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In Vitro Incubations

> Humans are part of the world-body space in its dynamic structuration. Does this mean that humans have no responsibility for the outcomes of specific practices? . . . [D]oes that mean that human subjects are merely pawns in the game of life, victims of the same practices that produce the phenomena being investigated?
>
> —KAREN BARAD

> The heart of the project of philosophy as Deleuze conceives it . . . show[s] that going "beyond" the human condition does not entail leaving the "human" behind, but rather aims to broaden the horizon of its experience.
>
> —KEITH ANSELL PEARSON

Years ago, while preparing to split nearly confluent plates of immortalized mouse hypothalamic neurons, I had an experience in the lab that gave me pause. That pause has lingered with me ever since. It took place during a routine cell subculturing procedure, while I sat in front of a cold sterile fume hood with my latex-gloved hands placed on the door handle of a warm 37°C CO_2 incubator. Something happened in my otherwise unremarkable lab routine: I felt guilty for the shock in temperature I was about to inflict on unsuspecting neurons growing inside a warm bath of media and nutrients. I held off on opening the incubator door for a few labored seconds, then immediately considered the absurdity of the moment. I asked myself, What would these *in vitro* neurons think if they knew what I was about to do?

I had caught myself not questioning whether those neuronal cells growing *in vitro* were alive, or whether they could think, but rather, assuming that these neurons were living and already knew how to know, I was concerned with what their *response* would be in the moment that was about to unfold. I didn't quite see myself as a human pawn or a victim entangled in this phenomenon. Instead, I wondered about the lives of these neurons and the complex set of events that had come together at that moment to create an ontological crisis for me out of what was otherwise the mundane molecular biology practice of passaging cells. Only by spending time in a lab, and by using the practices of molecular biology, have I learned to generate such questions about nonhuman life and biology. This in turn has prompted me to consider an ethics of matter.

The *in vitro* lab protocol known as splitting, subculturing, or passaging allows the molecular biologist to keep cell lines alive for use in experimentation. However, unless one is willing and able to deal with an entire population of multiplying cells in culture, it also requires getting rid of, or killing, a vast number of these cells. In my case, once the cell line I was using was established, approximately 75–80 percent of the growing cells were discarded during any given cell passage procedure if they were not being used for experimentation; the remaining cells were placed in new plates with fresh media, fetal bovine serum, and other goodies to stimulate cell growth and division. Hannah Landecker has provided a rich analysis of how cells actually became technologies; she argues "that the history of cell cultivation is the history of an approach to living matter."[1] As part of her methodology of examining this history, Landecker places an emphasis on the importance of practice and the material basis of research, stating:

> Attention to the things people work with in experiments and to the ways they attempt to stabilize living objects such as the cell for scientific study has allowed historians and anthropologists to address the conditions under which scientific novelty is produced. Looking closely at the routine or infrastructural conditions that constantly allow the production of new things is a method for getting around having to explain all scientific developments as a "paradigm-ordered or theory-driven activity." In other words, the scientist does not have to think of it first, and

> act on the biological thing accordingly; change can arise from the objects and practices of experimentation themselves—how cells are kept, watched, represented, manipulated, and how they react and adapt to their technical milieu.[2]

Landecker's methodology deeply resonates with the emphasis I have placed on learning from experimental science and developing a practice-oriented feminist STS. However, Landecker also notes that it is by observing the everyday experimental activities of scientists that historians and anthropologists (*and presumably not scientists themselves*) are able to address what it is that scientists do, further suggesting in reference to *in vitro* cell cultures that "it takes an anthropologist in the laboratory to note the strangeness of what has become quickly routinized or banal to its practitioners."[3] Landecker assumes that most scientists are not aware of or changed by the daily activities found in a lab. I agree that many scientists may not be sufficiently reflexive. But this is not the case for all scientists. In fact, this chapter is dedicated to exploring a pause that was generated precisely by such a strangeness. The pattern of growth, division, and purposely inflicted death that took place every three to four days in the *in vitro* cell line of neurons that I worked with created a distinct temporal cyclicity, which although was unlikely to occur anywhere *in vivo*, nevertheless became part of my own basal rhythms. Just as I was responsible for designing experiments using these cells, the patterns of growth and multiplication of these neurons, and their cyclic hormone secretions, regulated my life for years.

On that particular day when I paused to open the incubator door, this rhythm was interrupted as the weight of several entanglements I could not continue to ignore came to bear on me, on the stainless-steel handle of that incubator door, and on the cell line of gonadotropin releasing hormone (GnRH) neurons known as GT1-7 cells. These entanglements included acknowledging accountability for the human practice of developing cancer in mice and killing animals and cells for research purposes. Obtained from the brains of transgenic mice that had been created through the technique of targeted tumorigenesis, these particular *in vitro* neurons were genetically designed to express an oncogene that led to the development of hypothalamic tumors.[4] Before I even came to work with these neurons, there was already an entanglement with a molecular

biology technique that involved the noninnocent human-mediated infection of polyomavirus isolated from monkey kidney cells to produce SV40 T-antigen, which caused malignant transformation of the infected cells. There were further entanglements of a reproductive justice movement and an antagonist and partial agonist of the progesterone receptor RU486 that was behind the pause I experienced that day.[5] While leading many feminists to march in the streets for reproductive justice, the compound RU486 led me straight into a molecular biology and reproductive neuroendocrinology lab with the desire to learn more about the molecular mechanisms involved in the regulation of reproduction. Once there, I found myself intimately entwined in a molecular relationship with this *in vitro* cell line of neurons.

As significant as that pause was for me that day, and despite the fact that I knew I had to confront this challenging but generative ontological quandary, I did not have the language or skill set at the time to articulate my question about the lives and responses of *in vitro* neurons in a way that would be recognizable to my colleagues in the sciences. When I think about my interest in the response of those *in vitro* neurons in the lab, I realize now that even back then I was on my way to becoming an interdisciplinary scholar. The examples of interdisciplinary work available to me at the time were not particularly amenable or easily translatable to the inquiry I had generated as a feminist scientist. A new era of interdisciplinary exchange between the humanities and the sciences has helped to relieve some of this unintelligibility.

Interdisciplinary Incubations

These are indeed exciting times for interdisciplinary scholarship. For me, the pauses and causes for reflection encountered by trying to bring together the sciences and humanities can be incredibly complicated but also generative. Over the past decade, I have found a space within the field of women's studies to carry that pause I experienced in a molecular biology and reproductive neuroendocrinology lab along with me and to begin articulating that moment as a meaningful one, worth further reflection. As an invested onlooker and participant in feminist STS, I have witnessed significant paradigm shifts not only within this subfield in regard to its relationship with the sciences, but more generally also in the broader

discipline of women's studies itself. These paradigm shifts may be connected to the intellectual fallout from the science wars that took place in the mid-1990s as well as the ever-increasing uneven distribution of funding between the sciences and the humanities. Regardless, it is safe to say that the discipline of women's studies (along with many other humanities-based disciplines) is currently undergoing significant paradigm shifts to reorient itself in relation to the "hard" and natural sciences. The subfield of feminist STS serves as an example of the magnitude of these reorientations, as scholars wrestle not only with the fast-paced development of new biotechnologies but also with the impacts of recent ontological, posthumanist, and material turns in women's studies and the humanities at large.

The critique of poststructuralism's influence on feminist theory and its apparent inability to deal with matter itself has brought forward calls for developing new types of engagements with biology—namely, through scholarship in material feminisms and feminist new materialisms.[6] These calls have brought with them an era of enlivened regard for the sciences. Moving from in-depth critiques of gendered language and the use of gendered paradigms in science, to mining scientific research and data in efforts to move feminist theory forward, there has undoubtedly been a significant shift in the tone with which some women's studies scholars (particularly those who are not trained in the sciences) now voice their interest in the sciences. Having placed questions that are central to the humanities in exchange with research in the natural sciences, this era of interdisciplinarity has made the question that I posed that day in the lab—What would these neurons think?—while holding on tight to that incubator door, somewhat more legible. However, this increased exchange between the humanities and the sciences has also precipitated two major challenges for feminist STS scholars: first, being able to acknowledge life and the living at the level of the *in vitro*, the molecular, and even the inorganic; and second, being able to respond to and deepen our human entanglements with these very lives by paying attention to questions of context and calls for social justice.

Just as an earlier wave of interdisciplinary work in the humanities forced us to examine the question of what it means to be human through multiple and inevitably intersecting frames of sex, gender, race, class, sexuality, ability, and more, as a result of new exchanges with the sciences, the first challenge that the next generation of feminist scholars must face

is to trouble the central premise of this very question. The current generation of feminist STS scholars is working hard to learn about the natural sciences, but not simply to find ways to understand the human condition alone. Rather, new alliances between the natural sciences and such fields as women's studies are in fact working to decenter the question of the human within the humanities. Sustained entanglements with animal behavior research, evolutionary biology, molecular genetics, and more have complicated our understandings of exactly what gets to count as a "life" and which lives are included in our concerns regarding "expressive life."[7]

The growth of posthumanist and animal studies is an indication of this paradigm shift when it comes to thinking about the ontological contours of "life." In the field of women's studies, for example, distinctions between the human and nonhuman and the living and nonliving have been troubled by Donna Haraway's idea of naturecultures, Karen Barad's theory of agential realism, Jane Bennett's notion of vibrant matter, and more recently, Mel Y. Chen's concept of animacy, to name but a few.[8] From these recent theoretical moorings, a question that seems important to address, when considering the future of feminist STS in this new era of interdisciplinary work, is not only whether we can continue to ask what it means to be human, but whether our theoretical frameworks and methodologies are prepared to support the question of what it means to be a life—nonhuman, inorganic, and otherwise. This chapter tries to better appreciate what this notion of life and life in the lab can mean by turning to research in synthetic biology. A field borne through molecular biology practices, synthetic biology has produced both *in vitro* and synthetic lives, made of assemblages of both organic and inorganic matter. These lives, known as minimal genome organisms or minimal cells, move across taxonomical thresholds. Interestingly, Michel Foucault wrote in *The Order of Things*, "Up to the end of the eighteenth century, in fact, life does not exist: only living beings. . . . As for life and the threshold it establishes, these can be made to slide from one end of the scale to the other, according to the criteria one adopts."[9]

It is evident that the line we draw between the living and nonliving can be made to slide according to the criteria we adopt. Similarly, Deleuze and Guattari have described life as an intensive and powerful life that is not organized or necessarily found within an organ or an organism. In the final plateau of *A Thousand Plateaus*, Deleuze and Guattari dedicate their

focus to the topic of space, discussing several modes of smooth (read as nomadic) and striated (read as sedentary) space, including technological, musical, maritime, mathematical, physical, and aesthetic space. Their discussion of aesthetic space emphasizes the mixture of smooth and striated space at all times, noting the lack of creativity that accompanies those lines that have been drawn to confine life within the organic alone. "If everything is alive," they wrote, "it is not because everything is organic or organized but, on the contrary, because the organism is a diversion of life. In short, the life in question is inorganic, germinal, and intensive, a powerful life without organs, a Body that is all the more alive for having no organs, everything that passes *between* organisms."[10]

I turn to the idea of the body without organs below, but here I want to emphasize that the technologies and practices of synthetic biology have most certainly redrawn lines and disrupted what we have come to consider as the thresholds of life. This disruption may be jarring to some but, similar to the pause that interrupted me while splitting *in vitro* neuronal cells in the lab that day, I believe it is important to reflect on this disruption and consider the possibility that these synthetic lives may not only be expressive but may also be reaching back out toward the surrounding world. The question is, Will we know how to respond?

The second challenge for feminist STS scholars arising from this interdisciplinary exchange is a direct result of the earlier challenge. As all eyes turn to the nonhuman and to molecular and subatomic matter, we must remain aware of the costs of building theoretical interventions apart from their human social and political implications and entanglements. Our ideas of the social and political can expand so as to include or even focus upon the nonhuman, but as we shift our central questions in the humanities, we must keep in mind the broader contexts and repercussions of this work. Thinking with the nonhuman or even the inorganic is an ethical project, but it does not mean, as the chapter epigraphs suggest, that we must leave humans behind or, for that matter, our notions of social justice behind. What is key here is *not to stop* theorizing once we have initiated our ontological, posthumanist, and material turns. We must keep theorizing our way through until we can connect these new insights to our role and contributions as humans within these turns. In addition, our ideas of social justice must apply to all forms of life—from humans to nonhumans,

from the organic to the inorganic. Haraway refers to this in her work as "multispecies ecojustice."[11]

In her work on Darwin, feminism, and sexual difference, Elizabeth Grosz asks us to consider the following: "How does biology—the structure and organization of living systems—facilitate and make possible cultural existence and social change?"[12] As a biologist, I am on board with the idea that biology can be used to initiate social change and even work toward social justice. In fact, an antagonist and partial agonist of the progesterone receptor are precisely what made me march straight into a molecular biology lab in the first place. I am committed to what feminists can come to know not just by collaborating with the sciences but also by collaborating with molecules. I am invested in the futures we can begin to imagine by turning to the practices of the biological sciences and to the capacities of biological matters. However, I also think that much about what we come to know and the future that we want to see depends on the specificity of which "social change" we are talking about, and the approaches we actually use to get there. Envisioning new ontological and ethical frameworks is difficult work as it is, but biophilosophies of becoming require that we figure out how to apply these frameworks and live with these difficulties.

Vicky Kirby has made a compelling case that bacterial cells write and that "it is in 'the nature of Nature' to write, to read and to model."[13] Her intervention is crucial in terms of the first challenge posed to interdisciplinary scholars in the humanities and sciences—namely, what it means to be nonhuman. For feminist, postcolonial, and decolonial STS scholars, who are committed to thinking about social justice and want to make connections between the humanities and sciences, such an ontological intervention must be expanded to meet the challenge of thinking about contextual accountability. In her work on Niels Bohr, Albert Einstein, Werner Heisenberg, and quantum physics, Karen Barad draws from Jacques Derrida's idea of "justice-to-come" to discuss entanglements and the behavior of atoms. She states:

> The past is never closed, never finished once and for all, but there is no taking it back, setting time aright, putting the world back on its axis. . . . The trace of all reconfigurings are written into the enfolded materialisations of what was/ is/ to-come. Time can't be fixed. To address the past

> (and future), to speak with ghosts, is not to entertain or reconstruct some narrative of the way it was, but to respond, to be responsible, to take responsibility for that which we inherit (from the past and the future), for the entangled relationalities of inheritance that "we" are. . . . Only in this ongoing responsibility to the entangled other, without dismissal (without "enough already!"), is there the possibility of justice-to-come.[14]

Barad emphasizes the importance of recalling the past and thinking about the responsibilities we as humans hold while trying to think differently about materiality.

Gill Jagger has recently argued that compared to Barad's theory of agential realism, Grosz's and Kirby's turns to nature fall short of providing a useful way of rethinking materiality. "Thus, if the aim of the new materialism is to provide a way of rethinking the interimplication of culture and nature," Jagger writes, "moving away from the negation of one in the determination of the other, difficulties remain in both Kirby's and Grosz' accounts. This is not the case, however, with Barad's account of the intra-action of nature and culture in the material-discursive relation: it involves a process of mutual articulation that is a matter of interimplication."[15] In my understanding of their work, Grosz and Kirby encourage us to think differently with the sciences to imagine biology and "nature" as providing the grounds for social change. In their own ways, Grosz, Kirby, and Barad each encourage us to find new ways to think about the relationships between human, nonhuman, organic, and inorganic lives through closer analyses of science, biology, physics, and matter. Perhaps because of Barad's training as a scientist, however, I would agree that her work may resonate more with the feminist scientist who is concerned with questions of interimplication. For feminists who are working directly in scientific disciplines, recalling the past is a reflexive practice that requires learning how to think about the context of a biological event as deeply and broadly as possible.

Roots and Shoots: Approaches to Life and Context

As part of the basic structure of many species of grass, horizontal stems known as rhizomes (stems that grow below ground) and stolons (stems that grow above the ground) can form "nodes," which in turn can give rise

to both "roots and shoots." These new roots and shoots can develop new "daughter" plants.[16] Similarly, molar and molecular politics can come together and form new projects in feminist STS. I have already started recounting my inquiries into the lives and responses of nonhumans by discussing my encounter with an *in vitro* cell line of neurons, developed through targeted tumorigenesis, and used for molecular biology research. This chapter brings into the mix other *in vitro* bio-actants such as minimal genomes, and bacterial and yeast cells that are referred to as surrogates in synthetic biology research. Yet before focusing on the intimacies of *in vitro* life, some may have more pressing concerns whether as humans we should be tampering with genes and organisms, or "playing god" at all.

For some of us, the more acceptable and familiar place to begin this interdisciplinary analysis might be to interrogate the processes that have led to the recombination of genes, the creation of transgenic animals, and the synthesis of new organisms in the first place. Some of us may also question the tenets of molecular biology itself and the validity of a science that places such authority and focus on DNA. Others might be more than wary of the pervading reductionist logic that lies behind molecular biology as a whole, which has resulted in the field of synthetic biology and forwarded a completely mechanistic view of life. Alternatively, some of us may be raising traditional bioethical concerns related to agency, choice, and the safety of conducting recombinant DNA, transgenic, and synthetic biology experiments. Of course, these concerns are valid and require much deliberation. Although these concerns are crucial, they also follow already well-established lines of inquiry between feminism and the biological sciences. They are molar in their approach not only because they represent tried-and-true modes of inquiry but also because in many cases they eventually return us to questions of human subjectivity, identity, and representation.

Once again, I want to be clear that in feminist STS, it is necessary for scholars to continue their interdisciplinary work through such molar approaches and lines of inquiry. However, it is also necessary for some feminist STS scholars to take more molecular approaches to their inquiries at the intersections of feminism and molecular biology. These molecular approaches may not begin by assessing the "appropriateness" of a science such as synthetic biology, or whether it is ethically "correct" to create transgenic cell lines or animals, or use bacteria as surrogates to create minimal synthetic bacterial cells. In this case, a molecular approach might be about

spending more time learning about the intricate practices of synthetic biology in order to look for places where feminist and scientific questions of life, matter, context, justice, and ethics may be placed together.[17] A molecular approach may also involve suspending (even if just for a moment) our capital "E" ethical judgments regarding whether synthetic organisms should exist at all. It is perfectly sound to ask the question, How did we arrive at this point? However, if we follow a molecular approach, the question might become, Now that we are here, what is our relationship with the synthetic lives that already live among us?

My tendency to turn toward molecular feminisms obviously stems from the pause I experienced in the lab while working with an *in vitro* cell line. However, it also reflects that long-standing interest I have had in thinking about biological matters in the lab through biophilosophies of becoming and reaching toward these matters through microphysiologies of desire. So far, I have focused on the qualities of changefulness, nonhuman becomings, kinship, and hylozoism in our encounters with nonhuman others such as grass and bacteria. In this last chapter I think about ways to encounter synthetic lives that are already our kin by highlighting the qualities of univocity and immanence. Although I barely begin to scratch the surface, I pursue this encounter in two ways: first, by posing the question of what constitutes life and the living in this era of synthetic biology; and second, by finding a way to consider the human entanglements that contribute to the contexts in which these lives are lived.

In *After Life*, Eugene Thacker has traced the ontology of life through a history of Western philosophy. He states:

> "Life" is a troubling and contradictory concept. . . . Today, in an era of biopolitics, it seems that life is everywhere at stake, and yet it is nowhere the same. The question of how and whether to value life is at the core of contemporary debates over bare life and the state of exception. At another level, in our scientific worldview, it seems that life is claimed of everything, and yet life in itself is nothing. While biologists continue to debate whether or not a virus is living, the advances in genetic engineering and artificial life have, in different ways, deconstructed the idea that life is exclusively natural or biological.[18]

Thacker suggests that there are three major modes through which philosophical engagements with the question of life are organized today. They are the affective-phenomenological, the biopolitical, and the political-theological.[19] It is within the affective-phenomenological mode that we find those approaches that relate to a biophilosophy of becoming and turn to the "immanently dynamic, self-organizing, and germinal qualities" of life.[20] Life in this sense is treated as an event, a proliferative one at that, bringing with it the capability of generating difference.

Thacker argues that our habits of thinking about life in a hierarchical fashion, beginning with biological elements and building layers of behavior, culture, and politics up onto this scaffold, is a direct result of Aristotle's philosophy of life. Starting with the philosophical works of Aristotle, Thacker turns to concepts of life that have attempted to work against this stratification. Although his project ultimately points to some inherent contradictions that are constitutive of the various concepts of life, Thacker provides a rich analysis of the importance of such concepts as univocity and immanence to understanding life in the biophilosophy of Deleuze. We know that for Deleuze, univocity is understood as a univocity of difference. The concept of univocity is what drives Deleuze's ontology and is crucial to the idea that life can exist as a multiplicity within an ontologically single field. As Thacker explains:

> In *Difference and Repetition*, Deleuze takes up the concept of univocity in a way that places it at the center of his ontology of difference. For Deleuze, traditional ontology is predicated on the concept of identity (vs. difference), of the One (vs. the Many), of Being (vs. becoming), and so on. That-which-differs can be regarded only as in some way falling away from, or dependent upon, that which does not differ, or that which is whole, Ideal, One. As Deleuze states at the outset, his aim is to think the concept of difference not as secondary or derivative, but in some way as primary to our thinking about that-which-differs as well as to the processes of differentiating and creating differences.[21]

This framing of life through univocity, where univocity plays a central role in an ontology marked by difference, is the molecular approach to life and the living that is taken up in this chapter. Synthetic life therefore can

be understood as an event, with the capacity for generating difference. I am particularly interested in the lives that have been created via human, bacteria, DNA, protein, and technological interactions, ones that notoriously zigzag across taxonomical lines (between the organic and inorganic, living and nonliving), and ones that are expressive. Although they are synthetic, there is much to learn from minimal genome organisms, if we are able to work with them through this concept of univocity and if we can orient our curiosities toward them upon an immanent plane.

In this synthetic era of biology, we are being pressed to reconsider our onto-ethical orientations toward lives that are beyond being merely recombinant or transgenic. Indeed, "oncomouse" has now become an elder at the table.[22] Minimal genome organisms, designed and produced synthetically in a lab, are taking us out of our previous comfort zones, demanding that we revisit and further expand our notions of kinship. The concept of immanence may help to bring us to this newly reconfigured table. "For Deleuze," as Thacker explains, "this conjunction of immanence and expression—or really, *of immanence and life*—has three fundamental principles."[23] These principles include the principle of equality, where "immanence is not only the immanence between Creator and creature (a vertical immanence), but the immanence between creature and creature (a horizontal immanence)." It also includes the principle of univocity as discussed earlier, which allows for an immanence that is "at the same time dispersive and inventive, distributive and creative, supernatural and natural." Lastly, immanence can be characterized by the principle of affirmation, incorporating "an ontological affirmation that supports a notion of being as purely superlative, affirmative, and creative" and not one defined negatively through lack.[24]

Several paradigms and practices come together to form the field of synthetic biology. The challenge we face as feminist STS scholars with this field is that while it has pushed us to question the boundaries drawn around life and the living, it has also created a novel synthetic life cycle. This synthetic life cycle first travels through a human-mediated and computer-coded inorganic phase, which begins with digital representations of DNA that are used to place molecular materials into synthetic structures such as the minimal genome. It then moves on to an organic phase where minimal bacterial genomes that have been genetically engineered are introduced into "surrogate" cells (whose "naturally" occurring genome

has been removed) to become an organism that transcribes, translates, and produce proteins of interest *in vitro*. Lastly, the life cycle progresses to what might be considered a social phase, whereby a minimal genome organism, that has been synthesized to contain genes of human interest, requires a variety of human and nonhuman systems and resources in order to thrive. During this phase new forms of expression such as technologies can emerge as a result of the synthetic life cycle that both organize and are organized by humans and the environment. The challenge is to treat each phase of this life cycle through the qualities of univocity and immanence, beginning with the inorganic phase.

Deleuze and Guattari speak of inorganic life that is expressive and germinal, that exists as a body without organs (BwO). For many scholars the ideas of inorganic life and a body without organs both represent highly contentious aspects of Deleuze and Guattari's work. The turn to inorganic life has been criticized as an attempt to recuperate some form of neovitalism.[25] In addition, there has been much confusion around their concept of the body without organs, often being interpreted as a stance against organs themselves.[26] I address both concerns here briefly. For many, vitalism is a highly fraught and untenable philosophical position. In my opinion, the charge of vitalism in Deleuze and Guattari's work, and perhaps in my own project here of thinking with the lives of bacteria, an *in vitro* neuronal cell line, and minimal genome organisms, represents a failure to recognize the important philosophical project of reframing and reimagining life, biology, and matter.[27] In his work on Deleuzian approaches to thinking about life, John Protevi explains, "Deleuze is a machinic materialist, not a mechanist, and it is only as a reaction to mechanism that classical vitalism makes sense. It is the impoverished sense of matter in mechanism, as chaotic or passive, that creates the temptation to classical vitalism of the 'entelechy' type. . . . What we need to look for in Deleuze's notion of vitalism is the 'life' that encompasses both organisms and 'nonorganic life.'"[28]

Similarly, the idea of a body without organs can easily be misread. Indeed, Deleuze and Guattari, much like their position toward trees, on a first read appear to be "anti-organ" or anti-organism. Yet when they make such statements as "we're tired of trees" or "the enemy is the organism," they are in fact referring to their position against an arborescent model of linear and hierarchical thought.[29] In the case of the BwO, they are

commenting on how life might be better understood by "situating it within the wider field of forces, intensities, and durations that give rise to it and which do not cease to involve a play between nonorganic and stratified life."[30] Leslie Dema has suggested that by using the idea of nonorganic or inorganic life, Deleuze and Guattari are attempting to disrupt our habit of creating taxonomical and terminological breaks and that "their theory of life directly challenges the idea of organic life that we find in contemporary biology."[31]

Although the idea of organic life in contemporary biology has been greatly troubled in recent years by the arrival of synthetic biology, Dema makes another crucial point regarding the philosophical challenge that is presented to us by confronting the idea of inorganic life. She explains that the best way to understand Deleuze and Guattari's idea of inorganic life is through their concept of assemblages. Assemblages are, according to Dema, "not like organs" but instead are "animated by coding and decoding, deterritorializations, and lines of flight." She states, "Assemblages are the symbiotic or sympathetic co-functioning of heterogeneous elements. They are formed through a rapport between partial objects that enter into monstrous couplings, experimental alliances, unnatural participations, and rhizomatic structures."[32] It is certainly fitting to characterize the inorganic life that begins the synthetic life cycle as a monstrous coupling or experimental alliance. With the coming together of digital DNA, humans, DNA synthesizers, Petri dishes, bacteria, and yeast, the idea of the assemblage is useful to contextualize a life produced by synthetic biology. Furthermore, the idea of an assemblage, similar to microphysiologies of desire, provides a way to encounter and extend ourselves toward synthetic lives through the qualities of univocity and immanence, and with a methodology to consider questions of context.

According to Deleuze and Guattari, there are two types of assemblages—namely, machinic assemblages of desire and collective assemblages of enunciation.[33] While collective assemblages of enunciation work at the level of language and the symbolic, Levi Bryant explains that "when Deleuze and Guattari refer to machinic assemblages they are talking about the domain of physical objects, how they interrelate, and how they affect and are affected by one another."[34] Thinking about life in terms of machinic assemblages and material objects that come together to influence each other and connect with each other presents an alternative to thinking about synthetic

life in only mechanistic terms such as DNA synthesis and protein production. In *Germinal Lives*, Keith Ansell Pearson has suggested that the process of paying attention to machinic assemblages is a key part of Deleuze and Guattari's strategy for approaching life itself. "A 'machinic' approach, then," he states, "will not treat machines as projections of the human but rather in terms of 'monstrous couplings' involving heterogeneous components that 'evolve' in terms of recurrence and communications. . . . Humans are both component parts of a machine and combine with other forms of organic and nonorganic life to constitute a machine (or, better, machinic assemblage since there exists no isolated and monadic machine)."[35]

Reiterating the sentiment from his chapter epigraph, Ansell Pearson sees the machinic assemblage as a togetherness of organic and inorganic forms, and most important, a togetherness where the human is not left behind. By using the idea of the machinic assemblage, and by aligning ourselves with the qualities of univocity and immanence, a biophilosophy of becoming that draws from Deleuze to "think beyond the human condition" does not need to leave humans behind.[36] Deleuze and Guattari describe the assemblage as a multiplicity, and a machinic assemblage more specifically as having one side that "faces the strata, which doubtless makes it a kind of organism" and another side "facing a body without organs, which is continually dismantling the organism."[37] In other words, an assemblage can orient itself toward both molar and molecular tendencies.

In addition to being easily characterized as its own monstrous coupling, throughout its lifecycle a synthetic life demands a great deal of support from human, machine, and environmental resources. To bridge concerns over what constitutes life and living in the synthetic age of biology, with concerns over context and the role that we as humans share in sustaining these life cycles, I suggest we see ourselves and these synthetic lives as part of a machinic assemblage. One side of this machinic assemblage faces toward molar tendencies of stratification, and the other toward molecular tendencies of dis-organ-ization. While discussing Deleuzian approaches to the question of life, Protevi explains: "For Deleuze and Guattari, 'life' has a double sense, reflecting both stratification and destratification. It means both 'organisms' as a certain set of stratified beings and also the creativity of complex systems, their capacity to produce new emergent properties, new behavior patterns, by destratifying and deterritorializing."[38]

Given that so much of the emphasis has been placed on the molecular within this text, the remainder of this chapter addresses the second challenge of finding ways to consider questions of context by reflecting on those elements of the machinic assemblage that face the molar or the side of stratification. As feminist STS scholars, we may not personally have a hand in creating new lives in this synthetic era of biology. However, we can begin to see ourselves as part of a machinic assemblage that includes these synthetic lives. If indeed we do begin to see ourselves as part of such an assemblage, there is a possibility to think differently about our role within that assemblage. We need to learn how to use both molecular and molar approaches in order to live and respond to those synthetic lives that are already here among us. This is perhaps one way to become accountable for our part within an entanglement or, as Barad says, aware of our responsibilities for "that which we [have come to] inherit."[39]

Inorganic Stratum: The Central Dogma and Its Implicit Forms

In the foreword to *The Order of Things*, Foucault states: "It is not always easy to determine what has caused a specific change in a science. What made such a discovery possible? Why did this new concept appear? Where did this or that theory come from? Questions like these are often highly embarrassing because there are no definite methodological principles on which to base such an analysis. The embarrassment is much greater in the case of those general changes that alter a science as a whole."[40]

Here Foucault suggests the difficulty in tracing the factors involved in a specific change in a science, or in other terms perhaps, the birth of a new paradigm. This is true, particularly in the case of tracing how scientists have come to think about life and what constitutes the attributes of the living. In 1958, however, an important event occurred, a kind of big bang one might say, that altered the future of molecular biology and genetics.[41] This event was the formulation of the central dogma. As embarrassingly simple the following tracing of the central dogma may be, I turn to it here because of its resemblance to expressions that can be found in inorganic strata. Protevi explains that "in the inorganic strata, expression is the molarization of molecular content that is, the carrying forth

to the macroscopic scale of the 'implicit forms' of molecular interactions."[42] While the central dogma cannot be easily determined as the one and only implicit form that changed how biologists went from thinking about molecules to macroscopic organisms, it is a significant event worth remembering for its role in shifting or "molarizing" how scientists have come to think about intensive or expressive aspects of life.

The central dogma refers to the process of the unidirectional and sequential flow of genetic information originating from DNA, moving to RNA, and then from RNA to protein.[43] DNA and RNA are both biopolymers that are made of nucleic acids and are comprised of the four nucleotides adenosine, guanine, cytosine, and thymine in the case of DNA, and adenosine, guanine, cytosine, and uracil in the case of RNA. The central dogma tells us that both DNA and RNA provide the code for protein synthesis, which occurs through a two-step process. The first step is referred to as transcription, whereby DNA serves as a template for the production of single strands of messenger RNA. The idea is that the information that is coded on the DNA template is transcribed or, similar to how the term is used in computer science, is transferred from one recording system to another. This transfer of DNA code is mediated by the enzyme RNA polymerase, which works to produce a new kind of information or code—one that is in the form of a complementary and antiparallel RNA sequence. For example, an antisense strand of DNA such as 3'ATGACGGA5' is transcribed into the sense mRNA strand 5'UACUGCCU3'. This newly synthesized RNA molecule, however, is simply another messenger or a go-between, destined only to deliver the command required for gathering amino acids in the final event of protein synthesis.

This next step of the mechanism of moving from code in messenger RNA to an ultimate protein destination is referred to in the field of molecular biology and genetics as the process of translation. Translation is an important in-between process that proceeds in four phases, including activation, initiation, elongation, and termination. During these four phases of translation, a series of three nucleotide base pairs come together to create what is called a codon. Each codon is then decoded by a ribosome, and with the help of transfer RNA (tRNA) molecules, a chain of amino acids come together to form a protein. In synthetic biology, scientists make use of the metaphor of code to write or to program this code in a

specific way and thereby have a hand in directing protein biosynthesis. Interestingly, if we recall Judith Butler's concern of "What of life exceeds the model?" noted in an earlier chapter and voiced during an interview with Vicky Kirby, we can see that the metaphors and models of coding, transcription, and translation, which have been used to explain and carry out the central dogma, have long become the ontology of molecular biology and life itself—and quite productively, I might add.[44]

The central dogma in molecular biology was created and so named by the scientist Francis Crick, biophysicist and codiscoverer of DNA's molecular structure. Prior to his collaboration with James Watson, Crick had been trained as a physicist and was working on the X-ray crystallography of proteins. However, starting in the 1940s, there was immense interest and growing excitement in the field of protein biochemistry, in great part due to the work of Linus Pauling, who had also been trained as a physicist. In 1945, Pauling submitted a grant to the Rockefeller Foundation to launch a research program that was to become the field now known as molecular biology.[45] Pauling was also responsible for popularizing the application of quantum physics into chemistry, in addition to developing the practice of 3-D molecular modeling. Since Pauling's day, the practice of protein modeling has moved from plastic balls and wooden sticks to highly complex computer modeling. I mention Pauling's and Crick's common background in physics and their shared interests in the physical and mechanistic aspects of protein chemistry and the structural modeling of proteins, because of what I see as an interconnected set of events that sheds light on a dominant paradigm that currently guides the field of synthetic biology and its purchase on life and the living.

When asked why he named the process of information transfer, from DNA to RNA to protein, the "central dogma," Crick apparently admitted to his mistake and laughed at his misunderstanding of the meaning of the word "dogma." In his autobiography, *What Mad Pursuit: A Personal View of Scientific Discovery*, Crick stated:

> I called this idea the central dogma, for two reasons, I suspect. I had already used the obvious word hypothesis in the sequence hypothesis, and in addition I wanted to suggest that this new assumption was more central and more powerful. . . . As it turned out, the use of the word dogma caused almost more trouble than it was worth. . . . Many years

> later Jacques Monod pointed out to me that I did not appear to understand the correct use of the word dogma, which is a belief that cannot be doubted. I did apprehend this in a vague sort of way but since I thought that all religious beliefs were without foundation, I used the word the way I myself thought about it, not as most of the world does, and simply applied it to a grand hypothesis that, however plausible, had little direct experimental support.[46]

Crick's central dogma continues to serve as a particularly powerful structural and functional paradigm. Even with the now accepted phenomenon of epigenetics, the linearity and simplicity of the central dogma serves as a cornerstone for understanding the organization of organic life and the emergence of proteins through the processes of transcription and translation. Crick's translation of the term dogma, or shall I say "mistranslation" of the term, has had profound ontological, epistemological, methodological, and ethical impacts on how we orient ourselves while dealing with DNA, cells, and organisms in the lab. It has had a profound influence on how we think about life itself in biological terms and how molecular content is "carrying forth to the macroscopic scale."[47] Molecular biologists have relied on the central dogma to develop recombinant DNA technologies to design and bring forward new lives such as transgenic organisms. The central dogma has served, if not as a religious belief, then as a highly revered principle for many scientists. It can be argued that the paradigm of the central dogma has provided the intellectual anchor for a number of additional scientific enterprises on a global scale, including the justification for spending billions of US taxpayer dollars to fund the Human Genome Project. It has also provided the scientific authority needed to continually drive social arguments based on genetic determinism, as is evident in the rise of a new eugenics.[48]

That the term "dogma" is generally understood as that which is authoritative and not to be disputed, but is simultaneously a belief that originates without reason or evidence, is not the meaning that Crick understood in his naming of a particularly important sequence of molecular events. I argue, however, that this is exactly how the central dogma has operated and continues to operate in molecular biology and, most effectively, in the field of synthetic biology. The idea that a unidirectional, linear, and hierarchical deployment of molecules inside an organism is required for the

structure and formation of life lays the intellectual foundation for the field of synthetic biology. Synthetic biologists, who apply engineering principles to the design and creation of new life forms, were raised on molecular biology's central dogma. Since the early 1970s and the advent of recombinant DNA technologies, scientists have been working on altering life forms. They have been guided by the central dogma but have also been taking advantage of the fact that DNA can be cut or digested with restriction enzymes, altered through the insertion of a foreign or synthetically produced piece of DNA, and then ligated back together. For instance, for decades now, molecular biologists have designed and used transgenic or knockout animals to understand the biological basis of human diseases. These animals have been designed to contain mutations in a specific gene, contain a completely "foreign" gene, or have a gene completely deleted in order to study a gene's function and correlation to human disease.

However, many molecular biologists have grown weary of the arduous hit-and-miss techniques of recombinant DNA technologies. These scientists are turning to the new tools of synthetic biology to study the material processes of biology. For synthetic biologists who see themselves as bioengineers, the beauty and simplicity of the central dogma lies in the fact that molecules such as DNA, and in turn molecular life, can exist in an inorganic form as a language or computer code. Instead of having a binary code of 1's and 0's used in computer processing, the main biological components of life are thought to be comprised of the four letters A, G, C, and T. The BioBricks Foundation, for instance, literally stores DNA as a code, and thousands of inorganic gene cassettes can be transferred onto a computer hard drive, in the form of magnets and megabytes. The foundation's goals are to make DNA (as inorganic and digital code) accessible to everyone and, as a result, create a better world through biology. The foundation's website explains:

> Biology is everywhere. And matters to everyone. It affects our food, medicines, homes, and environment. Yet people are not working well together as partners with biology. BioBricks Foundation believes in a future where there is a free-to-use language for programming life that benefits everyone. A future where people around the world communicate and collaborate to create local biological solutions to meet global

> needs. When people are inspired to work in partnership with biology this future is possible. When people have the tools and infrastructure to work with one another, we can meet global needs for food, medicines, shelter, clean water and air.[49]

In an effort to create such tools, there are three main ways of applying engineering principles to the material reconstruction of DNA—namely, the bottom-up, the top-down, and the pathways approaches.[50] The research of a few prominent synthetic biologists, whose work represents diverse interests in the field, is discussed briefly here to reveal the logic behind each of these three approaches.

The bottom-up or "parts-based" approach to creating synthetic life can be characterized by the work of Drew Endy, a civil and biochemical engineer, previously at MIT and currently at Stanford University. Endy, who is pushing for the creation of an open-source platform for genetic biotechnology, is the founder and president of the not-for-profit BioBricks Foundation. His bottom-up approach is based on forward engineering or the idea that DNA can be broken down into separate entities or cartridges that can then be used to deliberately assemble a specifically fashioned or desired biological product. Endy states:

> Consider that most early discoveries of genetically encoded functions depended on analysis of the linkage between natural or randomly generated mutations and phenotypes, a powerful approach akin to blindly smashing many cars with a hammer and then determining which broken parts matter by attempting to drive each machine. Over the past 30 years, the invention and development of DNA sequencing technology have provided a complementary approach for discovering genetic functions. . . . However, two additional approaches are needed to confirm and exhaustively identify all functions encoded by a natural DNA sequence. Specific DNA sequences thought to affect phenotypes must be purposely changed and the expected effect confirmed. Also, seemingly irrelevant DNA sequences must be removed, disrupted, or otherwise modified and shown to be unnecessary. . . . Going forward, the ability to implement many simultaneous and directed changes to natural DNA sequences and to build and test synthetic systems will give researchers a powerful new "hammer" for constructing how life works.[51]

Alternatively, the top-down approach is led by entrepreneur and geneticist J. Craig Venter, whose work is discussed in greater detail below. In contrast to the bottom-up approach, Venter's top-down approach can be summarized as starting with full genomes and then scaling them down to a minimal size, such as in the case of the minimal genome used to create the first minimal synthetic bacterial cell.[52] This approach has been described as being modeled upon a "plug-and-play" set of functions.[53] The last approach, roughly named the pathways approach, is illustrated by the work of Jay Keasling, professor of chemical engineering and bioengineering at UC Berkeley and associate director of the Lawrence Berkeley National Laboratory. Keasling's work, utilizes a pathways or problem-driven approach and opts for the use of any and all engineering approaches that make the modification of DNA more practical and cost-effective.[54] Regardless of their technical differences, what we are witnessing in this stage of the synthetic life cycle and from this particular orientation of the machinic assemblage is, as Protevi has called it, the "molarization of molecular content."[55] Each of these approaches falls in line with the workings of the inorganic stratum. We can see here exactly how far an implicit form, by way of the central dogma, has shaped and produced our knowledge regarding how molecules interact and how molecular structures can come together to form synthetic macromolecules. This implicit form has given birth to synthetic life.

Organic Stratum: Minimal Lives Respond to Problems

In *The Politics of Life Itself*, Nikolas Rose posits the politics of "life itself" as the vital politics of our time. He is concerned with the growing capacities to "control, manage, engineer, reshape, and modulate" the vital capacities of human beings as living creatures.[56] Defining the idea of vital politics he wishes to put forward, Rose describes what he calls a major shift in biopolitics today compared to the first half of the twentieth century. He suggests that recent developments in molecular biology have led to the phenomena of a "molecular vision of life."[57]

Rose is concerned with tracing an emergent form of life and biopolitics that foreground the human, but I argue that synthetic biology requires us to trace a different concept of "life itself" as it relates to the emergent capacities of nonhuman minimal genome organisms. The concept of "life

itself" that must be applied here relates not only to the organic bacterial "surrogates" that are part of the machinic assemblage but also to inorganic life and minimal genomes that come together to form synthetic life. If any life can be said to have gone through the phenomena of a "molecular vision of life," bacteria would have to be at the very top of this list.[58] The step-change in life that Rose argues we as humans have experienced is simply a change in scale, from whole organisms to the molecular parts of whole organisms. This change in scale is shadowed by the step-change that has occurred at the level of bacterial microorganisms. The step-change in life that I am referring to has occurred at the level of type, not scale. It is a step-change at the level of type because with the advent of synthetic biology, the definition of "life itself" is being shifted from an organic life contained within an organism, to an inorganic life that begins without organs, can be dis-organ-ized, and is comprised of code. Therefore, in addition to attending to what Rose sees as the extended reach of contemporary biopolitics and a "molecular vision of life itself," this step-change at the level of type forces us to appreciate the *expressive life of a molecule itself*, as synthetic biologists have already done.

If we approach the expressive life of a molecule as a machinic assemblage, we can begin to align our curiosities along the qualities of univocity and immanence. Returning to the work of Deleuze and Guattari, we can think about the second phase of the synthetic life cycle as facing the organic stratum, where "expression becomes autonomous in the linear genetic code, which results in greater deterritorialization (greater behavioral flexibility) of organisms."[59] As Sara Dawn Eimer has described it, the organic stratum is where "the form of a line of DNA, *itself molecular* . . . operates upon other molecules to produce the 'molar' entity, the organism."[60] In synthetic biology, entire genomes have been created through the top-down method of molecular manipulation.[61] These genomes are minimal in the sense that they have been designed to contain the minimum number of genes required for bacterial cell viability and growth.[62]

Minimal genomes may contain the minimal number of genes required for a cell to grow and replicate, but they still require other nonchromosomal elements for these genes to be transcribed and translated into proteins. The process of inserting a minimal genome into a "host" or "surrogate" bacterial or yeast cell whose own genome has been removed is referred to as "genome transplantation."[63] For example, the newly arrived

"minimal synthetic bacterial cell" created by the J. Craig Venter Institute is comprised of a synthetic minimal genome that is based on the genome of the bacteria *Mycoplasma mycoides* but has been transplanted into the bacteria *Mycoplasma capricolum* whose genome, in turn, has been removed.[64] Through the process of genome transplantation, we see the coming together of a genetically engineered minimal genome or line of DNA and a surrogate cell. This allows the machinic assemblage to shift its orientation from the inorganic stratum to the organic stratum, moving it from the form of a line of DNA to a molar entity that can be identified as an organism. The minimal genome becomes a minimal genome organism thanks to its surrogate.

It is precisely due to their capabilities of replicating DNA, transcribing DNA, and translating RNA into proteins that bacteria and yeast have long been perceived as potential surrogates or machines in molecular and synthetic biology. For instance, in 2012 a team of synthetic biologists based out of the University of Nottingham announced their intention to create an operating system for new cellular life forms. Their project—named Towards a Universal Biological-Cell Operating System (or AUdACiOuS for short)—was supported through a $1.58 million grant awarded by the Engineering and Physical Sciences Research Council in the UK. This project treated *E. coli* as an "information processing machine."[65] It was aimed at creating a line of bacterial cells that contained the minimal requirement of components to stay alive, but that could easily be programmed to execute specific functions through protein biosynthesis. Natalio Krasnogor, the primary scientist on this project, summarized the research as follows:

> A living cell, e.g. a bacterium, is an information processing machine. It is composed of a series of sub-systems that work in concert by sensing external stimuli, assessing its own internal states and making decisions through a network of complex and interlinked biological regulatory networks (BRN) motifs that act as the bacterium neural network. A bacterium's decision making processes often result in a variety of outputs, e.g. the creation of more cells, chemotaxis, bio-film formation, etc. It was recently shown that cells not only react to their environment but that they can even predict environmental changes. The emerging discipline of Synthetic Biology (SB) considers the cell to be a machine

> that can be built—from parts—in a manner similar to, e.g., electronic circuits, airplanes, etc. SB has sought to co-opt cells for nano-computation and nano-manufacturing purposes. During this leadership fellowship programme of research I will aim at making *E. coli* bacteria much more easily to program and hence harness for useful purposes. In order to achieve this, I plan to use the tools, methodologies and resources that computer science created for writing computer programs and find ways of making them useful in the microbiology laboratory.[66]

Sophia Roosth has also discussed the capabilities of microorganisms—namely, the ability of yeast to scream.[67] Although Roosth does not refer specifically to synthetic yeast, she argues that scientists who work with the technique of sonocytology on yeast species such as *Saccharomyces cerevisiae* make a distinction between yeast cellular signaling and so-called baseline or background noise by approaching yeast cells as "subjects capable of speaking to their conditions."[68] Despite the fact that these scientists treat bacteria as machines, they also note the wide range of capabilities that bacteria have, including the capacity to react or respond to their environment. In the organic stratum we start seeing self-organization and that "life responds to problems by experimenting with different kinds of solutions."[69] As it turns out, synthetic organisms show indications of having behavioral flexibility and problem-solving skills.[70] The problem is that they need to learn how to cooperate with one another.

Maitreya Dunham has raised a crucial aspect of this phase of the synthetic life cycle in her commentary "Synthetic Ecology: A Model system for Cooperation." She writes:

> Synthetic biology offers the promise of a better understanding of biological systems through constructing them. Unlike naturally occurring biological systems, which are generally complicated by multiple variables and difficult to isolate components, synthetic systems can be simplified to allow for experiments that would be too difficult to interpret if done in their full natural context. Up to now, synthetic biologists have primarily focused on gene circuits . . . [learning] more about the rules of gene expression and regulation, including fundamental issues regarding noise, timing, and signal fidelity. In this issue of PNAS, *Shou et al.* demonstrate an example of a new direction for synthetic biology, what

might be called synthetic ecology. Rather than using gene modules as building blocks, they mix cell populations to construct a synthetic simple obligatory cooperative ecology.[71]

Our understanding of biology has come to this. Lives that exist as "naturally" occurring systems are far too complicated. However, even though these systems can be simplified through synthetic biology, once they are created, they need to be able to respond to the problem of how to cooperate with each other in order to live in a broader ecology.

Scientists, and particularly molecular biologists, have used the linearity of the central dogma alongside the principles of reductionism to gather more details about the natural world. With synthetic biology, however, we are witnessing something new. What we have here is an ontological premise based on reductionism (DNA, RNA, and proteins) and linearity (transcription and translation) that has gone so far into itself that it has nowhere else to go but back out, sending out new lines of flight. It turns out that in order to survive and thrive, synthetic lives such as minimal genome organisms need to be able cooperate with one another and build themselves back up again, molecule by molecule, in an environment-dependent and context-ridden "natural" world. Computational biologist Wenying Shou and colleagues argue that in the context of synthetic biology, "cooperative interactions are key to diverse biological phenomena" and that "such diversity makes the ability to create and control cooperation desirable for potential applications in areas as varied as agriculture, pollutant treatment, and medicine."[72]

Recognizing the importance of cooperation, Shou and colleagues show that "persistent cooperation can be engineered."[73] They state: "Specifically, we report the construction of a synthetic obligatory cooperative system, termed CoSMO (cooperation that is synthetic and mutually obligatory), which consists of a pair of nonmating yeast strains, each supplying an essential metabolite to the other strain. . . . Extending synthetic biology from the design of genetic circuits to the engineering of ecological interactions, CoSMO provides a quantitative system for linking processes at the cellular level to the collective behavior at the system level, as well as a genetically tractable system for studying the evolution of cooperation."[74] Linear thinking and reductionism have run their course, bringing us full circle. It turns out that synthetic organisms themselves are asking

scientists to consider Butler's question, "What of life exceeds the model?"[75] Answering this call presents an opportunity for feminist scientists and feminist STS scholars. It invites us to consider what our responses will be, and what our encounters with these organisms will look like, when we realize that synthetic lives become expressive lives, capable of developing the quality of changefulness and desires for kinship.

Alloplastic Stratum: Deterritorializations through Postcolonial and Decolonial STS

In *Life as Surplus: Biotechnology and Capitalism in the Neoliberal Era*, Melinda Cooper examines how the biotech revolution of the 1970s and early 1980s shifted economic production to the genetic, microbial, and cellular level.[76] She argues that the transformation of biological life, including bacterial life, into surplus value is at the core of the new postindustrial economy. I am interested in extending Cooper's astute analysis of bacterial life and labor and other social, political, and economic factors to our own machinic assemblage. Postcolonial and decolonial STS can help to reframe synthetic biology along the social or alloplastic stratum. In particular, I am interested in using postcolonial and decolonial STS analyses to ask how, for example, are humans and nonhumans being organized to "manage the problems" posed by synthetic lives?[77] How, and from where, are the vast amounts of biomass that are required to support synthetic lives being obtained? The last phase of the synthetic life cycle progresses to a social phase that requires a great deal of support from both human and nonhuman systems and resources. New forms of labor and production are emerging as a result of these synthetic lives. I am interested in tracing those stories that shed new light onto our machinic assemblage, which up until this point has been comprised of various components, including humans, machines, digital DNA, minimal genomes, bacteria, yeast, and surrogate cells. As I explore this stratum, I analyze our machinic assemblage for its monstrous couplings with an STD, sugarcane plantations, and the Sargasso Sea.

The postcolonial and decolonial STS projects of thinking about "knowledge that is otherwise" and "reframing" biotechnological events resonate with new lines of flight that can form within Deleuze and Guattari's social or alloplastic stratum. In particular, the goal to actively "decolonize

relations and practices" works hand in hand with Deleuze and Guattari's idea of deterritorialization.[78] Using the alloplastic to describe social institutions and behavior that are human but not limited to the human, Deleuze and Guattari write:

> There is a third major grouping of strata, defined less by a human essence than, once again, by a new distribution of content and expression. Form of content becomes "alloplastic" rather than "homoplastic"; in other words, it brings about modifications in the external world. Form of expression becomes linguistic rather than genetic; in other words, it operates with symbols that are comprehensible, transmittable, and modifiable from outside. What some call the properties of human beings—technology and language, tool and symbol, free hand and supple larynx, "gesture and speech"—are in fact properties of this new distribution.[79]

The alloplastic therefore is seen as a social or cultural stratum that creates new forms of content and expression. Aligning our analysis of a technology along the alloplastic stratum can be useful to understand how a machinic assemblage is working to modify the external world. In the case of content, we have those monstrous couplings that bring together several different kinds of physical bodies. In the case of forms of expression, we have new forms of technology, tools, and language used by humans (but not limited to humans) that also work to modify the external world that are a result of similar assemblages.

For example, we can begin to map those sides of the machinic assemblage that face new economies of biocapital that have become possible through the labor and protein-production capacities not only belonging to minimal genomes organisms but also to those humans whose labor supports synthetic life. We can begin to take account of how this labor can be contextualized along colonial histories of plantation-based economies or recent forms of biopiracy. We can begin to approach new forms of expression created by this machinic assemblage through critiques of scientific imperialism and liberal humanist notions of individualism as they relate to synthetic biology. Since it is also in the alloplastic stratum that expression becomes most independent from content, allowing for the greatest amount of deterritorialization, we are further able to contextualize, resituate, know otherwise, and reframe these events

through other symbolic means, such as through the expressivity found in our stories and literature.[80]

Vignette 1: STDs

To begin, we can examine how the minimal genome organism brings with it a new genesis story. In January 2008 a team of seventeen scientists at the J. Craig Venter Institute (JCVI) in Rockland, Maryland, announced that they had successfully created the first synthetic bacterial genome.[81] Using the top-down approach and a variety of genetic engineering techniques, including *in vitro* recombination, cloning, PCR, *in vivo* recombination in yeast, and "shotgun" sequencing, Venter and his colleagues synthesized, assembled, and cloned the complete bacterial genome referred to as *Mycoplasma genitalium* JCVI 1.0. In 2016, Venter and his colleagues produced the even more streamlined version of the minimal bacterial genome referred to as JVCI-syn3.0, which contains only 531 kilobase pairs coding for 473 genes.[82] Interestingly, members of the Action Group on Erosion, Technology, and Concentration (ETC), an organization that analyses the socioeconomic ramifications of new technologies and is dedicated to the sustainable advancement of ecological diversity, referred to JVCI-syn1.0 as the "original syn." They have since dubbed JVCI-syn3.0 as Synthia 3.0.[83] Given Venter's previous ventures, we should have known that this day was coming.

In 1984, Venter held a position at the National Institutes of Health, where he began to work on a new technique for rapid gene discovery. He takes credit for developing a DNA sequencing technique referred to as expressed sequence tags (ESTs). In his biography on the JVCI website, it is suggested that in 1995 the ESTs technique led him to decode the genome of the first free-living organism using his new whole genome shotgun technique.[84] This was not the end for Venter and his biotechnological ambitions.[85] In fact, Venter actually traces his move toward synthetic biology to 1995, when he sequenced *Haemophilus influenza*. This genome was found to have about 1,800 genes. The same year, Venter collaborated with other scientists to work on the bacterium *Mycoplasma genitalia*. This bacteria was chosen because it has the smallest "naturally occurring" genome of any self-replicating organism, with only about 482 protein coding genes and approximately 580 kilobases.[86] However, some of us may find it extremely interesting to know that *Mycoplasma genitalia*, the "original"

organism from which Venter's transformed minimal bacterial genome organisms are based, is a bacteria that causes a sexually transmitted disease (STD) in humans, known to lead to pelvic inflammatory disease (PID) in women. PID is a "major public health problem associated with substantial medical complications (e.g., infertility, ectopic pregnancy, and chronic pelvic pain) and healthcare costs."[87] In men, *Mycoplasma genitalia* is the "third most frequent pathogen causing non-chlamydial, non-gonococcal urethritis."[88]

Why would Venter choose a bacterial organism, known to cause a debilitating human disease that likely affects already vulnerable populations disproportionately, to serve as the biological backbone for the first synthetic life? From postcolonial and decolonial perspectives, we can see neoliberal and capitalist strategies at work. In this business model the concern over whether a minimal genome organism derived from a STD-causing bacteria poses a health concern to already economically and politically vulnerable groups is overshadowed by the speculative futures promised by synthetic biology. Referring to the growth of the pharmaceutical industry and the AIDS epidemic in Africa, Cooper explains that "one could go further along these lines and argue that the simultaneity of the North American–led biotech revolution and the troubling return of infectious disease of all kinds, in both the developing world and advanced capitalist centers, is symptomatic of the intrinsic contradictions of capitalism. The peculiarity of capitalism on this argument would lie in its tendency to create both an excess of promise and an excess of waste, or in Marx's words, a promissory surplus of life and an actual devastation of life in the present."[89] As a modern technoscience of the global North, the possible futures that have been promised by synthetic biology include biotechnologies of personalized biomedicine, bioremediation, and bioenergy applications. These technologies are primarily geared toward already well-resourced groups, and apparently their potential benefits outweigh the risk associated with the possible spread of a minimal genome organism that is STD-adjacent.

Vignette 2: Sugarcane Plantations

In 2004 the Bill and Melinda Gates Foundation donated $42.6 million to fund Jay Keasling's research on developing a synthetic antimalarial drug.

A proponent of the pathways approach, Keasling and his partners at the biotech startup Amyris (a not-for-profit at the time) went to work using *E. coli* and brewer's yeast to design a microbial cell whose metabolic pathways could be manipulated to incorporate the production of artemisinic acid, the precursor of the compound artemisinin.[90] Originally extracted from the plant *Artemesia annua* found mostly in China and southeast Asia, artemisinin has been the favored antimalarial drug for several years now due to the fact that plasmodium parasites have become resistant to quinine- and chloroquine-based treatments.[91] The reported problem back in 2005, when Keasling was conducting this research, was that plant-derived artemisinin was in "short supply and unaffordable to most malaria sufferers."[92] The tools of synthetic biology were supposed to fix this problem.

In 2006, Keasling and his team reported that they were successful in engineering the yeast *Saccharomyces cerevisiae* to produce high titers of artemisinic acid through the process of fermentation.[93] However, it was not until 2013 that they were able to report the production of "commercially relevant concentrations" of artemisinic acid.[94] The key limiting factor had been the ability to sustain the growth and fermentation of the synthetically modified brewer's yeast at an industrial level.[95] Since then, Amyris has become a private for-profit company, and using the technologies and expertise gained by having to produce semisynthetic artemisinin at industrial levels, they have expanded the applications of their synthetic microbial engineering model to include mass-scale production of cosmetics and biofuels. They have designed a synthetic yeast cell to produce high levels of the molecule farnesene, which "has many potential applications as a renewable feedstock for diesel fuel, polymers, and cosmetics." [96] Fermentation in yeast species such as *Saccharomyces cerevisiae* is a metabolic process that converts sugars and starches into acids, gases, and alcohol. However, in order to carry out industrial levels of yeast fermentation, one also needs industrial amounts of sugar and starch-based biomass for the desired metabolic processes to occur. Therefore, while entering the market of cosmetics and biofuel production, Amyris also purchased sugarcane fields in Brazil to carry out their mass-scale operations.

As a global leader in biofuel production, Brazil has been producing ethanol-based biofuel from sugar and sugarcane-derived biomass for several decades. Amyris decided to develop its own farnesene manufacturing facilities by using the country's already well-established sugarcane

production infrastructure. As such, the company acquired portions of existing sugarcane fields as well as new feedstock facilities that are adjacent to existing sugarcane mills, such as in the municipality of Brotas, in São Paulo, Brazil. Adrian MacKenzie explains:

> The Brazilian sugar-cane industry is the largest producer of sugar in the world. Rather than producing ethanol through the long-established industrial techniques of fermentation, some of the Brazilian sugar-cane will become something different in Amyris' bolt-on bioreactors at Usina São Martinho in Brazil. The years of metabolic engineering that Keasling's team put into the isoprenoid pathway in yeast pays dividends now in the form of a usefully transformable chemical, farnesene. The millions of tons of sugar cane moving through Usina São Martinho no longer simply ferment as ethanol, the biofuel that Brazil has produced in quantity since the 1970s. Via Amyris' re-engineered yeast strains, the chemical substrates present in sugar will be re-routed as feedstock for a much more complicated and efficient metabolic pathway, the melavonate or "HMG-CoA reductase pathway."[97]

Drawing on the philosophical work of Gilbert Simondon, MacKenzie conducts a rich analysis of biofuel, treating it as a technical object whose "genesis involves processes of concretisation that negotiate between heterogeneous geographical, biological, technical, scientific, and commercial realities."[98] I would add to this list of realities the colonial histories of sugarcane plantation–based capitalist economies, the indigenous peoples who were displaced or killed by European settlers, and the labor and bodies that were organized by this economy.

Brazil, like many other countries in the Caribbean and Latin America, experienced its first wave of European colonial expansion soon after Christopher Columbus returned from his initial voyage to the "new world." In fact, the earliest record of large-scale sugar production goes back to 1550, when the Portuguese built mills along the Atlantic coast of Brazil.[99] Caribbean scholar Fernando Ortiz discussed the politics of tobacco and sugar production in Cuba in his influential work *Cuban Counterpoint*, and his analysis of the European establishment of sugar plantations as a strategy for economic claims to the colonies can be extended to Brazil. Ortiz explains:

> It is one thing to have cane and another to produce sugar on a commercial scale. Between the raising of the cane, which experience had shown to be merely a question of man power, and the commercial production of sugar, which in Europe had a steady and growing market, stood the problem of industrial production, which demanded machinery and technicians that did not exist here, and of necessity had to be imported from Europe. In a word, capital was needed to buy slaves, to bring in experts and skilled workers and all the machinery for milling, boiling, evaporating, and refining. Even aside from the land required, the production of sugar was perforce a capitalist enterprise.[100]

Postcolonial and decolonial analyses encourage us to probe what the effects of sugarcane production were not only on the local indigenous populations in Brazil but also on the slaves who were brought from Africa over a period of roughly three hundred years to sustain the industrial production of sugar. What modifications to the external world were caused by the machinic assemblage that was, at the time, a monstrous coupling of sugarcane plantations, mills, slaves, and sugar? What were its effects on the lives of individuals who had been displaced by slavery? Ortiz describes the effects of displacement and the backbreaking labor in those sugar plantations:

> At the same time there was going on the transculturation of a steady human stream of African Negroes coming from all the coastal regions of Africa along the Atlantic, from Senegal, Guinea, the Congo, and Angola and as far away as Mozambique on the opposite shore of that continent. All of them snatched from their original social groups, their own cultures destroyed and crushed under the weight of the cultures in existence here, like sugar cane ground in the rollers of the mill . . . [they] brought with their bodies their souls, but not their institutions nor their implements. . . . They arrived deracinated, wounded, shattered, like the cane of the fields, and like it they were ground and crushed to extract the juice of their labor.[101]

Given the wealth that was generated by slave labor in the sugarcane plantations, it is no surprise that Brazil was the last country to abolish slavery in the Americas.

Although I am no way suggesting that Amyris's new sugarcane mills that produce semisynthetic cosmetics and biofuels employ slave labor in their fields, maintaining the sugarcane crops and operating the fermentation plants must involve the extraction of local human labor. Even if much of the processes are now mechanized, a machinic assemblage that brings together a monstrous coupling of sugarcane fields, mills, laborers, sugar, and synthetic yeast organisms is still an assemblage that modifies the external world—namely by organizing the bodies and cultures of specific humans. It is important that the history of labor practices and worker conditions associated with sugar and sugarcane-derived biomass in Brazil and other countries not be forgotten.[102] These histories can be used to better understand the effects incurred by the practices of transnational companies such as Amyris and the naturalization of similar capitalist practices. For instance, in her efforts to create anticapitalist transnational feminist practices, Chandra Talpade Mohanty asks us to bring forward the question of native or indigenous struggles in our analyses. "Economically and politically," she writes, "the declining power of self-governance among certain poorer nations is matched by the rising significance of transnational institutions such as the World Trade Organization and governing bodies such as the European Union, not to mention for-profit corporations. . . . [T]he hegemony of neoliberalism, alongside the naturalization of capitalist values, influences the ability to make choices on one's own behalf in the daily lives of economically marginalized as well as economically privileged communities around the globe."[103]

As we think about the sugar and sugarcane biomass needed for the production of malaria drugs, cosmetics, and biofuels by synthetically developed microorganisms, we should keep in mind that our decisions regarding the development and commercialization of new technologies and products for consumption will have local and global impacts. We must also keep in mind that many of these decisions are being made without input from the people whose lives will likely be disproportionately impacted. As ETC spokesperson Jim Thomas has pointed out, we live in an unjust world and if we want to develop technologies that are not going to add to this injustice, synthetic biologists need to realize that marginalized communities must have a say in what comes to constitute their reality.[104]

Vignette 3: The Sargasso Sea

Interdisciplinary scholarship is a fantastic place for discovery, but sometimes ideas can easily get lost—a bit of a scholarly Bermuda Triangle one might even say. With this admission, I end this chapter by moving quickly into muddier waters, to the Sargasso Sea in particular, with the hope that our machinic assemblage doesn't get marooned. Despite its reportedly weak currents and calm winds, the Sargasso Sea located in the North Atlantic Ocean is a busy place, playing host to the imaginations of colonial explorers, novelists, postcolonial theorists, marine microorganisms, pirates, biopirates, and synthetic biologists. Like the floating beds of sargassum seaweed, after which the sea is named, entanglements come easily here. Here, our machinic assemblage is oriented to face the alloplastic stratum, where postcolonial and decolonial perspectives help us to reflect on synthetic life and the emergence of neoliberal forms of individualism and imperialism.

In 2004, J. Craig Venter and colleagues published the article "Environmental Genome Shotgun Sequencing of the Sargasso Sea" in the prestigious journal *Science*. Using his personal yacht, the *Sorcerer II*, Venter and his team had taken sail a few years earlier and applied the whole-genome shotgun sequencing technique to "microbial populations collected en masse . . . from seawater samples collected from the Sargasso Sea near Bermuda."[105] Funded largely by the US Department of Energy as well as the Discovery Channel, Venter and his team of scientists set sail again aboard the *Sorcerer II* in 2009, this time with the intention of traveling around the globe, collecting more marine microbial samples.[106] Why this interest in marine microbes? Similar to the scientists at Amyris, Venter and many others saw the promise of using synthetic organisms to produce biofuels. However, instead of using brewer's yeast and *E. coli*, in Venter's case the synthetic powerhouse he had in mind for the job of biofuel production was a marine microbe, particularly a microalgae. This microalgae-based future was full of so much promise that in 2009 the oil and gas giant ExxonMobil partnered with Venter's startup Synthetic Genomics Incorporated and contributed $600 million to jumpstart synthetic biofuel research.

Since the 1970s, scientists have been experimenting with different strains of microalgae to take advantage of their ability to produce lipids,

which can be transformed into biofuels. The main stumbling block for these scientists has involved finding a microalgae that can photosynthesize "efficiently" enough to convert light energy and CO_2 into industrial levels of biomass and lipid production.[107] In 2017 it was announced that the collaboration between ExxonMobil and Synthetic Genomics had finally led to the creation of a synthetically engineered and phototropic strain of microalgae (*Nannochloropsis gaditana*) that would overcome these barriers. As the scientists of this joint venture explain in an article published in *Nature Biotechnology*, they developed a CRISPR-Cas9 reverse-genetics pipeline and used it to identify and modulate expression of a lipid regulator in *N. gaditana*, increasing its lipid production to commercially relevant levels. They state: "Using a microalga to produce lipids offers the potential advantages of being able to phototropically convert CO_2 to lipids without relying on agriculturally derived sugars, thus mitigating the demand for arable land and freshwater. Our findings represent a step toward understanding and controlling lipid production in algae. This ability to control algal lipid production might eventually enable the commercialization of microalgal-derived biofuels."[108] Cofounder, chairman, and co–chief scientific officer of Synthetic Genomics, Venter adds that "the SGI-ExxonMobil science teams have made significant advances over the last several years in efforts to optimize lipid production in algae. This important publication today is evidence of this work, and we remain convinced that synthetic biology holds crucial answers to unlocking the potential of algae as a renewable energy source. We look forward to continued work with ExxonMobil so that eventually we will indeed have a viable alternative energy source."[109]

While we learn about the promises of synthetic algae serving as a source of biofuel that meets our growing needs for alternative energy sources, we also witness the intimate partnering or placing together of synthetic biology research and a giant transnational oil and gas company.[110] Some of us may be reminded of the Exxon *Valdez* oil tanker spill in 1989 and the environmental disaster that occurred in the waters off the coast of Prince William Sound, Alaska. Some of us may also remember the devastating effects of this environmental disaster on local wildlife and the economic effects that were felt by local indigenous communities in the area. Postcolonial and decolonial STS analyses urge us to recall this history as we attempt to reframe current microbe exploration and synthetic

biofuel research that is being supported by ExxonMobil. We may begin to see a pattern of imperialist practices that include the impulses to explore "uncharted" spaces and to claim direct access to or ownership over natural resources in a faraway land—biopiracy by other means.

In this light, the vision of Venter sailing in his luxury yacht in the waters of the Sargasso Sea, collecting samples of microalgae to sequence their DNA, begins to look less like a journey of basic scientific inquiry into the evolution of marine life and more like the voyage of a venture capitalist who is shoring up promissory futures by gathering DNA samples and data from microbial life forms. Although patent applications were submitted for his two minimal genome organisms, Venter claims that he is not interested in patenting the microbial genome sequences obtained from the Sargasso Sea. Indeed, the strategy that he and others have developed is not to place a patent on the "natural" genome sequence of an organism itself. This information is entered into public databases such as the National Institutes of Health's GenBank. Rather, a patent is taken out on the tools and technologies developed to design and engineer synthetic genome organisms based on these "natural" organisms.[111]

Venter has gone so far as to chastise the governments of poorer countries who share the waters of the Sargasso Sea such as Bermuda for voicing concern over Venter's collection of water and soil samples from within their national coastal borders. In an interview with *Discovery Magazine*, Venter stated:

> Most of the ocean is claimed by one or more countries. A lot of politics is building up around this thing. So now we're evil because we're putting data in the public domain. A group of people who are following everything we do is putting out a lot of false information. You go on to some Web sites, and they say we're trying to patent everything. [Interviewer: Are you?] No, and that's the ultimate irony. We're doing the stuff and giving it to the world, and now it's evil because all these poor little countries like Bermuda want to profit somehow from this data. They don't realize that they can profit from the knowledge. I think people just like to attack what we're doing because we're always on the leading edge.[112]

It is unclear what the distinction is that Venter is trying to make by chastising so-called "poor countries" for wanting to profit from the data when

Venter's own privately held company Synthetic Genomics is poised to profit enormously from the commercial applications made possible by the very same data.

In an interview with *Bio-IT World*, Venter was reported to have said: "It was a big surprise to me that there's very little international waters left. I thought I was out sailing free in the ocean and somebody's claimed it all."[113] Venter's desire to sail free into the Sargasso Sea, and to sequence the genome of all the organisms he could find, paints a familiar picture of neoliberal forms of imperialism and individualism. In 2007, Venter took pride in this individualism while appearing on the talk show *The Colbert Report* to promote his book *A Life Decoded: My Genome, My Life*. Having unveiled his own genome sequence and made it publicly available on the internet, Venter said, "I think we found that we're far more different than each other than we thought even a few years ago. We're 1 to 2% different instead of one letter out of a thousand base pairs. We don't all have the same genes—we have major differences. As an individualist, I find that very encouraging."[114] Venter sees himself as an individualist and is delighted to have discovered that humans are more different from each other, by an entire order of magnitude. Basically, he is happy to announce that he is even more different from his human others than he previously thought. This understanding of difference is motivated by individualism and is not the proliferative difference found in Deleuze's ontology of univocity. Postcolonial and decolonial STS analyses would have us consider what the consequences will be of this newer version of an old worldview, whereby the white male human subject gets to distance himself even further from his human others, let alone the nonhuman synthetic others that he creates.

Years ago, in her essay "Three Women's Texts and a Critique of Imperialism," Gayatri Spivak also took us on a voyage to the Sargasso Sea. Writing about the crucial role of imperialism in the "cultural representation of England to the English," she directed us to the novel *Wide Sargasso Sea* (1966) written by Jean Rhys, as well as Charlotte Bronte's *Jane Eyre* (1847) and Mary Shelley's *Frankenstein* (1818), to argue that the "project of imperialism has always already historically refracted what might have been the absolutely Other into a domesticated Other that consolidates the imperialist self." Spivak wrote this article mainly as a

postcolonial critique of nineteenth-century English literature that promoted feminist individualism; however, she also pointed out that the continued success of the imperialist project is due to it being "displaced and dispersed into more modern forms."[115] When Spivak published this piece in 1985, I don't think she was thinking about synthetic biology, minimal genome organisms, or the production of biofuels by nonhuman, nonanimal, marine microbes in the Sargasso Sea as modern forms of the imperialist project. But who knows, perhaps she was, for the imperialist project that Spivak describes in the three novels above speaks surprisingly well to the neoliberal practices being co-constituted with synthetic biology today.

For instance, in *Wide Sargasso Sea*, Rhys tells us the story of a white Creole woman from Jamaica. The novel delivers the untold story of Bertha Mason, the "mad" West Indian woman in Bronte's *Jane Eyre* who is locked up in her husband's house in England but in the end manages to escape, burn down the house, and take her own life. Born in Dominica in 1890, and being of white Creole descent herself, Rhys saw the injustice being played out in Bronte's literary treatment of Caribbean women through the character depiction of Bertha. *Wide Sargasso Sea* is written as a prequel to *Jane Eyre* and tells the heart-wrenching story of Antoinette (renamed Bertha) Mason's life, with a backdrop in a time and place when the emancipation of slaves was under way in the British colonies of both Jamaica and Dominica. Rhys's novel, in its own way, addresses the cost of British imperialism on human lives by attempting to give a voice to the other within Bronte's text. In her critique of *Wide Sargasso Sea*, however, Spivak suggests that the story of Antoinette, presented as the unwritten story of a white Creole woman, in fact "reinscribes" the weighty absence of the other in Bronte's *Jane Eyre*. "As the female individualist, not-quite/not-male, articulates herself in shifting relationship to what is at stake," Spivak writes, "the 'native female' as such (within discourse, as a signifier) is excluded from any share in this emerging norm."[116]

Much in the same vein that Antoinette or Bertha's story is absent in *Jane Eyre*, Spivak notes that "Christophine's unfinished story is the tangent" in Rhys's *Wide Sargasso Sea*.[117] In the novel, Christophine is a black woman from Martinique who practices obeah, was given to Antoinette's mother as a wedding gift, and serves as Antoinette's nurse. Although

Christophine's character is given a crucial role in the novel, much like Bertha in Bronte's text, Christophine disappears in *Wide Sargasso Sea* after confronting Antoinette's husband, who embodies the mission of British imperialism. There is a distinction to be drawn, however, in the disappearance of Christophine and the limited depiction of Bertha. As Spivak suggests:

> She [Christophine] cannot be contained by a novel which rewrites a canonical English text within the European novelistic tradition in the interest of the white Creole rather than the native. . . . Attempts to construct the "Third World Woman" as a signifier remind us that the hegemonic definition of literature is itself caught within the history of imperialism. A full literary reinscription cannot easily flourish in the imperialist fracture or discontinuity, covered over by an alien legal system masquerading as Law as such, an alien ideology established as only Truth, and a set of human sciences busy establishing the "native" as self-consolidating Other.[118]

Spivak points out that although such novels as *Wide Sargasso Sea* and *Jane Eyre* are often celebrated as proto-feminist works, they also promote forms of feminist individualism that feed into the imperialist project. Through these literatures we can see how such individualism was only able to occur through the subjugation of others. Spivak is critical of the glorification of feminist individualism, for she argues that "what is at stake . . . in the age of imperialism, is precisely the making of human beings, the constitution and 'interpellation' of the subject not only as individual but as 'individualist.'"[119] In an era of biocapital, the self-interest of individualism and the legacy of the imperialist project collide in fascinating ways. Of course, it goes without saying that the self-interest of the individualist gels very nicely with the subject formation necessary to propel oneself forward in a global economy based on such neoliberal values. It is this very skill set that is required for one to venture and set sail, as Venter and others have done, into a life of biopiracy.

This chapter has covered a great deal of ground (and water). I have interrogated two main challenges we will face as we turn our attention toward the *in vitro*, the molecular, the synthetic, and the nonhuman. First, we must consider the question of what constitutes life and the living, and

second, we must figure out how to orient these questions so as not to leave the human behind. Interdisciplinary incubations produced through the encounters between molecular biology, feminism, postcolonial theory, and decolonial studies will be key in addressing these challenges. As we learn how to see the world and furthermore, how to encounter that world, these incubations will sustain us in our pauses even as we race toward new biotechnological futures.