



Reinventing biological life, reinventing ‘the human’*

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abstract

The techno-scientific framework known as biomimicry ‘reverse-engineers’ animal life to develop technologies and tactics that solve social and environmental problems. Its advocates have promised that it will spark a technological, environmental, and even social revolution. By viewing nature as a ‘mentor’ rather than a resource to be extracted, members of the biomimetic movement have also suggested that its practice will also overturn notions of human exceptionalism. This paper explores biomimicry’s ‘revolutionary’ potential by analyzing the work of advocates and supporters of biomimicry in the context of posthuman theory. It further places this potential in conversation with the broader economic conditions of biomimetic production. It ultimately asks how, in spite of its promises, biomimetic productions have thus far only managed to reinvent and reinforce current circuits of economic and geopolitical power. In conclusion, the paper works toward highlighting – and embracing – the ambivalence of both biomimicry and so-called post-humanism as the first step in developing a politics adequate to new forms of technological and biological production.

There is a promising *autre-mondialisation* to be learned in retying some of the knots of ordinary multispecies living on earth. (Haraway, 2008: 3)

1. Consider the RoboLobster

As biomimeticist Michael Roggero tells it, living creatures are continually emitting low-level auras of chemical compounds, ‘donating’ small portions of themselves – ourselves – to the environmental media that surrounds them. On land, such chemical effluents are released into the air and deposited on our material surroundings. Underwater, they create a plume that fans out from living things in a distance and direction governed by the velocity of the current.

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Lobsters, if you can take a moment and picture them, have two pair of antennae. Biologists consider the first and longer pair mechano-receptive: it relays information about the animal's material environment. The smaller pair is considered chemo-receptive, serving as the lobster's olfactory organ. Together, these two pair of bilaterally symmetrical antennae enable the lobster to map and track chemical plumes with considerable accuracy.¹

A human body, of course, lacks such a talent. Yet the presence of certain underwater chemical trails is associated with threats to human life as well as environmental, economic, or political stability. Oil spills, toxic effluents, chemical leaks, and underwater mines, for example, have persuaded certain humans – namely those engaged with managing threats to political and human security – to covet the chemical-tracking capacities of the lobster. Such envy has inspired imitation.

Roggero is primarily a behavioral biologist. But he is also a computer programmer and something of an engineer. Along with neuroethologist Maurice Evens and others who have been involved with such research, Roggero has conducted extensive research into the behavior and neuroethology of lobster life. Using video recordings and analytic software, scientists have tracked and quantified lobster movement on treadmills, in channels of moving water, or in large tanks that simulate marine condition. They have implanted hair-thin electrodes in their thoracic ganglia, their sub-thoracic ganglia and on down at each of the nodes of the lobster's neural network to generate readings of the electric impulses that power and coordinate its movement.

What has been gained from this research is a working body of knowledge that has generated working bodies – robots that behave like lobsters. But these robot lobsters also offer much more: within the field of neuroscience, working models of the lobster's inner life – far more simple than that of a human – serve as building blocks toward understanding more complex organisms and processes. Within the field of robotics, the lobster represents a body that can do things never before engineered, using frameworks more robust and 'lifelike' than those developed by traditional robotic programming. Beyond its benefits to techno-science, this process also transforms – even reinvents – how we consider the lobster. The lobsters in these laboratories have little relation to American cuisine,² to lobster breeding and feeding habits in the wild, or to their

1 For work on lobsters and lobster-mimesis, see: Beglane, Paul, Frank Grasso, Jennifer Basil, and Jelle Atema (1997) 'Far Field Chemo-orientation in the American Lobster, *Homarus americanus*: Effects of Unilateral Ablation and Lesioning of the Lateral Antennule.' *Biological Bulletin* 193: 214-215, Grasso, Frank. 2001. 'Invertebrate-Inspired Sensory-Motor Systems and Autonomous, Olfactory-Guided Exploration.' *Biological Bulletin* 200:260-168, Grasso, Frank, Thomas Consi, David Mountain, and Jelle Atema. 2000. 'Biomimetic robot lobster performs chemo-orientation in turbulence using a pair of spatially separated sensors: Progress and challenges.' *Robotics and Autonomous Systems* 30 115-131, Grasso, Frank, Jonathan Dale, Thomas Consi, David Mountain, and Jelle Atema. 1996. 'Behavior of Purely Chemotactic Robot Lobster Reveals Different Odor Dispersal Patterns in the Jet Region and the Patch Field of a Turbulent Plum'. *Biological Bulletin* 191: 312-313, Mjos, Katrin, Frank Grasso, and Jelle Atema. 1999. 'Antennule Use by the America Lobster, *Homarus americanus*, During Chemo-orientation in Three Turbulent Odor Plumes'. *Biological Bulletin* 197: 249-250.

2 Biomimetic robots themselves reveal little about American cuisine, but neuroethologist and biomimeticist, Joseph Ayers, does reveal much of what he has learned throughout a career of working

population growth in comparison to rates at which humans consume them. These lobsters open no new windows onto ocean ecology nor do they reveal the 'secrets' of marine life.³ They do, however, shed light on novel arrangements of humans, animals, and technology by linking biological knowledge directly to social and political problems in new ways. They also draw attention to a host of other projects hoping to bestow upon us the physiological and behavioral capacities of these (and other) animals. Research into lobster life only scratches the surface of an emerging techno-scientific framework that has come to be known as 'biomimicry': stigmergy navigation in ants and geese, gecko adhesion, bat sonar, squirrel hibernation, spider and fly vision, lizard limb regeneration, chemo-sensing in moths, the creation of spider web materials, flexibility and strength in octopus and squid arms are all part of a diverse field of objectives, methods, and tactics for making biology relevant to technological development and for harnessing the observed physiological and neurological architectures of nonhuman life to solve material problems that span species and spaces.

2. Life out of joint

This is not animism, any more than it is mechanism; rather, it is universal machinism. (Deleuze and Guattari, 1988: 283)

Biomimetic innovation is built on the detailed study of 'existence proofs' exhibited in animal physiology: an animal's capacities are taken as evidence of an existing potential already designed and engineered to work in the world.⁴ It proceeds by 'reverse engineering' the observable behaviors expressed in biological life: without fully understanding an organism's 'design code', biomimeticists attempt to engineer machinic organisms or synthetic materials capable of expressing that animal's functions. An array of techniques and technologies – chemical engineering, robotic hardware, advanced computing technologies, and mathematical modeling software – are marshaled to enhance our own techno-abilities by remaking the capacities found in biological life.

Naturalists, ecologists, and evolutionary biologists historically presented an understanding of lobsters in relation to their 'natural' marine habitat, in connection to the organisms and the nonliving systems in which they live and to which they are related. In zoology textbooks, lobsters are situated next to their kin: pages on shrimp, crayfish, and other crustaceans surround those on the lobster (see, for example, Castro and Huber, 2005). Natural historians and ecologists place primacy on how lobster

with (and eating) the crustacean subjects of his research in his cookbook, *Dr. Ayers Cooks with Cognac*. Dr. Ayers has also contributed to debates around the question of ethics in relation to the boiling of live lobsters.

- 3 See Trevor Corson's *The Secret Life of Lobsters* (2004), in which lobster biomimicry is strongly derided.
- 4 There are two purposes of biomimetic robotic design: The first uses the construction of biomimetic robots for hypothesis testing – it is presumed that if the robot behaves as the organism modeled does, the knowledge gained is an accurate representative model. The second use of biomimetic technologies is task-based: biology is mimicked so that a particular task to which the animal is suited can be performed. For further clarification, see Blazis and Grasso (2001).

bodies emerged within an historical trajectory or how they relate to other bodies within a bounded ecological assemblage. Biomimicry, on the other hand, is unconcerned with the 'place' or the 'natural' order of the organism's evolutionary development. Indeed, as a practice, it expresses little interest in where, when, and how lobsters emerged or in the crabs, clams, and shrimp related to them by networks of kinship or consumption. Instead, biomimetic scientists investigate lobster bodies for what they can do: how they orient themselves to the world and how such orientations are different from our own. Rather than being concerned with classification, biomimeticists attend to the animal's potential to connect with other forms of life, technologies, and social problems, valuing lobsters for their capacity to move with agility and track chemicals underwater.

Biomimicry's transformative potential is seductive; it is easy to fixate on how and where biomimetics shifts our conceptions of 'life'. One may be (as I was) drawn to the ways in which biomimicry is Spinozan or Deleuzian in its attention to embodied capacities and its drive to appropriate them in bodies elsewhere. Machines that become lobsters or lobsters that become machines are not, as they say, associated by 'mere metaphor'. These animals, their traits, and the products developed with knowledge of them are not valorized on account of animal symbolisms or the meanings attributed to their animality (as in Nicole Shukin's work). Rather, these animals become valued because of their functionality, efficiency, and 'natural' talents. Biomimicry breaks down bodies the barriers: animal and machine become indistinguishable as the capacities of one are substituted for another. A lobster on a treadmill is a lobster defined by its 'intensive' functions – what its neuroethology can do and how it does it. Indeed, the animals that inspire biomimetic design may be best understood as 'composition[s] of speeds and affects on the plane of consistency: a plan(e), a program, or rather a diagram, a problem, a question-machine' (Deleuze and Guattari, 1988: 258). This biological apparatus thus can be read as a set of 'intensive parts': powerful and embodied capacities for action that are transferable from one body to another to solve any barrier to movement as the need – or question – arises. Read in this way, biomimetic practices are perhaps less 'post-human' than post-animal or post-species altogether.⁵

Supporters of the so-called biomimetic movement have billed it a 'revolution' in technoscientific innovation. But what kind of revolution is this? What are we to make of these rearrangements of biology and technology? Do lobsters and their robotic counterparts merely offer a vivid illustration of Deleuze and Guattari's machinic assemblage of bodies and relations of moving parts? Or is there something more potent – politically, ethically, socially – to be expected from biomimicry's techno-biologies? Advocates of biomimicry would have us think as much. So too would much of the existing literature in 'post-humanism' and animal studies.

5 I agree with Haraway's contention that Deleuze and Guattari 'don't give a flying damn about animals', at least not as such, even in their chapter on 'Becoming Animal' (Gane and Haraway, 2006: 143). While animal life may be merely used as a foil for their anti-oedipal project, Deleuze and Guattari's dedication to unnerving human exceptionalism and associated subject positions in favor of 'machinic assemblages' and relational 'becomings' does take us 'beyond the human', if not in the direction that Haraway herself would like to move.

Historical traditions founded on a purified category of 'the human' absorb the blame for many of the problems characteristic of our contemporary global situation. Giorgio Agamben's figuration of 'bare life' encapsulates this argument in what are perhaps the starkest of terms. A life is rendered 'bare' when it subject to exclusion from the protections provided by law or social securities: the taking or neglect of 'bare life' requires no accountability. Agamben argues that such a state is predicated on the philosophical distinction between human and animal, a distinction that allows for the subsequent attribution of 'animal' qualities to the lives of humans. As inferior to but resident within 'the human', category of 'the animal' legitimizes the labeling of populations as 'unfit' for life in the polis, be they excluded on the basis of race, religion ethnicity, gender, class, or geographical origins (Agamben, 2004). In *The Open*, Agamben explores the history of science and philosophy that articulates this process of categorization as a legitimation of exclusion. He names this process the 'anthropological machine'. Following this logic, Kelly Oliver notes that the human and animal, distinguished as such, serve as the founding concepts that ground acts of injustice and cruelty to humans as well all other species: 'the anthropological machine... produces the monstrous category "animal" that not only effaces nearly infinite differences between species but also corrals them all into the same abject and inferior pen' (Oliver, 2007: 11).

Similarly, but from within a more materialist tradition, Donna Haraway's *Cyborg Manifesto* catalyzed a conversation that has located the negative qualities of science and politics in the 'Western' tradition – 'racist, male-dominant capitalism; the tradition of progress; the tradition of the appropriation of nature as resource for the productions of culture; the tradition of reproduction of the self from the reflections of the other' – within origin myths of purity and the maintenance of a 'border war' a between organisms and machines as well as humans and animals (Haraway, 1991: 150).

The appointed 'guru' of the biomimetic movement and recent recipient of the UN's 'Champion of the Earth' award in Science and Innovation, Janine Benyus, has composed a narrative of the our ecological crisis and its associated injustices that resonates with both Agamben and Haraway's work. She locates our collective crisis on Earth in the 'severed' connection between humans and the Earth. As in Agamben's narrative, this loss of connection is the result of an originary rupture, located in this instance with the agricultural revolution. We have lost, she laments, 'cooking fires to storytell around [and] ceremonial dances to reenact the movement of the herds' (Benyus, 1997: 183). But, for Benyus, historical progress has been one of a continual series of such ruptures, each inaugurated by technological development, and each leading humans further from what Benyus refers to as 'our home'. The following is her version of the historical narrative:

Our journey began ten thousand years ago with the Agricultural Revolution, when we broke free from the vicissitudes of hunting and gathering and learned to stock our own pantries. It accelerated with the Scientific Revolution, when we learned, in Francis Bacon's words, to 'torture nature for her secrets.' Finally when the afterburners of the Industrial Revolution kicked in, machines replaced muscles and we learned to rock the world. But these revolutions were only a warm-up for our real break from Earthly orbit – the Petro-chemical and Genetic Engineering Revolutions. Now that we can synthesize what we need and arrange the genetic alphabet to our liking, we have gained what we think of as autonomy. Strapped to our juggernaut of technology, we fancy ourselves as gods, very far from home indeed. (ibid)

Benyus's history of our collective loss of connection to the earth is a story of compounding catastrophe that calls to mind Walter Benjamin's *Angelus Novus*, who 'sees one single catastrophe, which keeps piling wreckage upon wreckage and hurls it at his feet' (Benjamin, 1996: 392).

3. Remaking life, remaking the human

Life creates the conditions conducive to life. (Benyus, 2002)

For Benyus as for Agamben, salvaging a saner life from the wreckage of history seems to require somehow absolving ourselves of 'original' catastrophe by rearticulating the human (and animal) differently. Indeed, like all of the aforementioned theorists, Benyus calls for dismantling conceptions of human exceptionalism that seems to have become increasingly sedimented throughout history as the 'wreckage' is piled higher and higher. For Agamben – as well as Kelly Oliver and Cary Wolfe – this requires the destabilization or even erasure of the categories of human and animal through the recognition of shared limits, vulnerability, or an embrace of Derrida's 'nonpower at the heart of power'. Haraway, along with Bruno Latour, Michel Serres, Sarah Whatmore, and Jane Bennett, attempts to rework the 'human' in practice, by writing of bodies-in-relation – bodies that have 'never been human' in spite of the centuries of philosophical and political writings that seem to assure the contrary. These writers enliven alternative histories, citing empirical evidence of our becomings with objects, animals, and bacteria and telling stories in which 'the human' is neither the protagonist nor even an active agent. Like the work of Deleuze and Guattari, these histories are meant to transform how we envision our own life activity. Together these authors all suggest that we not only recognize and acknowledge, but also actively practice ever-changing 'strange kinships' that '[allow] for an intimate relation based on shared embodiment without denying differences between life-styles or styles of being' (Oliver, 2007: 18); we are encouraged to reproduce life as if we were accountable for the entire 'universal machine' rather than the individuals and groups (some, although not others) who we have selected out of it. For Haraway, this consists of 'retying the knots of multi-specied living on earth' (Haraway, 2008: 2) and better attending to the 'sym-bio-genesis' of all beings by recognizing that they are "the fruit of 'the co-opting of strangers, the involvement and infolding of others into ever more complex and miscegenous genome'" (Margulis and Sagen, quoted in Haraway, 2008: 31). Accordingly, such transformations in how we practice everyday life and how we imagine our own subjectivities offer the potential to enact 'autre-mondializations' – alternative global political arrangements divorced from neoliberalism and liberal humanism (Haraway, 2008).

Janine Benyus's work and that of the biomimeticists with which she is associated seem to follow through on these recommendations in practice. While less Continental philosophy than New Age, Benyus's 1997 book, *Biomimicry: Innovation Inspired by Nature*, describes a collection of projects that suture together the now existing pieces of our historical 'wreckage' with the products of biological histories. The ultimate aim is to remake how we make technologies by modeling them on biological structures and functions. Rather than blindly push forward with a vision of technological 'progress'

whose outcomes are unknown, we can look to nature to identify how it creates the conditions for life's expansion. As she explains:

Evolution itself is believed to have occurred in fits and starts, plateauing for millions of years and then leaping to a whole new level of creativity after crises... my hope is that we'll have turned this juggernaut around, and instead of fleeing the Earth, we'll be homeward bound, letting nature lead us to our landing, as the orchid leads the bee. (Benyus, 1997: 5)

This is not all, however, as according to Benyus, engineering a future that is both 'calm' and sustainable requires more than the technological fix that biomimicry promises. Rather, it also requires fixing what we broke in the Agricultural Revolution in her narrative: our connection to the earth. And this, she suggests, is the ultimate promise of biomimicry – that it will undermine the conceptions of human and nonhuman life upon which the traditions of technological production and progress were built.

Print and online news media outlets view biomimetic productions with a sense of profound irony: journalists approach the idea that scientists at elite institutions and engineers at multinational corporations are looking to 'lowly creatures' to teach them how to overcome technological and conceptual roadblocks with humor (Gaidos, 2010: 22; Stresing, 2003). Benyus, however, foregrounds the potential for biomimicry to unsettle our notions of human exceptionalism as its most profound contribution. Rejecting a human-environment relationship best characterized by extraction, exploitation, and domination, Benyus characterizes biomimicry as a means of production founded on mutual enhancement and education: it's not 'what we can *extract* from nature, but ... what we can *learn* from her' (Benyus, 1997: 2, emphasis in original). For her, biomimetic production is not about using animal life (or using it up), but about exploring it as a source of enchantment and inspiration. And, for Benyus, this is the true hope of biomimicry: that they will engender a more respectful, responsible, and humble engagement with nonhuman as well as human life.

When we view nature as a source of ideas instead of goods, the rationale for protecting wild species and their habitats becomes self-evident. To have more people realize this is my fondest hope. In the end, I think biomimicry's greatest legacy will be more than a stronger fiber or a new drug. It will be gratitude, and from this, an ardent desire to protect the genius that surrounds us. (Benyus, 2008)

By transforming how we make everything from plumbing pipes to robots, Benyus argues that biomimicry naturally stretches the categories of human and nonhuman beyond their limits, shaking the foundation of human exceptionalism and forging more collaborative engagements with nonhumans for a more democratic and sustainable future. If we accept these conclusions, such engagements not only promise to solve our ecological crisis, but also the problematic social and political conditions that have led to it. Just as biomimicry disintegrates what we know of 'lobsters', Benyus and other advocates promise that it will break apart the human, locating it *elsewhere*, outside of itself in such a way that it can no longer refer back to an essential identity or reproduce an idealized image of human nature. Read through this lens, biomimicry might suggest an end to the 'lethal and bloody' operation of the 'anthropological machine' through a re-making of production and the reconsideration of the how humans, animals, and other things come together to produce things and, subsequently, to produce the world. Its practice of transgressing traditions borders and its emphasis on inspiration over

appropriation seem to offer a foundation for modes of production that are more ethical, more attentive to and responsible for the bodies with which we produce. In Benyus's words, 'We will have to climb down from our pedestal and begin to see ourselves as simply a species among species, as one vote in a parliament of 30 million. When we accept this fact, we start to realize that what is good for the living Earth is good for us as well' (ibid).

While ambitious, I think we want to take these wagers on the future and the transformations they promise – both those of biomimicry and posthuman theory – seriously. But can either one really follow through on them? It may be that we can't know the answer to that in advance, but, perhaps more to the point, we may not be able to develop an adequate response to biomimetic production – or to understand its ethical and political implications – until we better understand the conditions of its making. Following Haraway, we might ask, 'what is the apparatus of production of these new sorts of being?' (Haraway, 2008: 157). For those desiring transformation to either 'racist, male-dominated capitalism' or an end to the 'anthropological machine' the answer may be less than promising.

4. Futures beyond I: Biomimetic capitalism

Bio-inspiration is a genuine new frontier. (Forbes, 2005: 6)

Benyus, along with a 'revolutionized' and now-humbled cadre of biomimetic designers, has very little to say about the politics of production in writing or in her lectures. Yet her work reveals much about political economies. In conjunction with her sustainability narrative and urgent call for the overturning of human exceptionalism, Benyus and other advocates of biomimicry celebrate its potential as a working framework for 'greening' – and profiting – industrial capitalism. Benyus's consulting firm, the Biomimicry Guild (she is both its principal founder and 'innovation consultant'), seeks to link together industrial and commercial manufacturers with biological knowledge to create more sustainable and solidly-engineered products and practices. They refer to themselves as 'nature's translators'. The service they provide to enterprises and industries offers '∞ possibilities for innovation and sustainability'. Their website explains:

For centuries, biologists have been in labs and fields taking notes on the adaptive strategies life has developed. Unfortunately, much of this information is inaccessible, locked up in technical, scientific papers written for other biologists, and rarely organized by engineering or design function.

The Biomimicry Guild has proven methods and experience in accessing [biological] information. We have a staff of biologists, known as BaDTs (Biologists at the Design Table), who excel at searching through biological research to find the natural strategies that meet your company's challenges, and then assessing which of those designs, chemical recipes, or system strategies are most promising for your needs. Our staff is also adept at taking complex and technical biological data and translating it into language digestible by any business department, from marketing to R&D. (Biomimicry Guild, 2010)

The Guild has been seemingly successful in selling its consulting services and its BaDTs have delivered on providing innovative ideas that cut costs, boost efficiency, and heighten sustainability. Their client list boasts an impressively diverse array of over 140 companies and institutions. A selection of these includes colleges and universities (including Stanford, Ishida University, UNC-Chapel Hill, Oberlin College), environmental and sustainability nonprofits (Sierra Club, the Land Institute, Rocky Mountain Institute, UK-based Forum for the Future, Bioneers), ecofriendly product corporations (Seventh Generation, Patagonia), states and state institutions (State of Montana, NASA, the EPA, US Fish and Wildlife Service, Washington State Department of Ecology), architecture and design firms (HOK Architects, American Society of Interior Designers, David Oakey Designs, Design Futures Council) as well as multi-national corporations (Dupont, Coca-Cola, the Dial Corporation, Boeing, Hewlett-Packard, General Electric, Nike, and Proctor and Gamble). Participation by companies and institutions in the biomimicry movement is meant to 'revolutionize' the products and services of these corporations, opening up new avenues for 'sustainable innovation'. The Guild's service to clients involves workshops 'on-site' at corporate or institution headquarters or 'field excursions' to Montana, Costa Rica, Mexico, South Africa, India, or other pre-designated locales. BaDTs take their clients through a four-step process in which they (1) boil down client needs to 'functional essence', (2) 'biologized' those needs by asking 'how would nature do this?', (3) generate a compendium of biological resources that answer that question and can address the client's needs, and (4) translate those natural functions into client-specific products and processes (Biomimicry Guild, 2010). The promise of the Guild is that such methods will generate not only innovative ideas (on their website, they assure that 90% of the 'best practices' they generate will be new to clients), but also that they will be cost-effective and 'inherently life-friendly and sustainable' (ibid).

While the 'needs' that require 'biologization' are those defined by the institutions and enterprises who can afford to invest in the Guild's consultation services, the Guild's hope is that 'biologizing' those needs will render them commensurate with the needs of planet. This hope is woven into the rhetoric of their website and in their brochure material and places their practice solidly within the growing industry of consultants and corporations actively working to 'green' capitalism. And, if their own literature does not make this point obvious enough, Benyus's work on biomimetics has been cited in seminal texts advocating eco-friendly profit generation. Jonathon Porritt's *Capitalism as if the World Matters* turns to biomimicry to suggest that sustainable capitalism does not mean 'an end of the huge global companies that have become so powerful over the last 20 years', but rather that it might 'really become a genuine "force for good", as well as a continuing engine of profit generation' (Porritt, 2005: 88). The authors of *Natural Capitalism: Creating the Next Industrial Revolution* – Paul Hawken, and Amory and L. Hunter Lovins – offer a similar perspective. They share Janine Benyus's views of both industrial history and potential futures of sustainable living and, like Benyus, present a vision of contemporary society at a crossroads: one path leads toward ecological (and subsequently social) crisis and another ends in a utopian scenario fueled by biomimetic innovation.⁶ This utopia is one characterized by both ecological stability and economic

6 Also like Janine Benyus, Paul Hawken and Amory Lovins work with and in industry as consultants and, in Hawken's case, as an engineer and entrepreneur. Hawken founded Highwater Research, a

expansion. Producing it, according to Hawken *et al.*, entails a revaluation of natural resource wealth *as* natural capital. For them, an incorporation of the externalities that so often are either ignored or stolen (through environmental degradation or the production of waste and general resource exploitation) into the market is necessary to promote 'responsible stewardship and prosperity'. This includes the promotion of biomimetic design and the creation of 'closed cycle' systems of production and waste (tying biomimicry to Walter Stahel's 'cradle to cradle' model of production developed two decades prior⁷) (Hawken *et al.*, 1999: 10).

Emulating the way in which nature makes things work – and makes them work efficiently – not only produces more sustainable systems of production, but also opens up exciting new 'frontiers' for innovation. Peter Forbes's book, *The Gecko's Foot*, explores the discovery of this 'new frontier': advances in biological science and microscopy better equip scientists to reveal the 'secrets' of how organisms function. Biomimetic production for Forbes – he refers to it as 'bioinspired' – can be geared as easily to generating sustainable profits as it can be toward producing sustainable ecosystems. His book showcases a series of commodities that scientists and their collaborators in industry have brought or are hoping to bring to the market, including paints, glass, and 'stone' products that are 'self cleaning' as a result of a structural composition on the molecular level that mimics the surface of a lotus leaf; Gecko Tape that adheres to dry and aqueous surfaces using Van-der-Waals forces at the nanoparticle scale as gecko feet do; and protective armor made of spider silk (Forbes, 2006). By offering more efficient models for production as well as potentially cheaper production materials, 'nature' is touted as an effective way to keep profit margins viable in a tight economy, particularly as industry is coerced by a public increasingly concerned with 'nature's limits'. As Robert Ackerman has suggested, the nonhuman environment may just be the 'ultimate free market for selecting effective structures' for technological development and engineering (Ackerman, 2000).

More than opening up new frontiers for technological production, the turn toward biomimicry may also be opening up a new category of workers. The Biomimicry Guild's BaDTs, for example, do the work of translation between the nonhuman world (or the biologists who produce knowledge about it) and engineers, service providers and designers who seek to produce from it. Beyond this, the San Diego Zoo has recently begun a program in which they hope to serve as the repository of biological inspiration: with one of the largest and most diverse collections of flora and fauna in the world, the

Socially Responsible Investing Research Firm; he is the CEO of PaxIT and PaxFan, subsidiaries of Pax Scientifica, an engineering firm that develops bioinspired cooling technologies; and he is the founder and Executive Director of the Natural Capital Institute, which runs the 'Wiser Earth' program, a social and professional networking tool that connects people and projects dedicated to environmental and social justice. Amory Lovins is Cofounder, chairman, and chief scientific officer of the Rocky Mountain Institute (RMI), a nonprofit dedicated to conserving natural resources through promoting efficient energy use. RMI works 'extensively with the private sector, as well as with civil society and government, to create abundance by design and to apply the framework of natural capitalism' (www.rmi.org).

7 For the original citation, see Stahel (1984). However, William McDonough and Michael Braungart's book, *Cradle to cradle: Remaking the way we make things*, served to define and publicize the movement, of which biomimicry is now an integral part.

zoo offers a 'multidisciplinary set of scientific and behavioral expertise and world-class facilities [that] can help you unlock nature's secrets and solve real-world problems with answers that have already been developed in nature' (San Diego Zoo, 2010).

While the narrative of ecological salvation remains very much in play in these contexts, advocates of the bio-inspired enhancement of industrial production has most often emphasized sustaining or expanding capitalism over sustaining or better serving human and nonhuman life-as-such. Beneath the rhetoric, advocating for green capital seems less about transforming our modes of production than intensifying them. The Biomimicry Guild itself promises a revolution in the forms of production. What it really seems to advertise to potential clients, however, is not greater sustainability, but rather endless possibilities for solving barriers to production: 'Whatever your company's design challenge, the odds are high that one or more of the world's 30 million creatures has not only faced the same challenge, but has evolved effective strategies to solve it' (Biomimicry Guild, 2010). Delivering on these promises may do more to expand capitalism's reach into the 'new frontiers' of environmental conservation and biological life – making all of 'the world's 30 million creatures' measurable and managed within the logic of capital – than they do to inject biological principles or social ethics into our present modes and methods of production. This seems to simply pervert Haraway's aims as well as those of Benyus: instead of rendering us accountable for the world – for all of the natural resources to which we are indebted – it only renders those resources quantifiable within the metrics of capitalism. As such, Benyus's hopes of transforming the relationship between human and nonhuman life lose their grounding. Rather than transforming nature into a 'mentor, a source of ideas and wisdom', its present status as a 'warehouse' seems likely to persist – only the potentials of its use have been expanded.

5. Futures beyond II: Military biomimetics

In addition to its cultivation within circuits of green capitalism, biomimicry has also been understood as an efficient way of altering the field of national security and battlefield combat. Social and technological transformations throughout the latter half of the twentieth century provoked a paradigm shift in national defense interests that came to be known as the latest US 'Revolution in Military Affairs' (RMA). In the late 1990s, the rise of asymmetrical warfare, non-state conflicts, guerrilla tactics, urban battlegrounds, rapid technological change, and environmental insecurities threatened to render conventional military doctrine (not to mention our 'social fabric') obsolete (Kaplan 1994, see also: Mazarr, 1994; Atta, *et al.* 2003; Bernstein, 1989; Jablonsky, 1994). As a result, the Department of Defense (DoD) has increasingly woven the promise of advanced technologies into a narrative of military crisis and technological salvation. As Michael Mazarr's text on the early days of the RMA narrates, '[a] powerful combination of social, technological, and political developments is revising the role of military force in national policy and changing the way wars are fought. In responding to this dizzying pace of change, our challenge... [is] to seize the opportunities of this new era in warfare, to make it work for us rather than against us' (Mazarr, 1994).

To achieve these goals, the most recent RMA in the US was designed primarily to advance technologies of 'surveillance, C3I [command, control, communications, and intelligence] and precision munitions [with new] operational concepts, including information warfare, continuous and rapid joint operations (faster than the adversary), and holding the entire theater at risk (i.e., no sanctuary for the enemy, even deep in his own battlespace)' (Krepinevich, 1994, quoted in Hundley, 1999: 8). But for the past 20 years, developing the technology to do this has gone beyond computers and traditional advances in machinic development and into (re)producing what bodies are and what they can do through biotechnology and, increasingly, the modeling of technological apparatuses on existing biological capacities.

Along with a smattering of projects that have developed with the support of the US Army, Air Force, and the Office of Naval Research, the Defense Advanced Research Projects Agency (DARPA), has been the heaviest supporter of research and development projects in biomimetic design. While the agency casts a wide net, DARPA has increasingly turned toward emulating such animal capabilities as a means of fulfilling its mission to 'accelerate the future into being'. While Defense-funded projects based on biomimetic principles began as early as the 1980s, biomimetic technologies for national defense began to be incorporated into research and development strategies of the different arms of the DoD around the turn of the century. In the late 1996, then head of the Defense Sciences Office at DARPA, Alan Rudolph, developed the 'Controlled Biological Systems Program' (CBSP), which involved the manipulation of biotechnologies as well as early research into biomimetic, design. Until their cancellation in 2010, the bi-annual DARPA Tech conference routinely brought together managers of defense research and development programs with scientists and developers in industry and academia to reveal and presage cutting edge biomimetic materials and technologies. DARPA Tech 1999 featured a series of conversations and discussion forums designed to strategize how to effectively bring biological research to bear on the development of defense technologies. As DARPA manager Dr. Stephen Squires put it in a talk entitled 'DARPA BioFutures', 'The challenge is to translate the emerging vision into action to begin adding the "Bio Dimension" to DARPA Futures to accelerate the process of discovery and enabling revolutions' (Squires, 1999).

Since the late 1990s, the 'bio dimension' has been heavily integrated into DARPA programs as well as other branches of the DoD. In 2000, the US Army made biomimetics a 'Strategic Research Objective' and CBSP had developed into a DARPA Defense Sciences Office (DSO) program for 'Biologically Inspired Platforms and Systems'. As the DSO explains, 'nature has evolved truly remarkable capabilities that, if properly understood, would create significant new defense capabilities. DSO's efforts focus on understanding, and then emulating, the unique locomotion and chemical, visual, and aural sensing capabilities of animals' (DARPA, 2008). Indeed, more than ecological salvation or the greening of capitalism, this narrative of biomimicry as a means toward geopolitical salvation has generated considerable scientific research as the Army, the Navy, the Airforce, and DARPA have funded collaborative research relationships around biomimetic design increasingly over the past 20 years. DARPA alone has generated a host of biomimetic projects: from the RoboLobster to gecko-inspired 'Z-Man' suits designed to enable soldiers to move vertically through urban battlespaces, the agency's three-billion-dollar research and development budget serves

as a significant funding source for biomimetics. Additionally, the Army's Institute for Collaborative Biotechnologies (to name just one example) has organized teams of over 60-university research faculty at three institutions with the goal of developing 'revolutionary technological innovations in bio-inspired materials and energy, biomolecular sensors, bio-inspired network science, and biotechnological tools' (ICB, 2005).

Within the scientific landscape of defense-driven biomimetics, its practice is not necessarily (or not at all) understood in terms of securing the future of human or ecological life as such. Indeed, the military's appropriation of biomimetic technologies has no truck with dreams of creating 'conditions conducive to life' or of dismantling notions of human exceptionalism, even when the biological sciences and biomimetic technologies are harnessed to ensure the lives of US warfighters. The DoD enrolls these practices in order to preempt emergent political threats to the present geopolitical order; they are used as a means of developing technologies that enable the 'full-spectrum dominance' of battle spaces as well as the emerging geopolitical landscape. Rather than serving life, biomimetic technologies instead serve to eliminate conditions that would allow for alternative futures – those disconnected from or in opposition to the legitimacy of US geopolitical power – to emerge into being.

6. Redirecting the narrative

After 3.8 billion years of research and development, failures are fossils, and what surrounds us is the secret to survival. (Benyus, 1997: 3)

In a recent Bioneers podcast – an online radio program with a tagline 'revolution from the heart of nature' – host Neil Harvey suggests that biomimicry will ultimately 'guide human ingenuity and our political will' (Bioneers, 2009). This too is the hope Janine Benyus as well as that of many posthuman theorists: that a reinvention of lobsters and, by extension, humans may revolutionize how we conceptualize and interact with 'life' of all forms. Benyus's narrative of human's historical progression and the biomimetic 'return-to-come' imagines a political and ethical milieu transformed by the material practices of production. The very act of making of technologies truly biomimetic, she seems to suggest, will ensure that we produce 'conditions conducive for life'. Much of the literature on posthumanism seems to lend weight to this argument. As Haraway suggests, when we 'become with' one another in new ways, we shift who and what we consider as qualified and relevant for political life. The making of productive encounters that decenter the human and place it outside of itself is said to present a ground upon which the future – future ethics, future politics – can be open. Biomimetic science seems to do exactly this by being open to biologies and biological processes that do what and go where our bodies cannot, thereby putting us in intimate conversation with both the limits of 'the human' and the vast potential of life outside it.

These promises of biomimetic technologies – that they will generate a revolution in how we live by recreating conditions conducive for life – are certainly tantalizing. However, if biomimetic practices are better suited to creating conditions conducive for capital and national defense interests, what then, if anything, is being transformed? Given the apparatuses of production that have thus far cultivated the biomimetic

movement, can we remain optimistic about the transformative political will that it engenders? As we shift our conception of nonhuman natures to understand it as 'our biggest and best R&D library' productive of 'elegant and efficient' design solutions (San Diego Zoo, 2010), do we really break from histories of anthropocentrism and resource exploitation that have been integral to geopolitics as well as industrial and post-Fordist capitalism? Or, are the biologies of biomimicry only incorporated – and inoculated – within them?

Melinda Cooper's work on the 'biologization' of the political economy in the US at the turn of the 21st Century might suggest the latter. Her work has explored the concept of 'emergence' in microbiology – descriptive of the tendency of bacteria and viruses to develop resistance in unpredictable ways – and its circulation within social movements, finance capitalism, and geopolitical strategies in the 1980s and 1990s. She reveals how biological science transformed political and economic life, but was ultimately used to advance US projects of neoliberalism and geopolitical security. In her account, narratives of 'emergence' induced the environmental movement, financial institutions, and national defense priorities to collectively adopt strategies that would guard against a myriad of catastrophes that *could* be imminent. The result was a political and economic system built around preemption. What these transformations ultimately ensured was the 'actual institutional conflation of security and public health research, military strategy, environmental politics, and the innovation economy' (Cooper, 2008: 98). Cooper contends that this conflation better allowed US government institutions and corporations (particularly under the Bush administration) to capitalize on biological and social reproduction and to 'expand the scope of legitimate security interventions' in all forms of life, domestic and foreign. Read in such a light, the robotic lobsters of the 'biomimetic revolution' fall squarely within this nexus of economic, political, and biosphere security. Although the DoD's bellicose visions of a future populated with biomimetic objects appear at odds with Janine Benyus's call to disarm conventional conceptions of human exceptionalism and regimes of production based on nature's mastery, the project of securitization – geopolitical and environmental – unites them. Indeed, despite the rhetoric, biomimicry advocacy organizations place primacy not on biomimicry's potential to transform, but to securitize, offering salvation in the form of ecological sustainability. Rather than opening up a posthumanist future, this narrative ultimately serves to reproduce an intensely conservative one of humans and animals reunited in a prelapsarian utopia.

The Biomimicry Guild's characterization of evolution is emblematic of this as they express evolutionary development as 'progress' rather than a contingent process. The nearly four billion years of life on earth has, in the Guild's rhetoric, proceeded linearly, accumulating 'wisdom' and skill along the way and achieving 'optimal' states of being. It is a discourse that invigorates thoroughly deposed interpretations of nonhuman natures and pre-human pasts as 'harmonious' and 'balanced'. As biomimetic production is made to promise a 'return' to such a state, it is charged with generating the environmental and social security required to get there. It is around this point where Benyus's vision in *Biomimicry* diverges from that of Haraway, Agamben, and other posthumanist theorists: such a future necessitates a present-day politics that operates by way of qualifying life, human and animal, to achieve its ends. And, while these narratives may displace essentialized conceptions of the animal and human, they

inadvertently revive the essentialism of nature, reinscribing the notion that nonhumans – and, by extension, their reinvention – are righteous and apolitical. Biomimetic production so conceived does not merely open new avenues for production; it imagines instead that it opens up access to the 'right ones', eliminating the potential for ecological, geopolitical, and economic contestations. The 'political will' that such a view engenders is one of acquiescence and blind acceptance of 'nature's wisdom' however it may be taken up and applied. As such, the conditions of biomimicry's production are easily sidelined, hidden behind a fascinating story of the recomposition of human and nonhuman productions.

At the end of the day, the question to be asked about biomimetics may not be whether or not it destabilizes 'the human', but rather about the ways in which its 'ever more complex and miscegenous genome[s]' (Haraway, 2008: 31) are incorporated within capitalist and geopolitical frameworks. The question that then remains is: can these practices still disrupt anthropocentric narratives of progress and securitization in order to produce futures that are not projected toward life's salvation, but toward its expansion? I would like to respond with a cautious yes, but only if we attend to what biomimicry actually teaches us: that natures – human or non, produced or reproduced – can be understood as neither 'right' nor optimal, but as radically ambivalent. If that is the case, our response to these transformations ought to be neither overly sanguine nor hopelessly fatalistic. To follow either path would be to imagine that biomimicry's processes of reinventing nature will automatically guide our political will in a direction most conducive for 'life', however that is defined. The task may instead be to develop a political will that is adequate to these new forms of production as well as the changing needs and meanings of human and nonhuman life-as-such. Such a response would first require a more militant inquiry into the contemporary social and political frameworks amid which these multi-specied encounters emerge, noting where and how they engage with the maintenance of geopolitical and biopolitical productions. It may also require a move away from questions of posthumanism or sustainability and toward what Melinda Cooper has referred to as 'creative sabotage of the future' (Cooper, 2006: 129). And what we may wish to sabotage is not only our traditional conceptions of humans and nonhumans, but also the conditions of production that presently coordinate the connections between lives on earth.

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