaunee Address to the World (1977)

The ideologies and discourses of globalization and neoliberalism dominate the planet as of the early 21st century. They are present in every domain of human and

nonhuman life – political, social, economic, technological and environmental. They are so dominant and so normalized that it is difficult for us to even imagine something like a world without capitalism. Proponents of other ontologies such as Indigenous peoples, radical environmentalists or spiritual ecologists are often ridiculed as out of touch, relics of the past, anti-science or utopian idealists. All of these claims serve to simply enhance and bolster the status quo and there is a lot of money and power riding on keeping that status quo firmly in place. Yet we know that we are pushing, or may have already surpassed, the planet's resource limits and we are changing the very climate that has supported us to this point. But rather than acknowledge these facts and seek alternatives, we find ways to capitalize even upon our own destruction. As the artic melts as a result of our copious use of fossil fuels, we argue over who should have the rights to exploit the fossil fuels contained under the melted ice; meanwhile seas rise and the poorest bear the greatest weight of the destruction. (http://www.ibtimes.com/us-military-responds-arctic-ocean-melting-polar-ice-melting-prompts-us-military-protect-new-1536942) Descartes' claim to human mastery was just one link in the long chain of the Scientific Revolution, a revolution in epistemology that left us with reductionist science and a compartmentalized view of reality that claims expert-only access to Truth and Knowledge through the exclusive lens of science. Nature was suddenly apart from Culture and inscribed only with value so far as it could be used and discarded for the advancement of the human species. (Descola, 2008; Latour, 2004; Morton, 2007; Sponsel, 2012)

While science parsed the world into smaller bits for commodification and control, religion did its part in conceiving of a world similarly constructed for human mastery.

Lynn White's famous 1967 essay The Historical Roots of the Modern Ecological Crisis published in Science magazine, was only a few pages in length and yet it spawned worldwide outrage, uproar and ultimately the self-critical reflection that eventually became the movement we call Spiritual Ecology. (White, 1967; Sponsel, 2012) In it White argued directly that, "Christianity is the most anthropocentric religion the world has seen," and that "Both our present science and our present technology are so tinctured with orthodox Christian arrogance toward nature that no solution for our ecologic crisis can be expected from them alone." (White, 1967, 1205-1207)

Just a few years prior, a relatively unknown scientist Rachel Carson, a woman without a PhD, published Silent Spring, a book that is credited with starting the modern environmental movement. She saw the environmental destruction being wrought by the industrial revolution and chemicals like DDT being released into the atmosphere and she spoke out, changing the mindset of a generation. Tracing the histories of colonialism, empire, science and imperialism as I have done in previous chapters, we can see the meanderings that led to these moments and that have continued to this day. We banned DDT only to create different, more and increasingly toxic chemicals to release into the air, water and bodies all around us. The scientific revolution, the industrial revolution, the information revolution and now the biotechnological revolution have all purported to herald a new beginning, life with less waste, more abundance, better health, social equality and on. I call this 'the myth of better' and seriously question the capacity of any revolution that is driven by patriarchal, neoliberal or imperialist ideologies to make life better for the common good – history keeps repeating itself, at some point we will have to learn or likely perish. We are living in the Anthropocene – the

modern era where everything on the planet from the macro to the micro has been altered by human influence. Jussi Parikka calls this the *Anthrobscene*, a time when all the promises of previous 'revolutions' to bring us a better world are manifested in a wasteland of refuse and industrial decay. (Parikka, 2015) As Thomas Berry laments, "after these centuries of industrial efforts to create a wonderworld we are in fact creating wasteworld." (Berry, 1999, 59) Now the biotechnology revolution promises to make it all better by engineering biology to create better fuels, better medicine, better food, a better life for all. We must seriously question these claims in the face of our shared history and instead look for truly viable alternatives to the blatantly failed project of modernity. I saw a synthetic biology startup raise major excitement in the room during a presentation on its 'revolutionary fuel' technology. A technology that captures the methane waste gas emitting from natural gas fracking sites and turns it into fuel. No one seemed to wonder if it's really a good idea to encourage fracking, a seriously environmentally questionable practice. There was only pure excitement at the race to capitalize on yet another 'green' fuel source. Stuck in the neoliberal hunger for profit, what we really need to be asking is how to design communities and technologies that need less or even no fuel at all.

Mary Evelyn Tucker and John Grim trace the evolving views of nature in the West from Animism to Monotheism, through the industrial/scientific revolutions and on to the Anthropocene, calling finally for an 'anthropocosmic' view of the human as a biocultural being situated in the context of a Universe of vibrant life – human and nonhuman. (Grim & Tucker, 2014) Familiarizing ourselves with these histories and allowing that knowledge to highlight the peculiarity of the present helps to denaturalize dominant ideologies and allow for spaces of creative imagining. Stuart Kauffman calls

attention to the emerging scientific disciplines of quantum physics as a radical reimagining of the Universe as emergent, creative, and radically unpredictable, a break in what he terms the 'Galilean spell' of a Universe governed strictly by immovable natural laws. (Kauffman, 2008) Kauffman cites at least "four injuries, which split our humanity down the center:"

1. The artificial division between science and the humanities
2. The worldview of reductionist science – an ontology that sees a world of fact devoid of values
3. The belief among 'secular humanists' that spirituality is foolish
4. That globally we lack a shared ethic (Kauffman, 2008)

Latour addresses these conflicts of paired values (science v. religion, etc) as category mistakes, tensions that "stem from the fact that the veracity of one mode is judged in terms of the conditions of veridiction for another mode." To repair our way out of this metaphysical error, Latour argues that we have to embrace a plurality of modes of existence and a "plurality of keys by means of which their truth or falsity is judged." (Latour, 2013, 17-18)

Spirituality and Science

"Human beings themselves are at risk – not just on some survival-of-civilization level, but more basically on the level of heart and soul."

~ Gary Snyder (Sessions,1995, 44)

"Earth as a biospiritual planet must become for us the basic referent in identifying our own future."

~ Thomas Berry (1999, 59)

We live in a world that is primarily informed by a nature/culture binary. This cosmology stems from a western, euro-centric narrative cemented in the scientific and industrial revolutions. I've spent a bit of time in previous chapters discussing both scientific reductionism and neoliberal ideologies in the sciences. These are major driving forces in the history environmental destruction. Another driving force is the prevalent notion that humans are (and should be) the masters of the nonhuman world, that it is our place, our duty, in fact our responsibility to master and control nature for the betterment of humankind. In 1637, Rene Descartes famously wrote, "And thereby we make ourselves, as it were, the lords and masters of nature." (Descartes, 1637) We sit at a juncture of several potentially disruptive and game changing technologies – and the convergence of these may serve to amplify their impacts even further. And yet we also sit at a moment where planetary limits are more visceral than ever. Climate change is wreaking havoc planet-wide, food and water are increasingly less secure for many of earth's inhabitants and by many accounts we are in the midst of the sixth major extinction event with estimates that we will lose 20-50% of earth's species by century's end. (http://www.nytimes.com/2014/02/16/books/review/the-sixth-extinction-by-elizabeth-kolbert.html) How might the collaboration of science and spirituality represent a significant resistance to the status quo and what creative ways through these crises might we imagine as a result of re-instilling primary reverence for nonhuman actants in the world?

Modern biosciences based in secular western worldviews are naturally vulnerable to the pressures of capitalism. If "physics has known for decades that mind and matter are not as separable as we once supposed," then why have we continued

on a suicidal course of planetary destruction? (Schiffman, 21) I believe it is the politics; that re-instilling reverence, reimagining the human beyond empire is what we need. Indigenous sciences and traditions like Spiritual Ecology enmesh the practice of science with explicit spiritual value and more naturally resist the pressures of commodification and capitalism. Rather than separating science and spirituality as we have done, in the 21st century a planetary politics capable of responsibly governing evolution will re-imagine spiritual values in science and instead separate science and capitalism. This research argues that an entanglement of spirituality and science offers the potential to bridge the philosophical chasm between modernity and reverence. I am admittedly skeptical of religion, saturated as it is in histories of oppressions and violence too lengthy to name here. I am likewise critical of romanticism, essentializing, and broad strokes. Manulani Meyer calls this the 'homogenizing impulse,' namely our desire to see Indigenous peoples, spiritual ecologists and the like as perfect examples of holistic life worlds and subjects of a homogenous cultural whole. (Meyer, 2003) Despite these critiques, it is clear that the deep and abiding values common to spiritual traditions offer a foundation upon which we might have a chance of responsibly governing evolution at the pace and capacity of something like synthetic biology. At the start of his classic A Sand County Almanac, Aldo Leopold writes, "There are some who can live without wild things, and some who cannot. These essays are the delights and dilemmas of one who cannot." (Wapner, 2013, 2) Like Leopold, I find myself in the latter category and so I engage in work that seeks to retain wildness for the future.

The Haudenosaunee address to the world, presented to the United Nations in 1977 makes the claim that "Spiritualism is the highest form of political consciousness.

And we, the Native peoples of the Western hemisphere, are among the world's surviving proprietors of that kind of consciousness." (Haudenosaunee, 1977) Spiritual Ecology exists at the intersection of religion, science and ecology. It brings together all of the world's religions and spiritual traditions under the banner of ecology, finding the ways in which each religion embraces a sense of interdependence and unity among beings, human and nonhuman, and focusing on those areas as productive sites of resistance to dominant discourses of neoliberalism and reductionist science. (Berry, 1999; Grim & Tucker, 2014; Nadeau, 2013; Oxford Handbook, 2006; Sponsel, 2010-2014) It is cross-cultural and does not adhere to socio-economic boundaries or national identities. I find this 'big tent' approach to be productive in its inclusiveness. By focusing on the connections between spiritual traditions and the ways in which all these traditions have aspects that honor human/nonhuman assemblages, Spiritual Ecology is able to harness the collective power of humanity in service of a preferred vision of the futures. Leslie Sponsel's powerful overview of the field in his book Spiritual Ecology: A quiet revolution, demonstrates its breadth and reach. In relation to conservation of the natural world, the collective philosophical impact of the world's spiritual traditions is undoubtedly massive; the collective physical impact of sacred lands planet-wide, spaces imbued with reverence for the unseen and nonhuman world has never been fully accounted but is surely significant. (Sponsel, 2012) While the history of religion has been tainted by excess, violence and imperialism, the common tenets of spirituality may hold a gentler, more resilient ethic – or so Spiritual Ecology contends. There is significant political power in mobilizing through religion, that is clear. (Oxford, 2006) Spiritual Ecology aims to steer that mobilization towards an ecocentric, 'anthopocosmic,' worldview that

decenters the human as just one actant in a creative, emergent cosmos. For my research, I'm interested in the political power of this imaginary to challenge hegemonic narratives of progress, reductionism and techno-optimism as I attempt to imagine alternative biotechnological futures.

Intergenerational equity

On March 18th, 2019 some 1.4 million young people left their schools around the world and took to the streets to protest and raise awareness about the rampant political inaction to address climate change. As Arielle Geismar, age 17, explained to The New York Times, "I'm supposed to be in school, but instead I'm out here trying to make sure my kids don't grow up in a wasteland." (https://www.nytimes.com/2019/03/15/climate/climate-school-strikes.html) Decisions made today to alter the genetic material of living beings will effect, in potentially dramatic ways, the type of world that future generations inherit. How might we consider the rights of future generations when considering the lengths to which we will go in governing and altering the course of evolution? In a 1992 essay on sustainable development, E.B. Weiss explains the necessity for a commitment to equity for future generations:

"This ethical and philosophical commitment acts as a constraint on a natural inclination to take advantage of our temporary control over the earth's resources, and to use them only for our own benefit without careful regard for what we leave to our children and their descendants." (Weiss, 1992, 19) This notion embraces the reality that we are only

temporary stewards of our resources and that we have an inherent ethical responsibility to consider the rights of future generations.

Weiss further elaborates on the principles of Intergenerational Equity:

> "1) conservation of options. "[E]ach generation should be required to con-serve the diversity of the natural and cultural base, so that it does not unduly restrict the options available to future generations in solving their problems and satisfying their own values . . .";
> (2) conservation of quality. "[E]ach generation should be required to maintain the quality of the planet so that it is passed on in no worse condition than that in which it was received . . .";
> (3) conservation of access. "[E]ach generation should provide its members with equitable rights of access to the legacy of past generations and should conserve this access for future generations." (Weiss, 1990)

She also delineates five duties of the use and care for resources:

> (1) the duty to conserve resources;
> (2) the duty to ensure equitable use;
> (3) the duty to avoid adverse impacts;
> (4) the duty to prevent disasters, minimize damage, and provide emergency assistance;
> (5) the duty to compensate for environmental harm. (Weiss, 1989)

This explicit commitment to steward the future many generations into the future is also present in numerous Indigenous cultures.

Jennifer Kuzma, co-director of the Genetic Engineering and Society Center at North Carolina State University, proposes that we consider the following questions when discussing the ethics of gene drives:

> "(1) How would the deployment of gene drives likely affect the ability of future generations to use the natural world to ensure global health and well-being?

(2) How would the deployment affect the ability of future generations to apply their own values to enjoy or appreciate the natural world?

(3) How reversible is the deployment so that future generations could apply their own values to restore their options for use or nonuse decisions?"

(https://www.humansandnature.org/future-generations-and-gene-drives)

The irreversibility of certain actions is critical when considering generational equity. How can we in good conscience deploy gene drives that perpetuate through generations? This is where something like the Daisy Chain gene drive, envisioned by Kevin Esvelt, with intentionally limited capacity to pass through reproducing generations becomes important to consider and research. Intergenerational Equity is not a black and white practice. Its philosophical application will vary when applied to synthetic biology's use in agriculture, medicine, heritable disease, species extinction or climate change.

Futurist Sohail Inayatullah explains that throughout Asia and Oceania, the concept of future generations thinking is more pervasive than the western notion of futures studies. Future generations thinking is much more concerned with the "survival of people and nature through deep time." (Inayatullah, 2007, 81) And it can be characterized by the following general traits:

1. Commitment to the **family** – extending to the planetary family
2. **Expansion of the notion of being** to include all sentient beings.
3. An **intergenerational approach** – generations into the past and generations into the futures.
4. **Values-based**, concerned with creating futures that rebalance the fundamental forces in the universe.

5. **Repeatability** – the notion that the survival of future generations is actually an important responsibility of keeping alive the dreaming of our ancestors. Past and future snake back into one another.
6. A **spiritual and collective view of choice and rationality**. Nonhumans interplay with humans in the act of choice and rationality is inclusive of other ways of knowing – intuition, etc.
7. Strong focus on **enhancing wisdom** rather than simply creating knowledge for knowledge sake.
8. **Sustainability** – respecting natural limits.

(Inayatullah, 2007, 81-82)

Like intergenerational thinking more generally, futures generations thinking specifically focuses on preferred futures as a way to activate ethical actions towards a viable and just future.

Ultimate Entanglement

"Every molecule in my body was birthed in a star hanging in space. I became aware that everything that exists is part of one intricately interconnected whole."

~ Edgar Mitchell, astronaut (2015)

If we hope to have any chance of working with and managing our relationship to the immense power of Synthetic Biology, we must first embrace and cultivate greater understanding of the ultimate entanglement of all things. This understanding of reality is present throughout a variety of Indigenous peoples' philosophical grounding.

Gregory Cajete delineates three basic concepts of universal creativity that he

argues frame the way Indigenous peoples 'envision the practice of science:'

- Chaos Theory – Chaos is the creative source/force of the universe. "The modern obsession with being in control and the dream of eliminating uncertainty through control of nature…must give way to the reality of moving creatively with the flow of events, which is the true reality of the universe." (Cajete, 1999, 16)

- The participation mystique – There is no 'objective detachment' from the world, the human is always already a participant with all the other nonhuman actants. "This active perceptual engagement with the world was termed the 'participation mystique.'" (Cajete, 1999, 27)

- Metaphoric Mind – "Science in every form…is a story of the world." (Cajete, 1999 27) This is the idea that we are born with a purely metaphoric mind, which is then subsumed by the rational mind as we learn to use language. Native societies retain a more balanced relationship between the two minds and the metaphoric mind is primary in Native science. (Cajete, 1999)

The ultimate entanglement that Cajete outlines with his principles is echoed in other Indigenous cosmologies. Katrina-Ann Oliveira explains that "Similar to the Māori concept of wairua (sprit), where all living and nonliving elements are believed to be interrelated and posses a spirit, many Kānaka likewise value mele koʻihonua (historical accounts) as the framework by which all things in the natural environment, including

people, are genealogically linked and ordered." (Oliveira, 2014, 2) The responsibility of Synthetic Biology demands this sort of deep commitment to interrelations between human and other-than-human worlds. The myths of decontextualization and precision along with the beliefs that parts of an organism can be understood separate from their wholes and that genetic code is predictably readable and writeable leave open massive spaces for unintended consequences that, with the added weight of generational hereditary transfer, are simply too great to risk.

In developing an Indigenous theory about science, E. Richard Atleo explains that in the theory of Tsawalk, a radical theory of interdependence and entanglement from the Nuu-chah-nulth worldview, the physical world we experience is merely a shadow or reflection of the spiritual realm. "The physical universe is like an insubstantial shadow of the actual, substantial Creator." Therefore the physical realm is secondary and dependent upon the spiritual realm. Which leads to the question, "Is it possible that scientific discoveries are not of the first order of existence, but of a second order?" (Atleo, 2004, xvi) Might science simply be one language with which we uncover the perennial truth of spirit? This inversion of the normalized rational scientific understanding of reality necessarily requires the core values I argue are needed to productively manage our relationship with Synthetic Biology: empathy, humility and altruism.

Core Values: Empathy, Humility, Altruism

"As we enter the 21st century we are experiencing a moment of grace. Such moments are privileged moments."

~ Thomas Berry (1999, 196)

Empathy exists within Thomas Berry's call for reimagining the 'viable human.' (Berry, 1999) If we are to be viable into the future as a species, Berry argues that, "the human community must move from its present anthropocentric norm to a geocentric norm of reality and value. Within the solar system, the earth is the immediate context of human existence." (Sessions, 1995, 8) If synthetic biology is premised on the decontextualization of DNA and the ultimate control of evolution, then I think it will be another failed project of modernity just as the industrial revolution and the information society have been. If our goal is to increase justice, social equality, quality of life and quality environments, and I have to believe that is a common shared goal of most of humanity, I don't believe that neoliberalism, imperialism or paternalism will get us there. Empathy might.

Theodore Roszak argues that science today requires not genius but moral wisdom, the ability to engage in honest self-assessment and philosophical debate. (Roszak, 2000) Where extractive capital, neoliberal temporalities, commercial pressures to commodify innovations, and intellectual property reign in the biosciences, it becomes increasingly difficult to slow down long enough to engage in self-reflection or philosophical questioning to any significant degree.

Rights of nature is an alternative movement that has gained more traction recently and one that embraces a radical empathy for other-than-humans:

> **"Rights of Nature** is the recognition and honoring that trees, oceans, animals, mountains have rights just as human beings have rights.

> Rather than treating nature as property under the law, rights of nature acknowledges that nature in all its life forms has the *right to exist, persist, maintain and regenerate its vital cycles*. The ecosystem itself can be named as a rights bearing subject with standing in a court of law." (http://therightsofnature.org/)

In just one example, the sacred Whanganui river in New Zealand was given rights as a legal entity with interests. Right now in Hawai'i, the battle is being waged over the sacred Mauna a Wākea where the University of Hawai'i wants to build a 30 meter telescope and Kānaka Maoli say that the needs and rights of the mountain should be part of the conversation. As Walter Anderson points out, the political system that we call the United States of America assumed the governance of not only people, but all the other living creatures inhabiting this physical, geographic space. "American history does not indicate that the birds, beasts, and flowers were ever consulted on this point… It was an implicit and unquestioned part of the consciousness of Western culture, as old as Genesis." (Anderson, 1987, 16) Philosophical discussions that legitimately and respectfully address alternative epistemologies through an empathetic lens are critical for the futures.

I've done some exploration around the concept of an aesthetic semiotics that is primarily informed by affect as a vector of inter-species and human/nonhuman communication – the way that 'things talk back.' (Bennett, 2010) This is an idea invested in transformative empathetic expansion of the human capacity to relate to other-than-humans. In thinking about the new viable human, Thomas Berry wrote that

we need a “conversion experience deep in the psychic structure of the human.” (Berry, 1999, 59) To do this, we need to find ways to cultivate more opportunities for conversion experiences, something made even more difficult by our urban lifestyles and the decreasing access to ‘wildness.’ And yet a heightened awareness of aesthetic semiotics may actually be made more possible by emerging biosciences. As they strip away the dominant nature/culture bifurcation on a wider scale, we may become more attuned to the nonhuman presence within and around us by default. Tim Ingold argues for a re-animation of scientific thought. Bringing a sense of astonishment back into science; that experience found on “the other side of the coin to the very openness to the world…fundamental to the animic way of being.” (Ingold 2006, 18) Animists are often accused of anthropomorphizing - infusing life into otherwise inert objects, when this act of ventriloquism belongs exclusively to science. What animism offers is a relationship with the world where we can again be astonished at the field of relations, human and nonhuman that “continually and reciprocally bring one another into existence.” (Ingold, 2006, 18) As we navigate the tricky ethics of reprogramming life, we will need this sense of astonishment and a commitment to empathetic relationships.

Humility and Altruism: Sheila Jasanoff writes of technology that we must cultivate ‘technologies of humility’ rather than the ‘technologies of hubris’ that have been dominant in the modern world. (Jasanoff, 2003) Her observation of the varied and serious signs that, “America’s ability to create and operate vast technological systems had outrun her capacity for prediction and control,” (what Charles Perrow dubs ‘normal accidents’ – climate change, Bhopal, Chernobyl, etc.) demonstrate the urgent need to reexamine our hubristic “pretentions of control over technological systems.” (Jasanoff,

2003, 223) Altruism is the act of putting another's needs ahead of your own. Together these powerful technologies of connection and interdependency offer a way to orient ourselves towards a preferred future with synthetic biology.

In this vein, Neil Postman writes that there are six basic questions to ask of any new technology:

1. What is the problem to which this technology is a solution? Is this an important problem to address?
2. Whose problem is it? Does it address issues of social justice?
3. Suppose we decisively solve the problem, what new problems might be created?
4. Which people and which institutions might be most seriously harmed by a technological solution?
5. What changes in language are being enforced by new technologies and what is being gained or lost by such changes?
6. What sort of people and institutions acquire special economic and political power because of a technological change? (Postman, 2000)

Humility will be a critical component in our relationship to synthetic biology. Just because we CAN do something does not mean that we should. And a commitment to altruism will keep our intentions and our experiments on the right path to greater flourishing for more of the planet. These two powerful and enduring values if held closely and widely can assist the scientific community with navigating the complex waters of governing evolution.

Empowering new voices of leadership – Hacking the Orgware

As I outlined in Chapter 2, Gene drive technologies have the potential to end the threat of malaria. So it should be shocking to know that African countries and African citizens who are disproportionately affected by malaria have been almost entirely left out of the conversation about how and when to use these new technologies. There are some hopeful signs that this tide is shifting. The Carl R. Woese Institute for Genomic Biology at the University of Illinois hosts a Summer Internship for Indigenous Peoples in Genomics (SING). It's a one week workshop that aims to discuss "the uses, misuses and limitations of genomics as a tool for indigenous peoples' communities." (sing.igb.illinois.edu) And the widely respected scientific journal Nature recently published a series of responses to the twin Chinese girls whose genes were edited by Dr. He. These included an Islamic approach to designing ethics for CRISPR and mention of several initiatives that address the ethical chasm faced by the field. (www.editingnature.org) These are initial and insufficient efforts, but they point to the need for inclusion of leadership from peoples and spaces previously marginalized in the evolution of synthetic biology and other biosciences. I call this hacking the orgware of synthetic biology. As the 'who, what, why, how and where' of synthetic biology has heretofore been shepherded by dominantly western scientists and ethicists, we should be looking much farther afield to engage and empower alternative voices. Voices of those for whom these technologies really could dramatically improve life experience and shift the balances of power and equity back to a more just and sustainable place. Voices of those who sit at the receiving end of most major climate catastrophes and for whom there is not a financial escape route.

In the Principles for the Oversight of Synthetic Biology, numerous organizations representing civil society groups, Indigenous peoples, environmental, scientific, human rights, religious and labor organizations among others came together to outline their proposal for the ethical oversight of synthetic biology. Approaching the issue from understanding the need to empower the leadership of unlikely voices, they argue for the following "principles necessary for the effective assessment and oversight of the emerging field of synthetic biology:

I. Employ the Precautionary Principle
II. Require mandatory synthetic biology-specific regulations
III. Protect public health and worker safety
IV. Protect the environment
V. Guarantee the right-to-know and democratic participation
VI. Require corporate accountability and manufacturer liability
VII. Protect economic and environmental justice" (www.wilsoncenter.org)

It has become extremely clear that a changing climate is the context of our time. The pressures and unpredictability of a radically altered and haphazardly changing climate require very different approaches to the management of evolution. Merging this new context with the trends of synthetic biology, advancing artificial intelligence, nanotechnology and other similarly disruptive technologies that will emerge in the futures, we have a brewing storm of radical societal changes. The tether of ethics and shared common human values is a critical life line if we hope to have a future that allows humans and other than humans to thrive. How might we chart a path forward for synthetic biology that embraces wholeheartedly the beautiful entanglement of all things,

the blessed responsbility to carefully steward the world for future generations, the richness of ancestral knowledge and the joy of empowering divergent voices in the creation of a preferred future? I think this is the critical question of political and ethical design that sits in front of us now. It is not unique to this realm of bioscience, it is the question of our historical moment on the planet. The forces that have brought us here demand a totally, radically new way of approaching knowledge, power and priviledge. We will not solve the problems we face with the same thinking that created those problems in the first place. We cannot make the world better for people who are consistently left out of the halls of power and priviledge unless we break down those walls and build totally new structures. This is both the challenge and the blessed opportunity we have been gifted. When systems collapse, as so many social and environmental systems around us are currently, we must be ready with a new way forward to fill the void. That opportunity is quite profoundly the opportunity to remake the world. The stakes are high, we must be ready.

EPILOGUE

IN THE END… CLIMATE CHANGES EVERYTHING

During the time spent these last few years writing this dissertation, it has become imminently clear to me amid a growing host of others that climate change is no longer an issue that we have the luxury of choosing to consider or not consider. It is rather part of the foundational context within which all issues, in fact all aspects of planetary happenings, exist. It is the context for any possible futures one could imagine at this point. Positing a future that does not have climate change as a central feature is simply no longer useful. This is a reality not so new to futurists. On the S-curve of climate change acceptance and activism, you could say most futurists fall squarely in the early adopters category along with many scientists, philosophers, ecologists and the like. But it seems that now, many more people are awakening to the fact that climate change is our context, it is part of our reality that touches on and effects every other thing just as much as the economy or politics. We no longer have the comfort of deciding whether or not we will 'deal' with the issue of climate change. We gave that up years ago with our persistent inaction. Instead we now must consider the profound climate uncertainty that *is* our reality and find new ways to think about how we think.

As I have argued throughout this dissertation, the pressures of climate change will push us to accept radical new technologies that promise to solve our ills much more quickly and with less oversight than we should accept. Synthetic biology, Geoengineering and the intersection of both of these with Artificial Intelligence (AI) will no doubt be game changers in ways we cannot possibly yet understand. But one can

easily imagine that without a pervasive ethics grounded in deep connection to spirituality, commitment to intergenerational and intercultural equity, and humility, this intersection of technologies will lead to likely intense levels of increased concentration of wealth and power along with forms of weaponization that will increase suffering for many of the planet's inhabitants (human and other-than-human). And this is why I believe this work and other work like this examining these emerging issues is so critical right now. We have the opportunity with the current worldwide Indigenous academic, political and cultural resurgence to engage new ways of thinking, being and creating knowledge that offer a way towards greater equity and less suffering.

Postcards from the Futures….

The Hawai'i Research Center for Futures Studies has long applied a Four Futures Archetypes lens to scenario building. Established in 1971, it is one of the world's oldest futures research centers. The Manoa school of alternative futures teaches a wide variety of futures methods, but a few steadfast, tried and tested rules guide our work in forecasting alternative futures.

The first is that the future does not exist. Rather there are always alternative futures with an emphasis on the 's.' Because the future does not exist, it is not possible to predict anything. So, while you cannot in any way accurately predict the future, you can and should forecast alternatives.

In addition to alternative futures, it is really important to consider, envision and plan for preferred futures. This collective and participatory process is where futures becomes empowering, enabling communities, organizations, governments to think

about first the possible futures and then the collective desired future in a way that supports action towards realizing that preferred image of the future. This is a process that is iterative and should be embedded in any organization as a repeated process, one that you learn from, revisit, revise and support.

What we call Dator's 2nd law of the future is perhaps the most famous Manoa school export. This is the rule that "any useful idea about the future should appear to be ridiculous." This is often followed by the caveat that not all ridiculous ideas will necessarily be useful. Once upon a time, generations could assume that their children's lives and their children's lives after that would be fairly similar in many ways. Change happened quite slowly. In the 21st century, this is no longer true. Change is happening at an increasingly rapid pace. We can barely keep up with the pace of technology. And as change increases so does uncertainty.

So, if you're thinking 50 years into the future, you have to imagine that the world will be quite different and anything you imagine in that future will quite likely appear ridiculous by today's standards. Our values, behaviors and beliefs change with time and it is the futurists job to think about what these changes might look like and what they might mean. In today's world we can see that what is one day considered ridiculous, may tomorrow be old news. Like the idea of in vitro meat grown in a petri dish. One day, an absurd idea, the next day the first in vitro lab grown hamburger was being served in London, and now a company called Mosa Meat has raised $8.8 million to fund the development of lab grown hamburger that will cost less than $10. It seems the trajectory from ridiculous to reality is quickening. (https://www.fastcompany.com/90203024/this-lab-grown-beef-will-be-in-restaurants-in-3-years)

The idea of alternative futures embraces the possibility of infinite alternatives, all of which are possible, not one of which is truly more probable than any other. We often want to think that one future is more probable, but we need only look to history to realize how often things turn out quite differently than we expected.

To help us manage all of these infinite possibilities and create useful scenarios, professor Jim Dator developed four futures archetypes. The archetypes resulted from endless hours analyzing all the images of the future in media and story. He saw that consistently, these images tended to fall into one of four general categories. These categories or archetypes are not meant to constrain a scenario, but rather to guide the scenario, and to help us to get out of the 'tyranny of the present' in order to envision truly different alternatives.

The first archetype is continued growth. This is the business as usual vision of the futures. It is the most common way that almost all organizations, governments, and even individuals envision their future – more of mostly the same, but more and usually, though not always, better. While Continued Growth typically implies increased economic development, it also very much includes the diffuse challenges enlivened by increasing growth. Getting people to envision a future beyond *Continued Growth* can often be one of the most important and difficult aspects of being a futurist since all institutions of modern society (especially education, governance, and of course the economy) are aimed at promoting growth, usually economic growth.

The collapse archetype is based in the belief that economic, environmental, government and social systems as we know them are unsustainable and will partially or fully collapse. While apocalyptic images of the future are popular today, collapse

scenarios are not inherently negative, bad, or strenuous. As easy as it is to imagine various ways in which humanity might go extinct, it seems hard for some people to imagine ways in which humans might in fact thrive following catastrophe and crisis even though history certainly offers many examples. We call this version of collapse – new beginnings. Many people and organizations argue that a collapse of current systems could allow us to start fresh and reimagine how we might better coexist with one another and with the planet.

A third archetype is discipline. One version of the discipline archetype is based on the idea that we can and might avoid environmental, social, economic or cultural collapse by restraining our behaviors so that we become sustainable in all these areas. However, while sustainable futures are inherently disciplined, not all disciplined scenarios are sustainable. Other versions of a disciplined image of the future say that even if continued growth can be made sustainable in terms of resources and the environment, continued economic growth by its very nature destroys certain basic values that should instead be the basis of a good life. Discipline may imply authoritarianism, but a discipline society can also be designed so that educational, institutional, structural, and similar systems encourage people to live peaceful, meaningful lives without the ceaseless demand for growth.

The transformation archetype is based on the idea that a technological and/or spiritual revolution will produce a future so profoundly different, that the world as we know it now will seem unrecognizable. In transformational images of the future, humanity experiences a total metamorphosis, even though old-fashioned *homosapiens* may no longer be at the center of it, or perhaps even survive in its present form. Energy

is ubiquitous, we are fully post human, man and machine have merged, the Singularity is realized. (Dator, Sweeney & Yee, 2015)

Applying the lens of climate change as context to the Manoa Four Futures Archetypes with the driver of intersecting disruptive technologies: synthetic biology, geoengineering and artificial intelligence let's imagine a few different possible futures for the year 2050, in America, 31 years from now. For these scenarios, I have chosen to combine two archetypes in each scenario. I do this because I believe that the technological utopianism of continued growth and transformation ignore socio-political implications in a very dangerous way that we must pay attention to. And that a collapse scenario without the guiding ethics of spirituality and connection to other-than-human lifeforms will lead to an undesirable disciplined future where we are grasping to maintain semblances of order at the expense of thriving. On this basis, one scenario will look at the Continued Growth and Transform archetypes and one will look at Collapse and Discipline together.

Continued Growth/Transform

Some of the continued growth trends that we have experienced in the last few decades include commodification of technological solutions, less oversight on radical new technologies and their uses, and a race to develop and patent as many new creations as possible by an ever-shrinking number of biotech firms as each new start up is swallowed up by massive corporate conglomerates. Politically America has continued in fits and starts down a path towards despotism and fascism. Corporations and politicians no longer bother to attempt to hide their interconnections and Corporations

as persons are now allowed to run for the office of Presidency. Climate change has ravaged the country. Sea level rise, increased droughts, floods, super storms and bizarre weather events have decimated large swaths of our country. Gated and walled communities allow those with means to create some semblance of normalcy while the ultra-wealthy have built mini-empires that operate like sub-states with their own rules and private security forces. Those less fortunate have the choice of squatting in mega-slums in decimated cityscapes or living nomadically, traveling with little to no possessions and taking on piece work where possible. Geoengineering really took off in the 2020's as the realities of climate change became too real to ignore. Countries entered a sort of climatic-arms-race seeking to beat adversaries to the punch and maintain their own national climate norms as much as possible while holding little regard for the fall out on the rest of the planet.

At the same time, all the major oil and gas corporations, the agri-business corporations, even Amazon, Google and the major tech corps dove head first into synthetic biology as they saw the financial boom it created in the late 2010's. But this financial windfall has only been experienced by a very few. Once again, AI automation technologies put many people out of work so that the increasing profits went to fewer and fewer elite families. Synthetic biology super charged by the onset of increasingly intelligent AI has mushroomed. But the benefits of synthetic biology are realized by only the elite few. They have access to incredible new medicines, bountiful synthetic food supply, entertainment and decadence rivaling the monarchy of the ages. For the less fortunate, the government offers certain perks like pain and fear reducing DNA enhancements. The purported purpose was to alleviate suffering for those in difficult

circumstances. But not surprisingly, this has only served to increase crime rates in the slums. Perhaps that was the point.

Their eyes were watching…

He stood there, shocked, unsure what to do. It couldn't be true. Fuck, they're going to know. He tried to delete the lines on the screen. Tried to take it back, but he already knew it was too late. He had discovered the gene that controls a person's ability to block fear. And he knew exactly what they would use it for.

The defense contractor had hired him to work on this project and when he first signed up it was mostly out of intrigue. But he knew as a Synthetic Biologist, they were always watching him. It was part of the trade. It was just the way the field worked. Ever since the U.S. had signed on to the International Agreement on Synthetic Biology monitoring, all scientists practicing gene editing knew that they were surveilled constantly. And that all their inventions would be owned and patented by the military. They had taken control of all new patents since the martial law was signed in after the water riots of 2052 swept the entire nation. National security, they claimed. And that claim had now simply become the norm.

But he didn't really think it was possible. How could you really turn a person's capacity to feel fear on or off? And now, here it was. He had found it. He couldn't unfind it. And he knew exactly what they would use it for…

Collapse/Discipline

The worst of the climate predictions have come to bear even beyond what the most 'alarmist' scientists had predicted. As a result, in 2052 the American government, in desperation from overwhelming infrastructure needs, a collapsed insurance market and a completely failing economy adopted the radical blueprint called Island Civilization. In the early 2010's Robert Nash, the visionary for Island Civilization, wrote that, "One way to look at the opportunity and the responsibility we have with regard to the environment is in terms of legacy." (Nash, 2010, 372) He cautioned that, "In a century wilderness could disappear or become so fragmented as to be ecologically

meaningless. Some now view this not just as a violation of the rights of humans to enjoy wild nature but of the rights of other species and self-willed environments themselves." (Nash, 2010, 376) Nash proposed a vision of humanity in the fourth millennium where the earth's population has willingly been reduced to 1.5 billion people living in 500 concentrated habitats – 3 million people per habitat living within a 100-mile radius with everything needed to survive and thrive produced locally. (Nash, 2010) We are far from that ambitious goal but like the moonshot of the 20th century, the government and citizens of America are on board to make this dream a reality as quickly as possible. Strict birth controls enable only the healthiest citizens or those who can buy their rights to have a child, and euthanasia is common for those with disease, especially those with disease and no financial resources. Travel, except that possible by foot, was banned two decades ago and people live in small communities made of multiple families sharing all their resources.

The first underwater communities and in-air communities have helped some first-adopters, climate pioneers really, to adapt to the realities of climate change. With major coastal cities under water and many parts of the country ravaged by storms, droughts and floods, there are increasingly fewer on land areas left that are very habitable. Government controlled geoengineering is making some strides in easing the uncertainty of the climate changes but there are so many unintended consequences. Just last year, a synthetic microbe designed to abate carbon in the atmosphere by converting it to oxygen mutated and rained toxic acid down on Los Angeles killing hundreds of thousands of residents and scores of wildlife in just a few months. Synthetically engineered food rations are all that is available to most people and strange diseases

have been popping up all over the place but no one has the resources or political will to figure out their origin or cause. As a result, life expectancy overall has dropped significantly. Children born today can expect to live into their 30's or 40's if they are so lucky.

Sweet Child of Mine…

She looked at the screen and felt the weight of indecision. Her mind racing with so many choices and no one to talk to about it.

Blue eyes, I guess… but do I really want her to be that tall? Sometimes it's hard being tall as a woman, but then there's sports, and I really have done ok being tall… I just don't know…

This would be so much easier if he was still alive…

It had been six months since her husband had died. She felt a familiar wave of gratitude that he had the foresight to freeze his DNA when he realized he was sick. He might be gone, but she could still have his baby and in that way, he would live on. Thank god her family had the money to buy rights for her to have this baby. She knew she had so much to be grateful for…

He had thought he was spared the genetic disease of his family line. They had told his parents that they designed out those genes when he was in the womb. But they didn't realize that the same gene that suppressed his family's rare particular disease would be the exact same gene that can mutate and ignite rapid, incurable liver cancer. It had gone so fast. She still felt in shock. Maybe that's why this whole baby design was so hard. She was still in a fog, couldn't think straight.

She sheepishly looked around the room, comfortable couches and cozy spaces, tastefully designed and beautiful. In each nook sat a couple, poring over their own screen, faces alight with hope, excitement, love in their eyes. She was the only one alone. She would have to do all of this alone.

I know I want a girl. I know I want her to be pretty. Long hair, thin. It'll just be so much easier for her that way… But how do I make sure she's healthy? Can I make sure she's healthy?

Click, click, click… she selected down the long list of options. Almost mindlessly selecting the fate of her child.

I wonder what it felt like in the old days when you just got pregnant and hoped for the best? That seems so reckless and weird. I don't know how they handled the not-knowing… I can't even imagine.

Her great grandmother had told her stories. Of the times when women gave birth to babies with all kinds of terrible diseases, still births, and from their own womb… She couldn't imagine letting her body stretch and distort that way, all the hormones, it all seemed so primitive.

Ok, I guess that's it… I've gone through all the screens… oh wait, one more to do… what's this? Oh just a privacy agreement. Of course, as if I don't already know they'll own all her DNA. I don't even know why they bother with the fine print anymore. Everyone knows privacy is so 20th century…

In the end…

Hopefully it is clear that neither of these visions represents a preferred futures scenario. The jagged contours of a preferred scenario has been the core focus of this dissertation: A decolonized synthetic biology that embraces the ethics of a planetary politics for human and other than human thriving. But such a preferred future is not the work of one academic or futurist. My contribution to this evolving canon is to sound the alarm and raise to eye-level the specter of possibilities. Any preferred future will be the collective work of many hearts, hands and minds with the capacity to craft it. I began this work explaining that it is at its best a work of speculative advocacy. Which is to say that it is a plea for a new way of being, doing and thus having a new sort of future become available to us. With the current trends and trajectories as they are, we need a decisive shift in our mode of operation. The systems we built through the industrial revolution are no longer serving us. The systems we built through the information revolution built themselves off the backs of the industrial revolution which itself was fueled by colonialism. None of this will work in the futures. The operating systems have far surpassed their expiration dates and we are scrambling to patch the holes with

resources we no longer have. The Hawaiian word na‘auao refers to being learned, enlightened, intelligent and is based off the root word na‘au which refers to the gut, the intestines, where Hawaiians believe the intelligence of the human resides. “Thinking and feeling are not separate… Hawaiians ‘felt‘ wisdom and ‘experienced‘ intellect… Intelligence was not void of sense or feeling. Emotions were not feared with regard to knowledge” (Meyer, 2003, 124). To meet the work at hand for the 21st century, we all must rapidly embrace this rich understanding of mind, body and diverse sources of wisdom as we move into the radical uncertainty of the futures we are creating. The Nuu-chah-nulth people say that all life’s beings have a divine origin, a common source, known at Qua-ootz, Owner of Reality. (Atleo, 2004,59) This divine responsibility, the kuleana of designing beings, designing evolution, is just that - *divine*. We must now seriously question whether dominant culture, deeply enmeshed as it is in the outdated orgware of nationalism, capitalism, settler-colonialism and all the other –isms, has the divinity to rise successfully to meet such a task for the futures.

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