BIOMIMICRY: NEW NATURES FOR AND AGAINST CAPITAL

ABSTRACT:

This paper explores how biomimicry, an increasingly popular trope within the discourses and practices of the green economy, encourages a new industrial paradigm that ostensibly leaves behind the crude violence of Francis Bacon, the domination of nature-as-machine, and a history of toxic production processes that have given rise to a present and coming climate crisis. By recasting natural resources as an untapped abundance of innovative potential rather than limited materials to extract, advocates of biomimicry imagine a future of sustainable production and limitless economic growth.

As part of a broader trend towards the conceptualization and development of a 'bioeconomy' in which the naturalized scarcity of classic economic thought gives way to a general surplus of and in nature, we argue here that biomimicry produces 'nature' in new ways. At face value, these new approaches to valuing nature may seem less violent and exploitative. Yet, new natures can and are tortured in new ways. Here, we argue that biomimicry produces 'nature' anew, but that it does so through well-worn logics of resource enclosure and privatization. We focus specifically upon two fundamental shifts in nature through the lens of biomimicry: (1) The production of nature as intellectual property (as opposed to raw materials); (2) The production of nature as an active subject (as opposed to a passive receptacle or vehicle).

KEYWORKS: Nature, Late Capitalism, Life, Environment, New Economy, Post-Industrial Society, Posthuman

Every culture knows…life works.

-Janine Benyus, 2012

Introduction

The complex web of living things, human and nonhuman alike, has long served to animate curiosity, stir emotions and guide much of human creativity. Yet according to conventional environmental wisdom, two long centuries of seemingly lifeless mechanical and now cybernetic industrialism has severed this relationship, leaving society out of touch with this dynamic, more-than-human world. The field of biomimicry, an emerging field of technoscience that unites biological research with technological engineering, breathes new life into this age-old connection. Drawing on 3.8 billion years of evolutionary 'research and development', environmentalists, the US Department of Energy (DoE), the Department of Defense (DoD), and many others hope to use natural forms as an instructive element in industrial engineering.

Biomimeticists draw on the knowledge of nonhuman life to inspire technological innovation. Practitioners argue that this will lead to more efficient, ecologically sustainable materials. Notable examples include termite mound-inspired building designs that regulate their own internal temperature and dramatically reduce heating and cooling costs, butterfly wing-inspired computer screens that reflect light and save energy, and spider-inspired materials that transform how we make bullet-proof fabrics. These only scratch the surface of biomimicry's potential to put life to work, capturing 'the latent value in biological processes and renewable bioresources' (OECD, 2005: 5).[1]

Those hoping to draw on biomimicry to generate more ecologically sustainable products and processes argue that the practice can not only spark innovation, but that it will also form the basis of a new industrial paradigm that leaves behind the crude violence of Francis Bacon, the domination of nature-as-machine, and a history of toxic production processes that have given and will give rise to ecological crises. By utilizing natural resources not as limited materials to extract, but rather as an untapped abundance of innovative potential, these biomimeticists imagine a future of sustainable production and limitless economic growth: a way to 'gain the benefits of nature without destroying it, [to create] a green industry' (Janine Benyus, quoted in Lieberman and Rosmarin, 2010).

On the surface, these new approaches to valuing nature seem less violent and exploitative than the prevailing norm. Yet we must beware: new natures can and are tortured in new ways. Here, we argue that biomimicry produces 'nature' anew, but that it does so through well-worn logics of resource enclosure and privatization. Accordingly, we find that the field traffics in empty promises, curbing aspirations of a new form of production more suitable to ecological longevity. Even more troubling, however, is that biomimicry opens up nature anew, generating novel materials--and even immaterial processes--upon which the old script of enclosure can be executed more widely and with heightened flexibility. Thus, biomimicry's rise parallels tendencies in the environmental movement toward market-based solutions, falling squarely within the rapidly growing 'bioeconomy', where life's processes are remade as engines of profit. In what follows, we focus specifically upon two fundamental elements of biomimicry's 'nature' that facilitate this new form of enclosure: (1) The production of nature as intellectual property rather than raw material; and (2) the production of nature as an active subject rather than a passive receptacle or vehicle. We note within these tendencies the pervasive presence of market

forces in environmental discourse. However, we also argue that biomimicry cannot be reduced to the role it plays in furthering capital accumulation. In fact, biomimicry's more-than-human approach to technological production may offer conceptual and even technical grounding as we struggle for a more liberatory, ecological-social-political metabolism with, through, and as nature.

From Bioeconomy to Biomimicry

From the Club of Rome's assessment of the limits to growth to the more recent 350.org 'Do the Math' campaign, mainstream environmentalists often frame the ecological crisis in terms of material limits. According to the conventional wisdom of the environmental movement, Enlightenment ideologies of nature as a resource for production have enabled excessive consumption and excessive waste. As the attendant acceleration of industrial production has overtaxed the earth's resources, it has put nonhuman ecologies and human civilization alike at risk. Strategies for mitigating—or altogether eliminating—that risk include overturning long held ideological assumptions of nature, thereby transforming our qualitative relationship with it. However, in the face of growing concern around climate change, reconciling our quantitative excesses seems the most urgent task at hand.

Yet, even as environmentalist movements continue to organize around limits, economic growth and visions of endlessly productive natures seem more persistent than ever. The 'population bomb' and 'peak oil' of the 1960s and the pending climate change crisis of today seem to have had little effect on established visions of persistent economic growth (Ehlich, 1976; Bardi, 2009). With the agricultural revolution, progress in geophysics and chemical processing,

and the development of biotechnologies and other advances in the life sciences, human society appears to be successfully expanding its resource base. Indeed, it may even seem as though we have fulfilled Julian Simon's 1981 prophecy that human ingenuity would overcome ecological limits, indefinitely extending life on earth in the process (Simon, 1981).[2] According to Simon—and much of the economic policy in the U.S.—nonhuman life continues to produce in abundance thanks to human ingenuity and market-response models of resource use.

Uneven geographies of economic production and regulatory limits on environmental degradation are generally accepted among environmental geographers and social scientists as a primary cause of this seemingly obdurate commitment to the status quo. Pockets of core economic activity--and attendant affluence--have distanced themselves from the increasingly toxic and wasteful realities of production. These privileged spaces have largely been shielded from the most acute effects of the planetary ecological crisis that continues to unfold. Capital's unflagging resilience and capacity for spatio-temporal fixes and a ubiquitous culture industry determined to have us 'keep calm and carry on', supporting the illusion that economic growth is not ecologically toxic. For those admitted by birth or privilege, the phantasmagoria of the marketplace promises 'next generation' gadgets that emerge and disappear with clockwork regularity, flowing alongside predictable currents of stylistic adjustment and relentless obsolescence. Unprecedented technological potentials are superseded only by the promise that soon, with 3D printing, we will be able to create earthly delights on demand. The ascent of innovation and service over extraction and material production in affluent areas of the globe have led thinkers operating in the privileged spaces of consumption and excess – from futurists and designers to sociologists and pundits – to envision the possibility of a truly post-industrial, and

therefore relatively dematerialized and decarbonized, economy (Toeffler, 1984; Friedman, 2009; Hardt and Negri, 2001; Milani, 2000).

A growing bioeconomy has emerged alongside the decline in industrial manufacturing and the ascendance of Post-Fordist production in the West, further fueling perceptions of limitless life. Throughout the late 20th and early 21st centuries, new connections between the life sciences, technological innovation, and the generation of profits have made 'life itself' an even more integral part of production practices (Rajan, 2006; Cooper, 2008; Braun 2008). Advances in the biotechnology industry as well as transformations in regulatory and market structures surrounding technoscience over the last forty years enroll life's most basic elements and processes more deeply within regimes of innovation, privatization and industrialization.[3] Together with the rise of venture capitalists willing to invest in these emergent, speculative and potentially lucrative fields, these events set the stage for life to figure productively with logics of a neoliberalizing economy, linking biological and technological innovation directly into circuits of financial capital (Cooper, 2008).[4]

The recent recognition of biological life as a resource for production and profit promises to ameliorate tensions between commercial industry and ecological health, further reinforcing the notion of perpetual economic growth. These trends thus can be seen as part of broader tendencies in business environmentalism, in which economic growth and environmental stewardship no longer appear to be in opposition. (Dowie, 1995). While many environmentalists continue to view environmental management and industrial growth as antagonistic to one another, the emerging role of biological life as a resource offers an opportunity to wed innovation with ecological health.

Biomimicry has emerged over the past two decades as one of the most promising avenues of 'green' innovation and bioeconomic production. The practice of drawing on nature to create tools for enhancing human civilization is nothing new. Humans have long paid attention to the behaviors of nonhumans to improve our chances of survival and to create innovative ways of engaging with the world. Observing other animals has shown us which plants and animals to consume and which to avoid. Leonardo De Vinci's unsuccessful flying machines were inspired by bird flight, as were the Wright brothers' more successful airplanes. Georges de Mestral's storied walk through a burr-filled forest inspired the eventual development of Velcro®. But, only over the past two decades has biomimicry gained purchase as a discipline and organizational framework that bridges engineering design and biological research. The Wright brothers may have been inspired by birds, but not with the level of detail and intensity of George Lesieutre's team of engineers at Penn State: they are presently attempting to develop more energy efficient airplane wings by studying how the wings of birds change shape during flight.

As a field, biomimicry is diverse and, at times, less than coherent. Its practitioners can scarcely agree on the term's definition, on what level of fidelity to nonhuman life is required for a project to count as 'biomimesis', or to what ends its methods are best applied. But environmentalists and innovators alike have lauded it as a way to maintain the expansion of profit while simultaneously encouraging an ecological consciousness. The concept appears in numerous texts advocating for a new green economy: *Natural Capitalism* (1999)*, Cradle to Cradle* (2002)*, Earth the Sequel* (2008)*, Zugunruhe* (2011) to name a few. Even military journalist Robert Ackerman celebrates biomimicry's potential to remake nature as the 'ultimate free market for selecting effective structures' for technological development and engineering (Ackerman, 2000). This marriage between economy and ecology is more than rhetorical: in

2009, inventors submitted over 900 patents containing the term 'biomimicry' to the US Patent and Trademark Office. And a 2010 report by Point Loma Nazarene University's Fermian Business and Economic Institute estimates that biomimicry could account for $300 billion of the US GDP by 2025 ('Global Biomimicry Efforts', 2010; see also Johnson, 2011). In 2011, the New York State Energy Research and Development Authority (NYSERDA) began a biomimetic R&D program in New York State, in the hope that biomimesis 'may be able to help usher an entrepreneur from concept to commercialization better, faster, and cheaper' (NYSERDA, 2013).

But biomimicry's most vocal advocates have come to define the practice in their own terms not only as a means of creating more sustainable practices of production, but as a way of 'revolutionizing' human consciousness and overturning the tenets of industrial production altogether. Janine Benyus and her organization, 'Biomimicry 3.8' are at the heart of that movement. Benyus is the appointed 'guru' of biomimicry and a celebrated figure among mainstream environmentalists. In her 1997 book, *Biomimicry: Innovation Inspired by Nature*, Benyus features a collection of scientists and engineers—biologists, material scientists, chemists, physicists, primatologists, computer scientists, and 'industrial ecologists'—who are developing innovative materials through biomimetics. Drawing on their work, Benyus brands biomimicry as a process capable of remaking human-environment relations. A host of biologists, naturalists, financiers, educators, and ecologically conscious designers have joined Benyus to usher in what can only now be called a global biomimicry movement (Harvey, 2009; see also Johnson, 2010). In the intervening decades, Benyus has worked to spread the word about the power of biomimesis through Biomimicry 3.8, a business platform for nonprofit education and networking and for-profit consultancy.

More than improving upon the products that we have, or creating a better, greener version of commodities, Benyus insists that biomimicry will remake the very processes of material production themselves by improving the *nature* of mass production in an industrial economy. In her writings and lectures, she crusades against what she refers to as '*Homo industrialis'* and, with it, the inefficiencies of the 'heat, beat, and treat' method of industrial production. For Benyus, 'heat, beat, and treat'—along with the environmental degradation that accompanies it—is the product of a Baconian ideology rooted in scientific rationality. This is an ideology that justifies and encourages a merciless drive for improvement and progress, and that has resulted in nothing short of a metaphorical and material enslavement of nature. The natural and applied sciences have emerged accordingly, licensed to 'torture nature for her secrets' and to extract seemingly limitless quantities of useful materials from the earth.

For Benyus, both *Homo industrialis*, its forms of production, and its ideology of nature have all reached their limits. As she writes, neither human life nor our methods of production are immune to the 'guidelines', 'standards', and 'operating conditions' of life on earth. But the biomimetic solution is not about forestalling or delimiting production. Instead, it is about reimagining and redirecting it.

For example, in her book, Benyus invites us to consider the making of Kevlar. Dupont's aramid fiber material is an incredibly strong composite, used in a wide range of products and industrial applications, including in fiber optic cables, industrial sealants and adhesives, aerospace and automotive components, and, most famously, body armor. To make it, DuPont pours a petroleum-derived synthetic into 'a pressurized vat of concentrated sulfuric acid', boiling it at extremely high heat, and then subjecting it again to high pressure in order to force it into fibers (Benyus, 1997: 134). From beginning to end, the process is as energy intensive as it is

toxic. It is a prime example of industrial production and its ills, expressing the kind of violence enacted against nature – justified in the name of improvement – that Benyus wants to challenge.

Benyus offers the challenge to Dupont's process in the form of Christopher Viney, an engineer cum bioscientist, who is looking for a biomimetic alternative to Dupont's product by studying the golden orb weaver (Nephila clavipes). Viney's lab specimen, affectionately named 'Tiny', produces a silk fiber that is, ounce for ounce, five times stronger than steel and 30% more flexible than nylon. It maintains its strength and flexibility under extreme temperatures without compromising its structure. Indeed, rather than becoming more brittle like steel, some silks are known to increase in strength at low temperature (Yang*, et al*., 2005). Most remarkable, Benyus tells us, is that Tiny creates this super-fiber without the excessive inputs of energy or outlays of toxic waste that goes into the production of Kevlar: the spider only uses 'local' inputs. As Benyus writes, the spider takes in 'flies and crickets at one end and processes a high-tech material at the other' (Benyus, 1997: 135). Viney hopes to concentrate and scale this spider-inspired production so as to make it commercially viable. If he can figure out a way to mimic Tiny's production--and thereby harness 'nature's chemistry'--he could weave the silk into a fabric that was five times as effective as Kevlar in withstanding stress.

For Benyus, biomimicry is a way to bring the 'wisdom' of Tiny and other creatures to bear on industrial production. Through this and other examples, she depicts a future industrial economy that abides 'nature' by tapping into the products and processes of evolution in order to 'gain benefits of nature without destroying it'. As noted, however, this elevation of nature as an expression of 'genius' nevertheless requires valorization: Tiny's wisdom must prove useful and—in this context—profitable. Accordingly, Benyus's organization Biomimicry 3.8 works to prove the potential profitability of this new approach to production. The organization works with

engineers and corporations to identify biological forms that might serve as inspiration for commercial production, fully confident that their clients will cut costs and generate revenue through the appropriation of nature's 'genius' (see biomimicry.net; Johnson, 2010).

Biomimicry offers the business community visions of a peaceful future, one in which the violent exploitation of 'nature's' resources – raw materials, land, water – is no longer necessary. However, as we will now show, this vision, predicated upon making 'nature' available to the business community as a source of limitless, immaterial inspiration requires the privatization of 'nature' and its enclosure as a new form of potential capital.

New Natures, New Enclosures

Political ecologists have well documented the rise of the bioeconomy around new forms of accumulation by dispossession, privatization or enclosure. While these concepts may not all be completely analogous, it is not our intention here to dissect their theoretical or conceptual differences, but instead to flag their commonality, referring to the many processes by which not-yet commodified entities can be transformed into fictitious commodities through political, legal, or what Robert Brenner terms, 'extra-economic means' (Poylani, 2001; Brenner, 1989).

Of course, the choice of the term 'enclosure' is not innocent, as it traces a lineage more or less directly back to the British mechanism of agrarian dispossession that went by the name, and which transformed this countryside over the course of hundreds of years, emptying it of the multitudinous array of common right property regimes that provided a central material underpinning of the feudal economy. While a minority perspective understands enclosure, or the broader process of 'primitive accumulation' as a periodizing concept, set prior to the ascent of

capitalist property relations, it is more commonly understood as an ongoing process, that in different capacities and forms preceded, initiated and continues to accompany ongoing capital accumulation.

The present status of enclosure is still a matter of debate. Some argue that the process is unfinished and ongoing (DeAngelis, 2004; Goldstein, 2012) while others add that the process has somehow been transformed, now operating in new ways (Katz, 1998; McCarthy, 2004; Smith, 2007). This later work looks specifically at how the process of enclosure, and more broadly the production of nature, transforms in relation to new targets such as those unearthed by bioprospecting or fabricated through new regulatory regimes. As both Cindi Katz and Neil Smith argue, such practices render nature itself – first nature – an accumulation strategy. Unlike prior forms of enclosure, which extended across space to capture ever more territory, these new enclosures extend into the depths of what we understand as nature, and as life. They go, as Neil Smith writes, 'all the way down'.

If scarcity (real or imagined) is what motivates instances of accumulation by dispossession or enclosures, exemplified by ruthless efforts across the globe to accumulate farm land and mineral rights and to monetize access to increasingly scarce potable water (Bakker, 2007; Swyngedouw, 2006; Bond, 2010), then it is surplus (real or imagined) that motivates these newer instances of enclosure in the bioeconomy. These new forms of enclosure are no longer strictly territorial, targeting a wide array of matter and practices. While the social science literature has paid much attention to the enclosure of formerly public or common resources such as water, wildlife, fisheries, or forest, 'new enclosures' also include forms of matter once considered incompatible with the very notion of privatization (Shiva, 2002; Robbins and Luginbuhl, 2006; Correia, 2006; St. Martin, 2006). The recent creation of regulatory markets and

the patenting of intellectual property has enabled the creation of a new frontier for accumulation, one that includes 'impossible subjects of enclosure' (McCarthy, 2004: 337) ranging from living bodies, cells, DNA, nano particles and air molecules to regulatory commitments and various other forms of knowledge (Katz, 1998; McCarthy, 2004; Prudham, 2007; Robertson, 2012; Sunder Rajan, 2012; Jansanoff, 2012). Biomimicry, as we will show, is one of these frontiers, whose 'impossible subject' is a well organized, complex and infinitely productive 3.8 billion year old research and development effort, undertaken by none other than nature itself.

It is difficult to overstate the novelty of these new economic practices and their attendant productions of nature. While the rise of the bioeconomy sets up new relationships among biological matter, immaterial processes, and production itself, Goldstein argues that the extension of processes of privatization to these new objects does not in itself constitute a new dimension of enclosure (Goldstein, 2012). Rather, it fulfills the much earlier seventeenth century promise, voiced then as a discourse of agricultural improvement, now as a more grandiose narrative of natural, or even planetary improvement. Then, as now, enclosure required a twofold transformation: first, a qualitative (intensive) one through which land was remapped as potential private property and second, a quantitative (extensive) expansion of control over this newly produced terrain (Goldstein, 2012). Accordingly, these early enclosures, and all those subsequent, entail a peculiar production of nature, one that conjures into being *terra economica*, a whole earth available to be put to (abstract) profitable use, or otherwise wasted.

Looking closely at this process however, there are shifts in how the script of enclosure plays out across 'immaterial' or knowledge-based forms of production. If early enclosures produced a whole earth available to be mined as a material resource (a process which continues apace), biomimicry and more broadly the bioeconomy, produces a *generally industrious* nature,

available to be understood and mimicked. We borrow the term *general industriousness* from Marx, who used it in his writings that have been posthumously published as the *Grundrisse* (1993). The term betrays Marx's most Promethean tendencies; his excitement for the techno-social possibilities afforded by a system of production dedicated to general, self-reproducing wealth (money-as-capital), as opposed to meeting particular needs. 'Money as aim here becomes the means of general industriousness... In this way the real sources of wealth are opened up… the individual's industriousness know no bounds' (Marx, 1993: 224)'. The pursuit of general social wealth opens up new, and newly productive capacities of the collective social body. Innovative ideas – embodied in the concept of a general intellect – and innovative technologies, products and infrastructures altogether comprise a general industriousness heretofore unimaginable in the history of human society.

In both the *Grundrisse* and *Capital, Volume One*, this general industriousness is implied in the productivity of industry that is made possible through the transition from manufacture to machinery. As Marx describes, this is a shift from production centered upon laboring bodies, augmented by various instruments and tools, to production centered upon machines, maintained and superintended by laborers whose bodies have been pushed to the periphery of the production process. And yet, the general intellectual capacities of this marginalized laboring population, taken all together as a collective laboring body, provide the conditions of possibility for this central machinery of production: scientific and technological innovations for which capital takes credit, as if it, and not the accumulated knowledge and capacities of the social body, is responsible.

Marx describes this transition—from the accumulation of labor power to the accumulation of knowledge – as a shift from the formal to the real subsumption of labor to

capital. Accordingly, we argue that the production of generally industrious nature results from its real subsumption of evolutionary products and processes to capital. This real subsumption of nature is by no means new, but its particularity is significant. Boyd, Prudham and Schurman argue that it entails a transition from extraction to cultivation; the former is primarily geological, the latter is primarily biological, and marked by the genetic revolution in agribusiness as well as all of the many new technologies and processes we have named above as the bioeconomy. Neil Smith (2007) counters that there is not in fact anything distinctly new in the transformation they've identified – both extraction and cultivation are longstanding dimensions of nature's production and of the justification for enclosure. For Smith, however, the real subsumption of nature only occurs through an intensification, or 'technological deepening' (33), of capital's circulation through nature as well as a transformation of this circulation, 'from an incidental effect of capital accumulation to an intended strategy' (Smith, 2007: 33).

Such characterizations of this transformation amount to shifts in direction, intensity and intention, but do not yet capture the underlying qualitative transformations at hand. Smith does however also argue that the real subsumption of nature to capital has to do with a shift from external nature to social nature. This is the insight we hope to develop further: the production of social nature out of, through and beyond an otherwise external nature represents a shift from a passive and inert nature to an active and innovative one. Generally industrious nature is not therefore simply a nature more 'deeply penetrated' by capital, but a nature understood to be productive at a general scale, a more-than-human extension of the general social productivity attributed to the laboring population – a concept whose anthropocentrism can hence be firmly laid bare.

To the extent that generally industrious nature is produced through a process of enclosure, it remains *terra economica*, a whole earth potentially available as and for capital. That said, with biomimicry the specific form of capital that appears potentially available is no longer the constant capital of raw materials, but is now instead an immaterial resource to be valued through the institution of intellectual property regimes.

1. Biomimicry's Nature As Intellectual Property

With the shift from nature characterized by material resources to immaterial inspiration, biomimetic enclosures produce life's extant objects—in the form of organisms, cells, DNA, etc.—through a new lens of Intellectual property, paralleling similar movements within the disciplines of neurology, micro-biology, bio-technology, and genetics (Jasanoff, 2012). While intellectual property has become an increasingly ubiquitous dimension of our socio-economic system (and with authorial integrity playing a fundamental role in our own lives as academics), it is easy to lose site of the peculiar social relationships underlying this legally-constituted fiction. If, to follow Marx, we consider knowledge to ultimately derive from the accumulated efforts of a collectively thinking social body; to emerge in and as part of a general intellect, then the possibility of owning or possessing an idea becomes impossible – especially when one considers the impossibility of having a socially meaningful idea independent of sharing that idea with others. The integrity of an idea as a divisible, stable and controllable part of this general intellectual wealth is always in jeopardy – ideas by their very nature proliferate; they cannot exist as knowledge without being more than singular, without being infinitely reproducible within the general circulation of ideas and those sharing amongst them. Hence the legal and financial

fictions of intellectual property are an effort to ascribe some form of property rights to an otherwise unruly and uncontrollable dimension of the collectively laboring (and thinking) social body.

Whereas commodities are produced to be sold, this is not the case for land or labor, which Karl Polanyi (2001 [1944]) terms fictitious commodities. Likewise with knowledge – whether derived from land and/or labor – it too is a fictitious commodity; an extension of the lively world that can never be fully reduced to the dead uniformity of the commodity form. Just as capital can only sell wage labor – the capacity to work - and not wage laborers (the humans themselves), the same is true of knowledge – intellectual property can be bought and sold, but never the intellect itself. In terms of 'nature' or the more than human contributors to the process of production, this is an important shift away from the status of raw material. Whereas the value of raw material is derived from the particular use of particular materials for particular processes of production (no matter how generalized this process has become – one tree can only be turned into one batch of furniture) the value of intellect-as-property lies in its applicability to production generally. Hence Tiny the spider's utility – to continue with our above example – is not as a silk-maker, but as a teacher, who will instruct us how to (industrially) make silk more effectively. Just as earlier (and ongoing) forms of enclosure reduced the myriad productivities of land into an endlessly capacious drive towards profit, so to with biomimicry-as-enclosure: the myriad social and ecological knowledges embodied in natural systems are reduced to a divisible, isolatable field of potential intellectual property. Patents replace fences and hedges, but the effect is much the same. *Terra economica* seems to have expanded, not only through its attachment to a wider array of objects. The legal structure of intellectual property also enables the expansion of *terra economica's* logic to emergent and unknown capacities of human and nonhuman life. Economic

value can now be attached to what Melinda Cooper refers to as 'principles of generation' (Cooper 2008: 24). Along with biotechnology, biomimesis enables production to remain in a permanent state of self-transformation, capable of pre-empting any possible limit to growth. Rather than enclosure through the claims on and the subsequent extraction of resources, biomimicry offers a new avenue for profit generation based on the production and capture of bio-futures.

It therefore seems that the creation of the bioeconomy and the growth of biomimicry as a discipline do not serve to dismantle the Enlightenment's notions of a 'productive' or 'machinic' nature, but rather extends and transforms them to all of life in new ways. Nature may produce many innovative capacities in an unfathomably complex web of living and non living entities, but the seeing of this complexity, as innumerable aliquot parts, each of which holds an innovative wisdom to be potentially unlocked, tapped, commercialized (or as is often the case with biomimetic research, militarized), this is a very specific nature – an enclosed nature where all is either potentially IP or otherwise wasted.

2. From Raw Material To Active Subject

The rise of a generally industrious nature entails more than privatization through IP legislation. It also involves a new ideological framing of nonhuman life; an attempt to unseat Baconian conceptions of nature as a passive dominated object, offering instead a reconceptualization of nature as a realm of active, collaborative participants.

By upsetting traditional hierarchies of life,. Benyus and other key thinkers in the biomimicry movement hope their new paradigm can recast the role of nature in society, ushering

in a less exploitative and more nurturing regime of human-nonhuman interactions. In what Biomimicry 3.8 considers 'true' biomimetic form, Tiny the spider would not be farmed for her silk or merely utilized to 'do the work for us'. Rather than being enslaved as a lab specimen, she is honored as a teacher and guide.[5] Her wisdom, once productively realized, will revolutionarily transform our vision of and relationship to the natural world by disrupting traditional hierarchies of life in which humans appear at the apex (Johnson, 2010). Drawing to mind Bruno Latour's notion of the 'Parliament of Things' (1993), Benyus's vision of nonhuman life recasts this engagement with an active nature as a "parliament of species," a democratic body in which we humans hold only one seat, and must learn to collaborate with our non-human counterparts.

Of course, this 'collaboration' must be carefully scrutinized. As we have shown above, biomimicry attempts to understand what 'nature' already does, and then models industrial production accordingly. This is very different from a Baconian exploration of what nature is, or what it can be used for. If biomimetic engineering promises to transform the relationship between nonhuman life and production, it does so by transforming the former into a field of traits capable of inspiring the latter. 'Nature's' participation in the process of industrial innovation is contingent on its own disassembly: species and individual organisms are not important. Tiny the spider becomes valued not for what she is, but for what she does and how she does it. Thus, the biomimeticist repurposes and redefines spiders anew. The spider's body is not alive in some transcendent sense, but its liveliness is dissected, pulled apart, and reconstituted as an assemblage of capacities. In the wild and in the laboratory, she becomes a collection of parts—glands, molecules, proteins, ducts, spinnerettes--that conspire to produce a potentially useful material. Tiny is not a spider situated within a complex ecosystemic web of life, Tiny is a silk-making machine. As its capacities are repositioned within the frame of technological

engineering, creatures like Tiny re-connect with the social field in new ways, becoming more than either wildlife or objects of science.

Perhaps even more importantly, the spider's capacity is valorized only in particular ways: it is not simply what the spider does, it is also how and in what ways the spider does things that 'we' find 'useful'. This narrows all of the many ways that the spider acts or exists into a realm of utility. But Biomimicry 3.8's philosophy does not simply work to identify the utility of specific natures to do specific tasks, like an ox pulling a cart, or a tree becoming a chair. Rather it exploits the general utility of generally industrious nature to demonstrate a general capacity to act.

Hence, biomimicry 'teaches' us how to improve our own actions, or productions, by 'tapping in' to its innovations, knowledge, and intellect. By turning to animal life as material for inspiration and innovation (rather than merely consumption), every aspect of life—including its as yet unrealized potentials—becomes employable: apes, spiders, the knowledge of indigenous communities, all are potentially active workers in the post-industrial innovation economy, all are bearers of an ancient intellect that we have as yet failed to tap.

Here, Benyus takes a cue directly from post-industrial management texts that encourage the active, creative participation of the labor force in processes of production. Paeans to the creative economy, from Toyatism to the ubiquity of flexibility and the embrace of precarious employment, paint a portrait of a post-industrial economy that has moved beyond the crass exploitation of dead end jobs and debilitating manual labor. Today, we all have computers. It is an information economy; clean, respectful, engaging, empowering. The laboring population is no longer comprised of subservient employees. Instead, we are all creators, entrepreneurial selves in a post-industrial world of surplus. The majority of 'designers' in this post-industrial economy are

overworked and contingently employed 'creatives' who spend their days collaborating on projects that further the mission of their corporate clients and employers. Benyus suggests that biomimeticists put nature to work in the same way, – that they collaborate with nature to further their mission of commercial or military success.

Somewhat surprisingly, Benyus' arguments for nature-as-mentor run parallel to those of Thomas Friedman, who envisions a world made flat by the leveling meritocratic effects of global entrepreneurship and digital technology. Missing for Friedman, as well as for Benyus, is all of the supporting work – both paid and unpaid, human and non-human – that makes this virtuous production possible, as well as the wasted remainder – those cast out of any creative and productive circuits of social production altogether; criminalized, excluded, or even left to die. If Friedman ignores surplus humanity, Benyus ignores surplus nature: the ongoing resource extraction and waste generation that these biomimetic projects will both support and depend upon.

Tiny will leave her ecosystem behind, to realize her entrepreneurial potential in Viney's laboratory, where together, man and spider will innovate industrially profitable technologies. Tiny may help Christopher Viney develop a material dramatically better than Kevlar, but what does Tiny, or her ecosystemic community for that matter, stand to gain? In this thoroughly neoliberal discourse, such matters are irrelevant, and the 'parliament of species' is hardly an empowered, or democratic body.

Benyus hopes that biomimetic projects will engender the production of 'conditions conducive to life' but in this, and most instances of actually funded biomimetic research, the reality of available funding streams would seem to betray this utopian vision. Most biomimetic research is only funded to the extent that it shows clear military or commercial potential. Tiny's

innovative silk is no exception; the Department of Defense's funding for Viney's research holds out the promise of bullet proof vests as thin as silk and as strong as steel.

Biomimicry, and for that matter the bioeconomy, do represent a departure from the crude materialism of Baconian extraction. Yet unfortunately, any promise that biomimetic production will constitute more 'symbiotic relationships, much more mutualism, [and] much more cooperation' seem unlikely as biomimetic processes and products are enclosed and deployed as private property. The promise of moving 'beyond improvement' comes falling back down upon the reality that improvement is more than a cultural or aspirational ideal, but a political and economic imperative (Wood 2002).

Biomimetic research is produced and reproduced within very specific circuits of capital investment, which in many ways make up their own self-reproducing eco-system. This social-spatial logic of capital's uneven development has been well documented. Distinct flows of resources and waste – both human (surplus populations) and non human (toxins, pollutants, trash) – have created a world in which small pockets of affluence can shield themselves from the vast landscapes of extraction and primary production that provide their conditions of possibility. This is, as Neil Smith has clearly demonstrated – a production of nature at the global scale.

Within this context, the logic of the market takes on an active – and actively unacknowledged – role in the production of life as it attempts to determine which natures get reproduced, how, and for what ends. Hence, far from simply accessing, or learning from the wisdom of a separate and prior first nature, biomimetic research is actively engaged in producing that first nature, by fundamentally altering the terms of its continued reproduction.

Nature has and may continue to inspire any number of benign, even positive techno-social developments, but if nature and her collaborators want seed capital, they are going to have

to show commercial promise. This is ultimately the problem with biomimicry: though its stated intention is to learn from, respect and honor nature, by doing so through the available investment options for industrial R&D, the reproduction of life is displaced by the reproduction of capital. As such, biomimicry seems to be an extension of what Perry Anderson has called an 'all-capitalist ideological universe' in which 'the sanctity of private property and superiority of private enterprise are truths taken for granted' (Anderson, 2013: 25).

From Terra Economica to Alternative Biomimetic Futures

Biomimicry promises to transform the way we envision, appreciate, and act with nature. It is about re-making who we are, how we see, and what we do to make our industrial lives possible. Against Enlightenment visions of nature as a machine to be 'tortured for its secrets', biomimicry reimagines nature as a mentor to be partnered with and revered. But there is an unresolved tension here: the rhetoric of biomimicry's advocates suggests that we produce 'conditions conducive to life' but its political economy demands instead the perpetuation, even expansion, of still-violent processes of enclosure. In practice, biomimicry puts nature to work as active participants in the business of economic and social development, making life's continuation synonymous with capital's expansion.

The biomimetic imaginary reconceptualizes nonhuman life as *terra economica*, a repository of potential - and potentially limitless - capacity, available for economic use or otherwise wasted (or wasteful). This entails a necessary and often unspoken process of selection as the world and its lifeforms are isolated, selected and reproduced for a decidedly capitalist future. The female golden orb weaver (Tiny the Spider) may make the cut, but what about her

less ‘productive’ mate, whose smaller body produces a finer silk, or the venomous brown recluse, who will be more difficult to include safely within Benyus’ Parliament of Species? The ideal of a biomimetic future may be all inclusive, but the biomimetic future being enacted is one in which conditions are made conducive to some lives and not others.

And yet, despite the necessary caution, we want to conclude with some brief reflections – or perhaps they are projections – on the promising, even liberatory possibilities that biomimicry can open for us.

Nature made generally industrious in this way offers new possibilities, not only for capital’s expanded reproduction, but also for the constitution of viable alternatives to future imaginaries sculpted solely out of liberal humanism. Like Donna Haraway (2007), Benyus encourages us to consider the making of more-than-human alliances that may participate in the making of new worlds. Turning toward nonhuman life in this way fulfills calls (from multiple theoretical directions) to reconsider the importance of animals and objects in the constitution of present and future worlds. Therein, we might find what Nicole Shukin has referred to as a ‘possibility that nature might be produced differently, as the “collective substance” of “communism”’ rather than capitalism (Shukin, 2009: 83). Considering the now-seeming imminence of ecological crisis, it seems ever more essential for our conceptions of a better possible world to be reconsidered in this way, or as Neil Smith writes, “all the way down” (2007).

This will require envisioning other possible ways of ‘tapping into’ the genius of the world, human and nonhuman alike, to find new potentials of and in this common substance that is always both not-capital and not-yet capital. These are the terms of our struggle.

And so we take from Benyus, from biomimicry, and more broadly from the promise of the bioeconomy, a gesture towards the poetics of a new form of production, one that elegantly manipulates nature for all life, as opposed to capital. We have no conclusions to make, but end instead with a series of essential questions that this investigation has opened for us: What can (re)productive, technologically mediated metabolisms between the human and non human world look like?; How can we imagine a form of production that can both reproduce beautiful lives and unmake the infrastructure of our ecologically catastrophic social formation? What forms of knowing – both embodied and immaterial – do we want to mobilize in our ongoing processes of world-making?

[1] Otto Schmitt, a biophysicist at the University of Minnesota, coined the term 'biomimicry' in 1969. He is often credited as the 'founder' of the field, at least in the United States. Even then, he noted that the concept lacked novelty: 'All humanly created mathematical models' Schmitt wrote, 'may properly be considered Biomimetic: in imitation of life, as they are created by biological creatures who have only biological figures of thought at their disposal'. The problem, Schmitt argued at the time, was that 'this plagiarism is usually not deliberate', to which he added that it might be 'interesting and perhaps rewarding to examine some simple information transform models deliberately developed biomimetically to learn whether such models offer easier or better human insight, better machine processing, or better information transmission, storage, and retrieval' (Schmitt 1969: 80). Biomimicry's more recent successes are often attributed to advances in microscopy and methods in the biological sciences that have enhanced scientists ability to see biological structures at an ever smaller scale (Forbes, 2005). At the same time, advanced computational capacities and the ability to engineer materials at the micro and nano scales has enhanced our ability to reproduce those structures.

[2] Indeed, Simon's most recent publications, *It's Getting Better all the Time (*2000) and *Hoodwinking the Nation* (2006) have vociferously argued this very claim.

[3] The patenting of genetically modified organisms in agriculture and medical sciences have created new opportunities to own and market lifeforms. Legal decisions such as Diamond vs. Chakrabarty (1980) and Moore vs. Regents of the University of California (1990), enabled bacteria and living human cells to be redefined as property (Jasanoff, 2012). Alongside bio-technological innovations and changing legal codes, transformations in the infrastructures that govern innovation, such as the Bayh Dole Act (1980), have enhanced links between corporate interests and university science (Rajan, 2006, 2012; Cooper, 2008).

[4] The Venture Capital market was flush with cash after a 1979 modification to the Employee Retirement Income Security Act (ERISA) that allowed for pension funds to make riskier investments with a portion of their portfolio – explicitly allowing them to invest substantially in venture funds.

REFERENCES

Ackerman, R. (2000) 'Futuristic Materials Inspired by Biological Counterparts', *SIGNAL*, 2000, www.afcea.org/signal.

Anderson, P. (2013) 'Homeland', *New Left Review* 81(May-June, 2013): 5–32.

Bakker, K. (2007) 'The "Commons" Versus the "Commodity": Alter-globalization, Anti-privatization and the Human Right to Water in the Global South', *Antipode* 39(3): 430–455.

Bardi, U. (2009) 'Peak oil: The four stages of a new idea', *Energy* 34(3): 323–326.

Biomimicry 3.8. (2012) Introduction to Biomimicry: Foundational Course (Online). Biomimicry 3.8. Retrieved from http://biomimicry.net/educating/online-courses/foundational-courses/, accessed 25 May, 2013.

Bond, P. (2010) 'Water, Health, and the Commodification Debate', *Review of Radical Political Economics,* 42(4), 445–464. doi:10.1177/0486613410375056

Brenner, R. (1989) 'Bourgeois Revolution and Transition to Capitalism', in A.L. Beier, et al. (eds) *The First Modern Society.* Cambridge, UK: Cambridge University Press.

Benyus, Janine M. (1997) *Biomimicry: Innovation Inspired by Nature.* New York, NY: Harper Collins.

Benyus, Janine M. (2005) 'Janine Benyus: Biomimicry in Action', Video on TED.com', URL (consulted May 2013): http://www.ted.com/talks/lang/eng/janine_benyus_biomimicry_in_action.html.

Braun, B. (2008) 'Inventive Life', *Progress in Human Geography* 32: 667–679.

Cooper, M. (2008) *Life as Surplus: Biotechnology and Capitalism in the Neoliberal Era*. Seattle, WA: University of Washington Press.

Cooper, M. (2010) 'Turbulent Worlds: Financial Markets and Environmental Crisis', *Theory, Culture and Society* 27, 167–90.

Correia, David. (2005) 'From Agropastoralism to Sustained Yield Forestry: Industrial Restructuring, Rural Change, and the Land-grant Commons in Northern New Mexico', *Capitalism Nature Socialism* 16(1): 25–44.

Cronon, William. (1996) *Uncommon Ground: Toward Reinventing Nature.* New York, NY: W. W. Norton & Company.

DeAngelis, M. (2004) 'Separating the doing and the deed: capital and the continuous character of enclosures', *Historical Materialism* 12: 57–87.

Dowie, M. (1995) *Losing ground : American environmentalism at the close of the twentieth century.* Cambridge, MA: MIT Press.

Ehrlich, Paul R. (1971) *The Population Bomb.* New York, NY: Ballantine Books.

Federici, Silvia. (2004) *Caliban and the Witch: Women, the Body and Primitive Accumulation.* New York, NY: Autonomedia.

Forbes, P. (2006) *The Gecko's Foot: Bio-inspiration: Engineering New Materials from Nature.* New York, NY: W. W. Norton & Company.

Friedman, Thomas L. (2009) *Hot, Flat, and Crowded 2.0: Why We Need a Green Revolution--and How It Can Renew America.* New York, NY: Macmillan.

'Global Biomimicry Efforts: An Economic Game Changer', (2010) A report commissioned by San Diego Zoo Global, November 2010.

Glover, L. (2006) 'From Love-ins to Logos: Charting the Demise of Renewable Energy as a Social Movement', in *Transforming Power*. New York, NY: Transaction Publishers.

Goldstein, J. (2012) 'Terra Economica: Waste and the Production of Enclosed Nature', *Antipode* 41(2): 357–375.

Haraway, D. (2007) *When Species Meet.* Minneapolis, MN: University of Minnesota Press.

Hardt, M. & A. Negri (2001) *Empire*. Cambridge, MA: Harvard University Press.

Hawken, P., A. Lovins, & L. Lovins (1999) *Natural capitalism : creating the next industrial revolution* (1st ed.). Boston, MA: Little, Brown and Co.

Jasanoff, S. (2012) 'Taking Life: Private Rights in Public Nature', in S. Rajan (ed) *Lively Capital: Biotechnologies, Ethics, and Governance in Global Markets*. Durham, NC: Duke University Press.

Harvey, N. (2009) 'What's Good for Life Wins: The Biomimicry Scientific Revolution', Bioneers Radio Series Podcast, available at http://www.bioneers.org/radio/series-archives/2009-series/episode-1-mirroring-nature, last accessed 22 July 2011.

Jamison, A. (2001) *The making of green knowledge environmental politics and cultural transformation.* Cambridge, UK: Cambridge University Press.

Jasanoff, S. (2012) 'Taking Life: Private Rights in Public Nature', in K.S. Rajan (ed) *Lively Capital: Biotechnologies, Ethics, and Governance in Global Markets.* Durham, NC: Duke University Press.

Johnson, E. (2010) ‘Reinventing biological life, reinventing “the human”’, *ephemera: theory and politics in organization* 10(2): 177–193.

Katz, C. (1998) ‘Private productions of space and the “preservation” of nature’, in B. Braun and N. Castree (eds), *Remaking Reality: Nature at the Millenium.* New York, NY: Routledge.

Klein, N. (2007) *The Shock Doctrine: The Rise of Disaster Capitalism* (First Edition.). New York, NY: Metropolitan Books.

Krupp, F., & M. Horn (2008) *Earth, the sequel : the race to reinvent energy and stop global warming* (1st ed.). New York, NY: W. W. Norton & Co.

Latour, B. (1993) *We Have Never Been Modern.* (C. Porter, Trans.). Cambridge, MA: Harvard University Press.

Lieberman, G. and M. Rosmarin (producers), G. Lieberman (director) (2010) *Second Nature* [DVD]. US.

Margulis, M. E., N. McKeon, & S. Borras (2013) ‘Land Grabbing and Global Governance: Critical Perspectives’, *Globalizations* 10(1): 1–23.

Marx, K. (1992) *Capital: Volume 1: A Critique of Political Economy.* (B. Fowkes, Trans.) (Reprint.) New York, NY: Penguin Classics.

Marx, K. (1993) *Grundrisse: Foundations of the Critique of Political Economy.* (M. Nicolaus, Trans.) (Reprint.) New York, NY: Penguin Classics.

Meadows, D. H., & Associates of the Club of Rome (1972) *The Limits to growth: a report for the Club of Rome’s project on the predicament of mankind.* New York, NY: Signet.

Merchant, C. (2010) *Ecological Revolutions: Nature, Gender, and Science in New England* (2nd Ed) Chapel Hill, NC: University of North Carolina Press.

Merchant, C. (1990) *The Death of Nature: Women, Ecology, and the Scientific Revolution*. New York, NY: Harper Collins.

McCarthy, J. (2004) ‘Privatizing conditions of production: trade agreements as neoliberal environmental governance’, *Geoforum* 35(3): 327–341.

McDonough, W. & M. Braungart (2002) *Cradle to cradle : remaking the way we make things* (1st ed). New York, NY: North Point Press.
McLennan, J. F. & M. A. Thomas (2011) *Zugunruhe: the inner migration to profound environmental change.* Bainbridge Island, WA: Ecotone Pub.

Milani, B. (2000) *Designing the Green Economy: The Postindustrial Alternative to Corporate Globalization.* New York, NY: Rowman & Littlefield.

Moore, S., & Simon, J. L. (2000) *It's Getting Better All the Time: 100 Greatest Trends of the Last 100 years* (First Edition.). Washington, DC: Cato Institute.

NYSERDA. (2013) 'Biomimicry: A Technique for Adapting Design Strategies from Nature for New and Improved Products', retrieved June 23, 2013, from http://www.nyserda.ny.gov/Energy-Innovation-and-Business-Development/Research-and-Development/Biomimicry.aspx

Organisation for Economic Cooperation and Development (OECD) (2005) *Proposal for a Major Project on the Bioeconomy in 2030.* Paris, FR: OECD Publications.

Pieterse, J.N. (1997) 'Multiculturalism and Museums: Discourse and Others in the Age of Globalization', *Theory, Culture & Society* 14(4): 123-46.

Polanyi, K. (2001) *The Great Transformation: The Political and Economic Origins of Our Time* (2nd ed.). Boston, MA: Beacon Press.

Prudham, S. (2007) 'The Fictions of Autonomous Invention: Accumulation by Dispossession, Commodification and Life Patents in Canada', *Antipode* 39(3): 406–429.

Rajan, K. S. (ed). (2012) *Lively Capital: Biotechnologies, Ethics, and Governance in Global Markets.* Durham, NC: Duke University Press Books.

Rajan, K. S. (2006) *Biocapital: The Constitution of Postgenomic Life.* Durham, NC: Duke University Press Books.

Robbins, P., & A. Luginbuhl (2005) 'The last enclosure: resisting privatization of wildlife in the Western United States', *Capitalism Nature Socialism* 16(1): 45–61.

Robertson, M. (2012) 'Measurement and alienation: making a world of ecosystem services', *Transactions of the Institute of British Geographers* 37(3), 386–401.

Schmitt, O. (1969) 'Some Interesting and Useful Biomimetic Transforms', *Proceedings of the Third International Biophysics Congress.* Boston, MA, Aug 29-Sept 3, 1969.

Shiva, V. (2002) *Water Wars: Privatization, Pollution and Profit.* Cambridge, MA: South End Press.

Shukin, N. (2009) *Animal Capital: Rendering Life in Biopolitical Times.* Minneapolis, MN: University of Minnesota Press.

Simon, J. (1981) *The Ultimate Resource*. Princeton, NJ: Princeton University Press.

Simon, J. L. (2006) *Hoodwinking the Nation*. Piscataway, NJ: Transaction Publishers.

Smith, N. (2007) 'Nature as Accumulation Strategy', *Socialist Register* 43.

St. Martin, K. (2005) ‘Disrupting enclosure in New England fisheries’, *Capitalism Nature Socialism* 16(1): 63–80.

Swyngedouw, E. (2006), ‘Dispossessing H2O: The Contested Terrain of Water Privatization’, in N. Heynen, J. McCarthy, S. Prudham, and P. Robbins (eds), *Neoliberal Environments.* New York, NY: Routledge.

Toffler, A. (1984) *Future Shock* (1st ed). New York, NY: Bantam.

U.S. Department of Energy (US DOE) (2004) ‘U.S. Department of Energy Performance and Accountability Report Highlights: Fiscal Year 2004’. DIANE Publishing.

Wood, E. M. (2002) *The origin of capitalism: A Longer View*. New York, NY: Verso.

Yang, Y., Chen, X., Shao, Z., Zhou, P., Porter, D., Knight, D. P., & Vollrath, F. (2005) ‘Toughness of Spider Silk at High and Low Temperatures’, *Advanced Materials* 17(1), 84–88.