The Creation to Come: Pre-empting the evolution of the bioeconomy

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Directing the Evolution of the Bioeconomy

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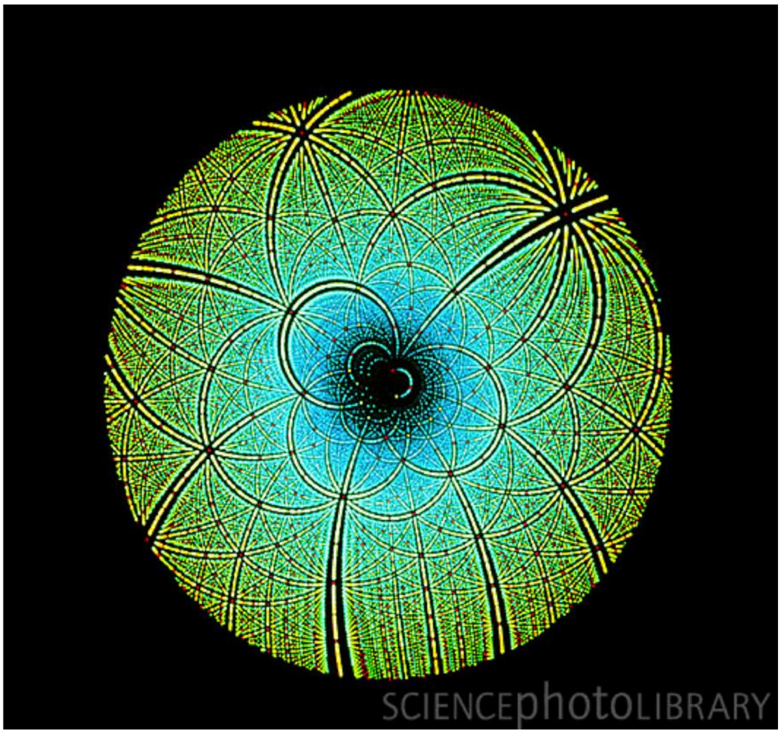

Laue diffraction pattern from a crystal of the enzyme Rubisco, essential to photosynthesis (ribulose bisphosphate carboxylase/oxygenase).[1]

Introduction

This chapter considers 'the emerging bioeonomy', a tangle of ill-defined utopias that have arisen in acknowledgement of the intensifying confrontation of modern industry with planetary processes. Although dampened by the lingering economic crisis, an official discourse anticipating an evolutionary leap to a 'knowledge-based bioeconomy' has maintained currency in the vision statements of the European Union, the United States, and other 'post-industrial' economies (e.g. European Commision 2005; White House 2012). The International Futures Programme of the OECD invites us to imagine the bioeconomy as:

> a world where biotechnology contributes to a significant share of economic output. The emerging bioeconomy is likely to be global and guided by principles of sustainable development and environmental sustainability. A bioeconomy involves three elements: biotechnological knowledge, renewable biomass, and integration across applications (Arundel and Sawaya 2009: 22).

Much of the critical literature conflates 'the bioeconomy' with biomedicine and Big Pharma, but the vision I am interested in here concerns *industrial* biotechnologies. At stake is a fundamental transformation of basic industrial processes, in which our current dependence upon fossil fuel combustion and petro-chemistry can be surpassed, through the harnessing of the immense genetic, metabolic and functional diversity of the largely unexplored microcosmos.

Microorganisms are ubiquitous, the pioneering ecological engineers of every corner of the planet. Single-celled organisms defy pre-genomic species concepts, due to a propensity for rapid evolution via horizontal gene transfer. They are nonetheless incredibly diverse. Of the billions of species of bacteria supposed to exist, less than 5% are thought to have been classified. As the biodiversity of microbial life is mapped, sequenced and screened, in mind is their potential to be re-engineered and synthesised as replacements for the destructive pyro-chemical processes at the heart of industrial production. Industrial biotechnology, according to Vandamme:

> exploits the genetic and biochemical machinery of useful microorganisms (bacteria, fungi, yeasts, and microalgae) and of higher cells for the synthesis of fine and bulk

> chemicals, pharmaceuticals, enzymes, biomaterials, and energy, using renewable resources rather than fossil ones. [...] Scientific breakthroughs in high-throughput screening methodologies, in molecular genetics of industrial microbial strains, in systems (micro)biology, in directed evolution, metabolic engineering, and modeling, but equally in enzyme and cell engineering, in novel culture techniques, rapid sampling and sensor methodologies, in bioreactor design and in downstream processing all have contributed to the growing interest and impact of industrial microbiology (2010: 254).

Synthetic chemicals, plastics and polymers, abiotic, xenobiotic and antibiotic, are to be replaced by novel substitutes produced by novel life-forms, at the low temperatures at which carbon-based biochemistry occurs, thereby saving energy (Herman 2007). The waste products of bio-based production will be fully biodegradable. Algae-based biofuels that can be grown in any rooftop tank or dam, or farmed at sea in floating chambers, could replace oil-based fuels. The unassimilable pollution of synthetic petro-chemistry could be neutralised through bioremediation.

In certain futurologies, the intensive capitalisation of microbial life will overcome the limits to growth represented by peak oil, bio-depletion and global warming. Retrieving the infinite frontier through downward rescaling, the US Department of Energy (2005: 5) enthuses that the "[u]nique microbial biochemistries amassed over eons in every niche on the planet now offer a deep and virtually limitless resource that can be applied to help enable biobased solutions for national needs… microbes produce energy… and… may be used to clean up environmental contaminants and control the cycling of carbon." However, beyond policy documents, technical articles, investment reports, or cyber-libertarian prophecy, there are few serious treatments of the world-making and world-redemptive promise of industrial biotechnology. By comparison with the GM food or stem-cell debates, civil society has been almost silent. WWF (2009) has offered endorsement, whilst the activist ETC Group warns of the corporate control of life and the irreversible transgenic accident. Scholars have noted the discursive neoliberalisation of knowledge and nature in the bioeconomy policy literature (Birch, Levidow & Papaioannou 2010). Yet there is more to be reckoned with here than a set of corporate interests seeking policy favour. Since the economy of life as we know it is at stake, it would seem that the 'thought bubble' of the bioeconomy should be treated with greater gravity. The mainstream canon of economic thought, insofar as it insists on explaining economic phenomena *subjectively* in terms of individual decisions to buy and sell in response to price movements whilst refusing scientific-materialist accounts of 'production', is deeply implicated in the political paralysis that prevents us from facing the crisis of the biosphere. Here I argue that even when articulated in the most conventional of terms, the discourse of the bioeconomy implicitly invokes a *vital materialism* which may yet be articulated into a profound ontological critique of the anti-materialist and anti-biotic tendencies of economics. The civilizational project for a bio-based economy is vitally important, and must remain open to capture and redefinition by democratic, non-neoliberal movements.

In its quest to present market exchange as natural, mainstream economic thought has always craved the prestige of natural science, and sought it via metaphorical appropriation; of energy physics by neoclassicals (Mirowski 1989), of Darwinism by the Austrian school (Hodgson 2002), and of both by the neoliberals and sociobiologists at the *Journal of Bioeconomics*. As economists have increasingly conflated the dynamics of market exchange with 'the economy', they have tended to exclude from its subject matter not only the crisis of the biosphere, but materiality, *tout court*. Thus it is crucial to note that despite the intimate historical connection of corporate biotechnology to the neoliberal 'thought collective' (with its knowledge privatisations, selective science denial, and transcendentalisation of the Market into a selection function on par with Darwinian evolution), the rationale for a bio-based economy has deeper roots than capitalist techno-science. These lie in the critical, heterodox counter-modernism of ecological economics. As Martinez-Alier (1989) shows, the shared intellectual genealogy of 20^{th} century systems ecology and ecological economics, both *potentially* subversive sciences, can be traced to the critical, 'metabolic' materialisms of Marx and many of his 19^{th} century contemporaries.

In this chapter I explore two latent themes of 'the bioeconomy'. Firstly, I argue that the ambition of industrial biotechnologists to refound key industries (energy, chemicals, polymers) in photosynthetic life amounts to a validation of ecological economics and its metabolic ontology, where metabolism refers to the totality of energetic and chemical processes by which organisms are materially produced, maintained and destroyed. As was argued by Georgescu-Roegen, a rigorous critic of the indifference of orthodox economists to the biophysical sciences (and an early skeptic of the 'genetical millennium'), economic growth is "completely tributary" to photosynthesis as the source of all energy captured by the biosphere, and to mining, especially of fossilised photosynthesis in the form of coal, oil and gas: "[T]he issue of returns boils down to that of returns in mining and in agriculture" (1971: 294). I will argue further, that the acceptance of photosynthesis as foundational to (bio)economic existence, indeed, to the stability of the biosphere, provides a heuristic, ethical and democratic touchstone from which to mount a positive critique of biopolitical economy.

The second theme is evolutionary, and concerns the juxtaposition of the devastating extinctions of natural life-forms and biotic communities with the artificial acceleration, direction and industrialisation of evolution through the techniques of synthetic biology. The out-of-control erosion of the Holocene biosphere attributable to fossil combustion and the petrochemical industries arguably alters the calculus for the ethical evaluation of biotechnical risk. Biosphere degradation is increasingly claimed as a moral framework validating the development of synthetic biology, with its aim to systematise the design-based assembly of novel life forms: the emergency of the biosphere tasks us with fostering the emergence of an artificial biosphere. Whilst it is certainly plausible that "the trajectory of capitalist technology is toward artificial life on a dead planet" (Thorpe 2013: 2) this is only one possible biofuture. If a microbial biosphere internalised within and transforming industrial processes may moderate the turbulent transition to a post-fossil era, whilst reducing future damage to the 'wild' biosphere, then 'the bioeconomy' ought to remain open to appropriation by democratic, non-capitalist forms of bio-social existence.

Microbial futures, oceanic despair

If, as Hans Jonas argued, we have an ethical responsibility to the living of the future not to "have spoiled for them the world or the human constitution through careless and avoidable deeds" (Jonas 1984: 41), then as excessive as this responsibility may be, we must contemplate the forbidding ontological horizons of the 'Anthropocene'. The chronology of deep time is designated by geochemical and palaeobiological signatures in geological strata, and the major divisions of geological time are marked by the five mass extinctions in the history of life. Should there be geologists in the deep future, our time will comprise the sixth such stratigraphic signal: the emergence of what we call 'the economy' will be marked by the cessation of inscription in the fossil record of numerous forms of life that were vital through epochs prior to the Anthropocene.

Defined as an event where three-quarters of species are terminated, mass extinction can be thought of as an 'end of evolution', a snuffing out of innumerable lives, genealogies, and worlds of experience: an anti-Genesis. Climate change, biodiversity loss, and ecological dysfunction are intimately interwoven phenomena: the causes of major extinction events can be divided into two categories, those that are unrelated to major disruptions of the carbon cycle (i.e. bolide impacts) and those that are (Veron 2008). Yet much of the public debate on 'climate policy' remains focused on atmospheric change and its terrestrial consequences, to the exclusion of the dramatic changes underway in the oceans. Perhaps social thought fails when we begin to think through the consequences of the heating, acidification, and oxygen depletion of the oceans.

Science studies scholars Paxson and Helmreich have observed that:

> at a time when biological nature writ large is widely understood to be under threat from such anthropogenic processes as climate change, agri-industrial degradation, rainforest depletion and overfishing, biologial nature writ small – microbial life – has attracted fresh attention…. Across diverse domains […] microbial ecosystems have come into view as plenteous, promising, full of potential (2014: 2).

Yet Helmreich's *Alien Ocean* (2009), a rich ethnography of the reconfiguration of our knowledge of life accomplished by marine genomics and ocean microbiology, seems to reprise the techno-fascination accompanying the opening of the microcosmic frontier. It contains no sustained reflection on the biodepletion of the 'macrocosm' of pelagic fisheries and coral reefs, nor on the catastrophic horizon of ocean acidification, nor on the possibility that the oceans, the great amniotic other of Anthropos, are already 'dying'.

Whilst contentious, recent research suggests that global populations of phytoplankton, the ubiquitous photosynthetic microbes at the base of the ocean food web, have declined by 40%

since 1950 and continue to do so. These organisms form half the world's biomass, fix vast quantities of carbon, and have historically released half of the oxygen in the atmosphere (Boyce, Lewis & Worm 2010). A major class of phytoplankton, coccolithophores such as *Emiliania huxleyi* [see Fig 16.1], form their cell wall by calcification. Thus they are immediately threatened by acidification, which will test their capacity for rapid evolution. According to one coral specialist (Veron 2008), three more decades of on-trend fossil fuel should result in levels of ocean acidification, heating and hypoxia sufficient to kill all the world's coral reefs, with the possibility that the oceans become dramatically depleted of oxygen within centuries. Oxygen-less oceans would be fishless and 'dead' from our point of view, they could, however, support masses of anaerobic bacteria. It is thus dark irony that the stratigraphic record linking super-greenhouse events to mass marine extinctions also coincides with the formation of the hydocarbon-rich sediments from which crude oil is extracted (Demaison & Moore 1980).

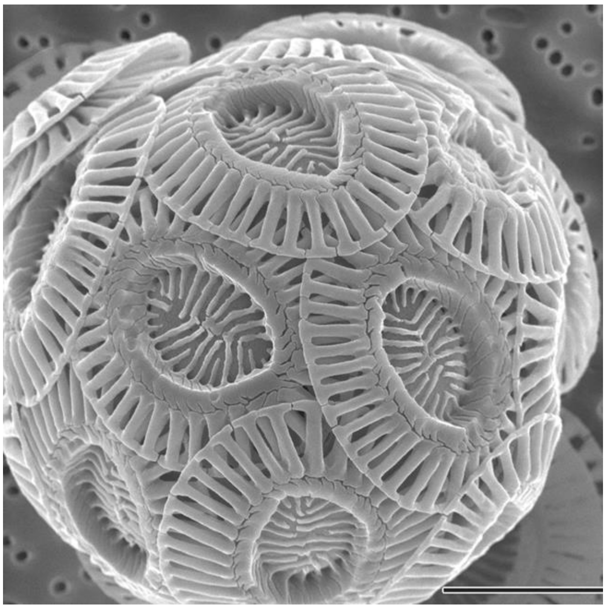

Figure: Coccolithophores such as *Emiliania huxleyi* are single-celled marine phytoplankton that produce calcium carbonate scales (coccoliths). They occur in all of the world's oceans and together represent the largest source of biogenic calcium carbonate on Earth, contributing significantly to the global carbon cycle.

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One explanation for microbial optimism might be the psychological difficulty of facing up to such destruction, to what Clair Colebrook calls the "monstrously impolitic" limits of politics, or what Elizabeth Grosz calls the "cosmic imponderables" of the vast complexity of the non-human order (in Clark 2013: 2831). Rather than helplessly mourn the passing of the integrity and abundance of the mesocosm, industrial genomics and ocean microbiology opens up a new frontier of biocultural hope along a contact zone that I would designate the 'bioeconomic frontier'. In this zone, some scientists document the altered biogeochemical processes that are the side effects of economic expansion (ocean acidification and heating, reef destruction) and others conduct the basic research for biotechnologies in which hopes for a transformation to a life-based and biodiversity-sustaining economic system are invested (artificial photosynthesis, microbial biofuels, bioremediation).

For some, the dawn of the Anthropocene augurs not mourning in the face of species extinction as an irreversible impoverishment of being. Nor does it warrant a call for a collective moral polity capable of averting apocalyptic change in the Earth's biogeochemistry, alterations which are so abrupt in evolutionary time that even if microbial life appears to be evolving rapidly in response, "[i]t remains to be seen whether organisms with longer generation times, smaller populations and larger sizes can do the same" (Gillings & Paulsen 2014: 1). Rather, the Anthropocene is heralded as a call to the self-deification of the bio-entrepreneur. As Steward Brand repeatedly intones, "we are as Gods and might as well get good at it" (1968: 1). Such bioengineering cultures generate enthralling visions of a flourishing *Regenesis* (Church & Regis 2012): of a future in which synthetic biology is perfected into a rich art of willed speciation, where full-genome engineering reverses the extinction of mammoths and other extinct keystone species, in which made-to-order microbes churn out squanderable quantities of renewable biofuel from nothing but water and sunlight, and our own bodies have been engineered for immunity to viral infection. Evolution will become post-Darwinian artifice, Anthropocentric in the fullest sense.

How then can we grapple with the ambiguous collisions occurring in the ontological basement of 'the bioeconomy'? On one hand, we witness the techno-scientific regeneration of a specifically Creationist eschatology, long ago secularised into the productivist ideology of infinite growth in and through crisis. On the other, an urgent call to ecological realism, to recognition of social and ecological responsibilities, of the pragmatic necessity of a profound transformation of economic thought, organisation and infrastructure in the name of survival and solidarity with all life, now and to come. In what follows, I attempt to clarify what is at stake – for theory, at least. I propose: (1) that the advent of the Anthropocene exposes the ontological status of economic categories; (2) that a critical, materialist bioeconomics adequate to our times must begin with photosynthesis; and (3) that Sloterdijk's 'spherological realism' offers a heuristic for a general bioeconomics of the Anthropocene. I will develop these ideas through the specific cases of algae biofuel development and artificial photosynthesis.

(1) Refusing the gift: economics as refusal of the earth

The categories of mainstream economic theory – market, individual, value, growth – are thoroughly ontological. Like a priori arguments for the existence of God, their logical adequacy and basic goodness cannot be falsified, as evidenced by the resilience of neoliberal doctrines after the deepest economic crisis since the 1930s. Yet nowhere is this more evident than in economists' refusal of the Earth. The Earth as biophysical resources was once acknowledged in the political economy category of *land*. The standard Walrasian equilibrium growth model dispenses with land, treating only circular flows between capital and labour, appealing to a generic 'technological residual' as the explanandum of 'growth'. And as Foucault (1979) presciently observed of Chicago-school neoliberalism, its potent move was to reclassify labour as merely a species of 'human' capital. According to textbook macroeconomics (ie. Mankiw 2014), which purports to study 'the economy' at the largest scale, the subject is exhausted by the analysis of relationships between money supply, investment, inflation, trade cycles, and employment, all to be measured against the prime constant, 'long-run growth'. The ontological power of such economic categories can be recognised in the regularity with which collective futures are sacrificed to 'the economy'. With its foundations occulted in the shadow world of naturalised metaphor and myth, our reigning *oikonomia* is resonant with the escapism of millenarian futurity, the providential miracle, and the political theology of redemptive violence.

Might ecology, the sister science of *oikonomia*, provide a counterpoint? As the history of economic thought and science suggests, at any moment, the reigning images of Nature – and their ontological baggage – are profoundly entangled with dominant images of economic activity. Even as 20th century economic thought came to abjure any account of the materiality of its object, as Worster observed (1977: 292), in achieving credibility as a non-vitalist science, systems ecology became, "to a great extent [..] 'bioeconomics': a cognate, or perhaps even subordinate, division of economics."

The current epistemic hierarchy, in which ecologists find themselves routinely subordinated to economists, exemplifies the political function of economics in what I would describe as an 'occultural' form of mythopoesis. Occultural processes, for our purposes, are cultural processes which serve to occult, obscure and render invisible the confrontation between 'the economy' as endlessly increasing 'production' and the irreversible destruction of significant swathes of the biosphere, manifest most starkly in the spectre of a gathering wave of extinctions. That the life of 'the economy', our artificial environment of commodities, heat engines, and everyday infrastructures, is a novel irruption from within the deep history and vital materiality of the solar driven biosphere, and could not exist without it, seems obvious. And yet the economic philosophy of history as the infinite growth, development and expansion of capital appears unshakeable, even amongst those economists who argue for market pricing of 'natural capital', 'ecosystem services' and carbon flows. It is also surprisingly rare for heterodox economists to ground the object to which economics refers – the social process of wealth accumulation and distribution – in the fiery dissipation of the fossilised ex-life exhumed from geological strata. What could 'the common-weal' mean in a world characterised by a drastic depletion of biological abundance, and the erosion of the sustaining and protective capacity of life?

(2) Photosynthesis as the ground of general economics

Being-as-such evades conceptualisation, and I am Levinasian in arguing that ontology, if it is not to be transcendentalised into History, must be bound to an embodied political ethics. Having disembodied 'the economy', academic economics is increasingly under the influence of Hayekian neoliberalism, which mobilises an extreme epistemic skepticism toward any collective knowledge claims (ie. those of scientists, or democratic assemblies) that have not been filtered by the distributed truth-arbitration of the 'market place of ideas'. Similiary, much critical social thought has tended to evade the earth. As Clark (2013: 2831) observes of certain actor-network theorists and Foucauldians:

> It is of course necessary for social science to interrogate the production of natural scientific knowledge. But the issues raised in the geoengineering debate thus far suggest there is also an urgent need for the social sciences to offer their commitment and support to those geophysical truth claims that (provisionally) pass the test... [I]n order to make a positive contribution to geoengineering and other geopolitical issues, key strands of social science will need reconsider their investment in ontopolitical thinking.

A counter-ontological position, or positive critique of biopolitical economy, might be described as an *Anthropocene bioeconomics,* and begin with photosynthesis. Here the economic, insofar as it addresses living beings and the determinative conditions of wealth as abundant life, is always *bio*-economics, and *Anthropos* refers to the distinction between the raw and cooked – to fire users.

Photosynthesis is as foundational to life on Earth as pyro-technologies are to human social being. Photosynthesis drives the global carbon cycle which makes the Earth habitable, and nearly all living things depend on photosynthetic cells for the complex carbon macromolecules which are their source of energy – as do, by a longer route, nearly all engines and machines. The following rough equations should be on the first page of any political economy textbook aspiring to scientific credibility in the Anthropocene:

Photosynthesis*:*

carbon dioxide + water + light energy → carbohydrates + oxygen

Combustion: (e.g. fire)

carbohydrates / hydrocarbons +oxygen → heat and light energy + carbon dioxide + water

Fire, which rapidly dissipates the solar energy slowly bound up in biomass by photosynthesis, is only possible because of photosynthesis. The oxygen in the atmosphere which makes fire possible accumulated there as a 'waste bi-product' of early microbial seas. Nearly all combustible fuel is of photosynthetic origin: either carbohydrate (wood) or hydrocarbon (coal, oil, methane). From the extensive arts of 'fire stick' farming practiced for millennia by the Australians, through to the intensive arts of contained fire in pottery, metallurgy, heat engines, and electricity generation, fire mastery is the unquestionably unique distinction of our 'species being', and prior to all 'modes of production'. As Bataille (1949) grasped earlier than most in his reading of Vernadsky's *Biosphere* (1926), the most general statements of economic theory are to be specified at the level the earth as a whole, with its openness to the sun. The economy of life is founded in life's spontaneously-organised dissipation of the excessive gifts of solar radiance. Vernadsky was himself so conscious of the interplay between the sun and plants that he referred to vegetal life as 'green fire'. Fire unwinds, unbinds and reverses the work of photosynthesis. The mass combustion of fossil fuels does this irreversibly, unmaking worlds made through the deep history of phostosynthetic life.

Our future, and indeed the future of the biosphere's evolutionary trajectory for millions of years hence, will hinge upon the outcome of a substantial transition, willed politically and technologically or catastrophically forced, from modern societies' dependence on the solar energy bound in the fossilised remnants of microbial seas and Carboniferous forests, to solar energy recently captured within our lifetime (or by technologies that harness the energy of Earth's heat and movement, or through artificial "photosynthesis machines" such as photovoltaic cells). The second postulate of this chapter, then is that our predicament involves not so much a 'clash of spontaneous orders' between the production relations of the neoliberal world market and the biosphere it threatens (Aarons 2009: 60) but a clash of barely imaginable photosynthetic temporalities. The brown fire of dead biocapital confronts the green fire of living metabolic labour.

(3) Bioeconomics as spherology

In a recent lecture series, Latour (2013) parses Peter Sloterdijk's critique of the impossible disembodiment of the modern cogito. Objecting in the first instance to the denial of the mother's womb, and by implication of all of that from which we are born, Sloterdijk evokes the immunological interiority and mutuality of the intra-uterine as a starting point for a critique of ontology which he dubs 'spherology'. To illustrate the disorienting shift in foundations of time, place and being at stake in the Anthropocene, Latour contrasts the moment in 1609 when Galileo's telescopic view of the Moon convinced him that the Earth was a planet *just like the others*, with Margulis and Lovelock's (1973) theses on the adaptive regulation of the atmosphere by the biosphere in far-from-equilibrium conditions: the Earth is *unlike* the others.

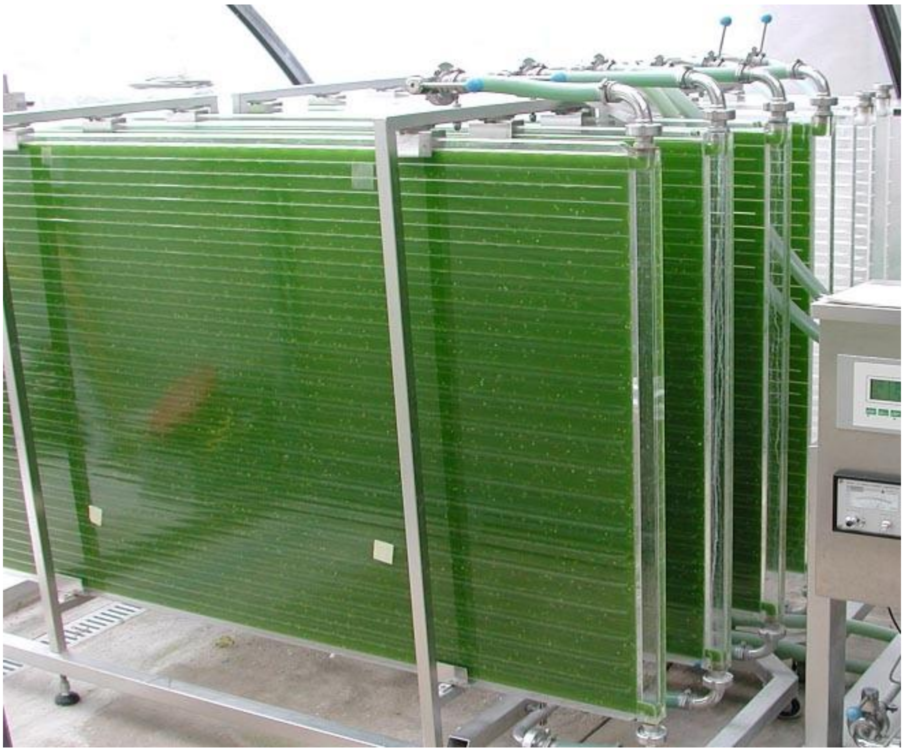
In her theory of the origin of eukaryotic cells and multicellular organisms, Margulis argues that complex organisms evolved through endo-symbiosis. Originally free-living organisms, the ancestors of chloroplasts (the bodies within algae and plant cells that capture the energy of sunlight to drive the process of photosynthesis) and mitochondria (the organelles inside animal and fungal cells that store and release the energy for metabolism) came to live *inside* the cell walls of other organisms, in relationships of mutual aid and dependency. Lovelock's work on comparitive atmospheric chemistry suggests the formula 'as below, so above': the biosphere depends for its security upon being interior to the atmosphere, an emergent effect of the photosynthetic microcosmos, a bubble of Gaia's own making.

The ontological postulate of spherological realism, "if you are in the world, you are always in a sphere" is arresting, invoking a plurality of enfolded and mutually dependent lifeworlds. Life emerging, differentiating and evolving via membrane-bounded vesicles or 'bubbles': the sun's radiant sphere harnessed by and for life within the photosynthesis complex, chloroplast within cytoplasm, embryo within womb, child within family, citizen in community, the anthropo-sphere inside the biosphere. As ontological critique, spherological realism exposes the impossibilty of *homo economicus,* a dicrete maximising agent constrained only by prices in a field of commodity choice. The *oikos* is always a subset of the biosphere. If "to define humans is to define the envelopes, the life support systems, the *Umwelt* that makes it possible for them to breathe" (Latour 2013: 107), the fragile immunological sphere of the bubble provides a provocative way to think about the transformative mission of industrial biotechnology, insofar as its seeks to construct a (synthetic) microbial biosphere internal to our industrial metabolism.

Experimental biospheres

The paradigmatic example of a bioeconomic project might be the search for a viable method to generate renewable energy in bulk, from photosynthetic microalgae that express, either naturally or through engineering, lipids and oils that can be refined into fuels. Algae are far more efficient photosynthesisers than land-based plants, capturing sunlight with much more rapid growth rates of cell division. Thus they offer a biofuel that does not require deforestation or compete for agricultural lands. The biochemical pathways of algae open the possibility that they could be grown using the concentrated carbon dioxide wastes of existing coal-fired plants or other heavy industry, or using nitrogen rich wastewater. Fuel could be grown in vats and tanks in almost any location: something that could radically democratise access to energy and diffuse the political violence around oil supply. Microbial biofuel production if technically successful – and in tandem with a utopian political settlement capable of keeping fossil fuels in the ground – could perhaps disclose the possibility of some kind of long term co-evolutionary escape for modernity from its counter-evolutionary confrontation with Gaia.

Of course, the magnitude of such a transformation is daunting. It is estimated, for example, that for each litre of petroleum around 23 metric tons of ancient marine life were geologically compressed and fossilised. Global oil use is approaching something like 1.6 billion litres per day. Every year, the energy realised from oil combustion is equivalent to the total energy photosynthesised by the biosphere over four centuries. And yet every day, the energy of sunlight received by the Earth is equivalent to about four times daily fossil energy consumption. According to one algae biofuel researcher, if Australians "devoted just 1 per cent of our land mass to algae farming, we could theoretically produce five times more oil than we currently consume. We could potentially become an oil exporter, rather than an importer" (Stephens 2013).



Photobioreactor for the cultivation of microalgae and other photosynthetic organisms.[2]

Perhaps then, the image of biocultural hope, of a Sloterdijkian immunological sphere, is to be found in the thriving, sunlit biomass living *in vitro* inside the experimental photobioreactors where different micro-alga and other photosynthetic microbes are trialled in the hope of finding species that can be 'improved' and scaled up for mass industrial processing. These artificial ecosystems provide the organisms inside with ideal combinations of gases, nutrients, temperature, pH and salinity to foster maximum photosynthetic growth. They also provide these unnaturally coddled, mono-cultural communities with biosecurity. As Stephens (2013) observes, naturally oil-rich algae are rarely fast-growing, "and they are tastier to predators - like microscopic scoops of ice cream".[3] In the ultimate 'infrastructural inversion' of the immunological interior, we might imagine these as yet experimental (photo)synthetic biospheres becoming increasingly diverse and ubiquitous. In coming to be the vital basis of a globalised industrial metabolism, synthetic biospheres may yet partially immunise the 'wild type' biosphere from the maelstrom of the Anthropocene.

Pre-emptive speciation: crisis as redemption for biocapital

For all the promissory rhetoric one encounters about a bioindustrial revolution, the biotech sector as whole is consistently unprofitable (Mirowski 2011). Biomedical engineering encounters cultural limits in the taboos unsettled by the eugenic possibilities of germ line therapy, stem-cell engineering and the spectre of human-animal chimeras. Perhaps due to the deep cultural intimacy we have with the domesticated species that share our passage through the Holocene, the genetic alteration of crops and grazing animals has often struck the lay imagination with moral dread. By contrast, given the alien-ness and invisibility of micro-organisms, and their lack of representation in venerable mythology and research ethics application forms, for most people micro-organisms exemplify *zoe*, 'bare life' in Agamben's terms, and can be subjected to technological imperatives without considering their 'right to exist' as natural kinds.

At a 2008 TED Talk, biotech impresario Craig Venter announced his lab's progress in constructing a viable synthetic cell. Identifying *Mycoplasma genitalium* as the species with the smallest genome capable of self-replicating in the laboratory, Venter and his team reduced the number of genes still further, and then synthetically produced the chromosome in DNA synthesis machines, which combine four base chemicals into combinations on the basis of information stored on a computer. Once this was inserted back into the living cytoplasm of a cell stripped of its genetic material, Venter reports, "all the characteristics of one species were lost and it converted totally into the new species based on the new software that we put in the cell. All the proteins changed, the membranes changed; when we read the genetic code, it's exactly what we had transferred in" (Venter 2008).

In this speech, Venter morally frames the future of synthetic genomics in terms of oil depletion and climate change. Contrasting vast daily fossil fuel consumption with the latent promise of micro-biodiversity, he points to the immense potential of combinatorial genomics. The entire electronics industry was founded in the standardisation of a few basic parts: transistors, capacitors, resistors etc. Industrial biology, by contrast, begins with the 50 million species already described, and a database of 20 million sequenced genes. To this will be applied the increasing power of DNA synthesis machines, "robots that can make a million chromosomes a day". Venter is modest enough to note that "this is not genesis; this is building on three and a half billion years of evolution."

Perhaps the unspoken realisation that our global Anthropos is dependent on a kind of necro-capitalism explains both the yearning for a solar bioeconomy and the recent rash of zombie films. Our industrial present is animated by digging up the numberless dead of the buried biospheres of the deep past, setting ex-life to work for us in our dominance of the living one. Since WWII, the industrial chemistry of organic compounds has given rise to millions of novel synthetic chemicals and commercial products (medicines, plastics, poisons, perfumes, paints) and thus to an anthropogenic chemosphere which is diffused throughout the biosphere. Thus it's strangely reassuring to hear Venter play Moses and point to a promised land, laughing about his "modest goal of replacing the entire petro-chemical industry". But it's not enough for him to merely act the prophet. Accused of playing God, Venter relishes the opportunity to retort "oh, we're not playing!" promising an anthropogenic mass speciation event to offset an ongoing mass extinction event. He offers a glimpse of the Creationism to come:

> of what the future may begin to look like with changing, now, the evolutionary tree, speeding up evolution with synthetic bacteria, Archaea and, eventually, eukaryotes. We're a ways away from improving people: our goal is just to make sure that we have a chance to survive long enough to maybe do that. […] we're about to perhaps create a new version of the Cambrian explosion, where there's massive new speciation based on this digital design (Venter 2008).

At the time Venter was negotiating an ultimately uncompleted $300 million contract to develop commercial algae biofuels, between his company Synthetic Genomics and Exxon. One of the world's most powerful corporations, Exxon is a prominent part of the thinktank network that has effectively lobbied against climate policy and made science-denial a respectable worldview in Anglophone democracies. We need to take Venter and his corporate Cambrian explosion seriously. Given that the crisis of extinction is the direct result of our existing industrial processes, how do we respond to Venter's call to assume responsibility for a practice of ‘pre-emptive speciation’, to direct a regenerative, artificial evolution of industrialism for the sake of ‘life as a whole’?

Rubisco engineering: a bigger, faster biosphere for today’s growing economy

Unfortunately for our bioeconomic utopia, it’s not easy to find a ‘wild type’ microbe and introduce it to a comfy tank to happily photosynthesize biodiesel or hydrogen fuel. While in theory, unicellular green algae could approach 100% efficiency in the utilisation of photons, in practice the optimal efficiency of sunlight absorption in mass monocultures is not even remotely approached, in part due to the inherent limitations of the photosynthesis reaction system as it has evolved since the Hadean biosphere of the young earth. As we learn in a volume on *Artificial Photosynthesis,* (Collings & Critchley 2005: v):

> The enzyme combination known as RuBiSco [ribulose bisphosphate carboxylase/oxygenase] – critical to the process of carbon fixation in photosynthesis – is one of the slowest enzymes known to science.

While it lacks efficiency at the molecular scale, *Rubisco* is the most abundant protein on earth. Not only is it the prime mover of the carbon cycle, it is is the ultimate source of energy for all organisms under the sun.[4]

> Rubisco’s catalytic performance dictates the maximum efficiency of photosynthesis in the use of light, water and fertilizer N[itrogen] resources. Thus, *the properties of Rubisco determines, among other things, the size of the biosphere.* Despite this critical role, Rubisco’s performance falls far short of the near-perfect speed and specificity attained by many other enzymes. The possibility of achieving profound improvements in such fundamental efficiencies focuses the attention of Rubisco researchers and funding agencies (Andrews & Whitney, in Collings and Critchley 2005: 245 *my emphasis*).

Given its role as the regenerative labourer of the whole world, certain scientists are determined to refashion Rubisco into the shockworker of the bioeconomy to come, through the directed evolution of enzyme engineering. If Rubisco took some three and a half billion years to evolve to its present state, our crisis demands the pre-emptive industrialisation of evolution and its application to the most foundational of the biosphere's metabolic processes, to ensure life and growth in and through crisis. Hence the project to screen existing organisms for the most kinetically efficient Rubiscos, to direct and accelerate their evolution through random mutagenesis and DNA shuffling (or in other words, through the systematic forcing of an array of genomic accidents), and to select favourable results for subsequent iterations and rational design. Über-Rubiscos might then be introduced into any photosynthesizing host species chosen for accelerated growth and productivity.

The circadian rhythms of growth and regeneration arising from the deep time of the biosphere are simply too slow for the 21st century economy. We might wonder how merely natural organisms will fare when exposed to competition from such hyper-efficient producers? Will such life-forms restore, or merely further unravel the complex meta-stability of abiding ecological relationships? If appeals to equilibrium, once integral to both systems ecology and neoclassical economics, have increasingly lost their intuitive appeal in the wake of financial and ecological turbulence, they reappear in the most unlikely of places. In the imagination of some synthetic biologists, the restorative fantasy of equilibrium takes the form of an omniscient control of 'side effects', even if the concept of naturalness has been resolutely cast aside as a nostalgic relic:

> It is […] possible to imagine a scenario where synthetic biology is [so] well developed in the future that every possible side effect will have a counter solution; and artificial designs of life-forms will integrate into the natural living system [such] that organisms based on unnatural DNA will become the norm (Lam et al 2009: 38).

The limits of photosynthesis again returns as a vital question of political ontology for any bioeconomics adequate to the Anthropocene.

Conclusion: biomass culture, or towards algal democracy

As Mitchell captures with his suggestive term 'carbon democracy' (2009), the history of the social democratic political settlements achieved in the West from the late 19th century onward were not merely a result of vast fossil energies harnessed to mass production by the thermo-industrial revolution, but also of the strategic opportunities to 'turn off the energy tap' that coalmines, railways and steamship port infrastructure offered to militant organised labour prepared to strike, in stark contrast to the anti-democratic, top-down and violent resource capture that has accompanied the 20th century with its dependence on oil. Certainly, there are abundant signs that the "democratic machineries that emerged to govern the age of carbon energy seem to be unable to address the processes that may end it" (Mitchell 2009: 399).

To be sure, the emergence of the bioeconomy remains contingent on a whole range of contradictory neoliberal policies: a selective denial of natural science, the self-defeating effects of knowledge privatisation, and the strategically disposable politics of 'market-led' environmental reform. The literature rarely suggests that there is any need for privileged consumer societies to revise their expectations of continuous increases in material consumption and security. Yet perhaps just as dangerous as the framing of climate policy as a 'left' issue is the dismissal of industrial biotechnology as merely a 'neoliberal' techno-fix. While there are vertiginous obstacles in its path, it is surely vital to hope for a solar-based civilisation: the pro-poor Cuban biotechnology sector, the open-source ethos of the iGEM competition and BioBricks registry, and the do-it-yourself garage biology of the 'biopunk' movement suggest the possibility of a pro-social justice, anti-capitalist, and democratic biotechnical commons. Wind power, solar photo-voltaics and perhaps microbial biofuel plants can be located almost anywhere, and offer a radically democratised and decentralized energy infrastructure that may yet re-invigorate zombie democracies captured by fossil fuel corporations, and may yet radically alter the territorial divisions of geopolitics and the *nomos* of the Earth.

Finally, the politics of extinction for 'earth system governance' suggests that we cannot but face up to the fact that we are engaged, for better or worse, in ecological engineering. Yet this need not imply the abandonment of 'the gift' that Western economic thought has sought so vainly to exteriorize – solar abundance, harnessed for life by photosynthesis, manifest in the immensely complex orderliness of the Holocene biotic community – for a future of artificial life on a dead planet. As Aldo Leopold (1953: 190) once said:

> If the biota, in the course of aeons, has built something we like but do not understand, then who but a fool would discard seemingly useless parts? To keep every cog and wheel is the first precaution of intelligent tinkering.

Staking out photosynthesis as ontological grounds from which to begin a vital, materialist politics that refuses to refuse the earth, I argue that we have little choice but to take the emerging bioeconomy seriously, indeed far more seriously than its current protagonists are inclined to.

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Endnotes

[1] Image from Sciencephoto

[2] Image supplied by IGV Biotech to Wikimedia Commons under a Creative Commons licence. http://en.wikipedia.org/wiki/Photobioreactor#mediaviewer/File:Photobioreactor_PBR_500_P_IGV_Biotech.jpg

[3] There remains the question of the ecological risk of escaped synthetic micro-organisms. One possibility mooted for ‘biocontainment’ is that they be engineered with ‘suicide genes’, to be triggered in the absence of some biochemical signal only available in the closed environment of the tank.

[4] With the exception of recently discovered *chemosynthetic* Archaea and the ecosystems they support in the lightless extremes of deep ocean thermal vents.