THE METAPHYSICS OF THE ANTHROPOGENIC EARTH
PART I: INTEGRATIVE COGNITIVISM

CENTER FOR EARTH SYSTEMS ENGINEERING AND MANAGEMENT
WORKING PAPER NUMBER 1

LINCOLN CENTER FOR APPLIED ETHICS
WORKING PAPER NUMBER 1

BRAD ALLENBY
Founding Director, Center for Earth Systems Engineering and Management
Lincoln Professor of Engineering and Ethics
Professor of Civil and Environmental Engineering
Arizona State University

"So long as we do not through thinking, experience what is, we can never belong to what will be . . . . The flight into tradition, out of a combination of humility and presumption, can bring about nothing in itself other than self deception and blindness in relation to the historical moment."

(Heideggar ([1952-1962]1977, at 49, 136)

THE METAPHYSICS OF THE ANTHROPOGENIC EARTH
PART I: INTEGRATIVE COGNITIVISM

Index

THE METAPHYSICS OF THE ANTHROPOGENIC EARTH
PART I: INTEGRATIVE COGNITIVISM

I. *The Anthropogenic Earth*

We live in a world that is fundamentally different from anything that we have known in the past. It is a world dominated by one species, its activities and technologies, its cultures, and the integrated effects of its historical evolution. It is a world where the critical dynamics of major earth systems, be they atmospheric, biological or radiative, or for that matter cultural, economic, or technological, increasingly bear the imprint of the human. Moreover, these human, built and natural systems are now so integrated that our habitual treatment of them as separate itself becomes increasingly obsolete. Welcome to the first terraformed planet: not Mars, or some esoteric globe in Andromeda . . . rather, the Earth. As the journal *Nature* put it in an editorial in 2003, "Welcome to the Anthropocene," roughly translated, the Age of the Human.

This anthropogenic Earth is a principle result of the Industrial Revolution and associated changes in human demographics, agricultural practices, technology systems, cultures, and economic systems. The anthropogenic earth is one in which the dynamics of major natural systems are increasingly dominated by human activity. That does not mean "deliberately designed by" humans, for many things, from human history to the Internet, are clearly human in origin, yet have not been consciously designed by anyone. But it does mean an Earth where human settlement, activity, culture, and technology increasingly modulate all earth systems, to the point where those that are not subject to such impact – volcanoes and earthquakes, say, or perhaps the biological communities around deep sea vents – are increasingly limited and unique.

It is challenge enough to simply perceive and accept what already is, given the ideologies, beliefs, and theologies that both define and cloud our vision. But we cannot rest there, for, while the gaps in current scientific, technological, institutional and governance structures are perhaps apparent to some, the profound philosophic and religious challenges – and the concomitant implications for design, operational, and policy decisions and institutions - posed by an earth increasingly dominated by one species is inadequately recognized.[1] For the anthropogenic Earth is the culmination of some 2500 years of human history, which has in fits and starts resulted in the ascendancy of technological humanity. As Barrett (1979, at 222) notes, "A great chapter in human history - twenty-five hundred years long, from the beginnings of rational thought among the Greeks to the present – has come to an end. . . . [a situation which] calls us towards

[1] One response is the development of earth systems engineering and management and related fields such as sustainable engineering and industrial ecology (Graedel and Allenby, 2003; Allenby, 2005; Allenby, 2007).

some other dimension of thinking of which we can catch now and then perhaps only glimmers."

The complexity of the discourse required by the evolution of the anthropogenic Earth should not be trivialized. Today's environmental and sustainability discourses have been powerful and valuable but, applied outside the implicit boundaries they have observed in the past, are fragmentary and dysfunctional, and carry within them the same authoritarian and destructive potential as any ideology. The technologist discourse, until it is leavened with a more sophisticated appreciation for the complexities of coupled human/natural/built systems, and a concomitant reduction of hubris, similarly carries within it seeds of high modernist disaster. The policy discourse, dominated by ideology, the outmoded concept of the absolute sovereignty of the nation-state, and a postmodernist drift (lack?) of values, is hopelessly inadequate to the task it faces. And yet there are substantial reasons for optimism, for this period is not an anomaly, stuck somewhere beyond all standard deviations; rather, it is a culmination of a unique period in the evolution of the world. One species, through technological, cultural and economic evolution, has evolved to dominate a planet and the dynamics of most of its fundamental systems. This is unprecedented and extraordinary. What is now happening is that the enormity of that accomplishment is just beginning to dawn on us . . . along with the understanding of how unprepared we are to respond in any reasonable way.

Of course we are. But it is not only the end of one phase of human history, it is the beginning of a new one: the age of the human Earth. And, like all beginnings, it is not only a challenge, but an opportunity. It will be human choice as to whether it becomes what it could, or should, be. And that process must begin by an understanding and perception that does not shrink to recognize the historical moment, as the Heideggar warning at the beginning of the paper indicates: We are indeed self-deceived and blind, and unfortunately have every incentive to remain in that state. Even in recognizing and accepting that, however, we begin to move beyond it, towards greater perception and authenticity.

I.A. *Natural Aspects of the Anthropocene*

For many people, the hardest part of accepting the anthropogenic nature of the world is the reality that critical dynamics of most fundamental natural systems are increasingly dominated by human activity.[2] The physics and chemistry of every cubic

---

[2] It is important to note that in many cases the human component of natural systems may be quantitatively small, but if it impacts critical points in the system, it may well dominate important systems dynamics. Thus, for example, the ocean contains some 40,000 gigatons of carbon, the biosphere some 2,000 gigatons, and the atmosphere about 750 gigatons. Next to these numbers, the annual release of carbon into the atmosphere from human use of fossil fuel (approximately 6 gigatons), and from land use and tropical deforestation (a little less than 3 gigatons) appear trivial (DoE, 1999). The anthropogenic releases, however, are sufficient to increase the carbon dioxide content of the atmosphere from roughly 260 to 380 parts per million, dramatically affecting the ability of the atmosphere to absorb energy that would otherwise be released into space, thus changing the energy density and behavior of the atmosphere in many ways. It is human impact on the *dynamics* of these natural systems that is important, not relative size of the human component compared to their other elements.

meter of air and of water has been affected in one way or another by human activity, a fact both recognized and decried by environmentalists (see, e.g., McKibben, 1989). Critical dynamics of elemental cycles through the human and natural spheres – those of nitrogen, carbon, sulfur, phosphorus, and the heavy metals – as well as the dynamics at all scales of atmospheric, oceanic and hydrological systems, are increasingly affected by the (usually unintended and sometimes unforeseen) byproducts of the technological activities of our species (Turner et al., 1990; *Science* 1997; Smil, 1997; McNeill, 2000). The biosphere itself, at levels from the genetic to the landscape, is increasingly a human product. The terraforming of Mars has long been the stuff of science fiction and the occasional visionary: ironically, we have all the while been terraforming earth.[3]

Consider, for example, the climate change negotiation process. For most people, it represents a relatively simple goal: to stabilize climate by reducing emissions of carbon dioxide into the atmosphere, which can be accomplished by cutting back sharply on fossil fuel consumption. Indeed, this is the core of the Kyoto Treaty, the current preferred method for addressing climate change on the part of the international environmental community. But in fact the climate change negotiations are the first small steps in a much larger journey. Even proponents of the Kyoto Treaty admit that, if implemented completely, the Treaty would have minimal effect on climate dynamics. This raises some political and ethical issues but, more importantly, points towards what the climate negotiations actually represent, which is the beginning of a dialog with not just the climate system, but with the carbon cycle itself.[4] And it does so because 6.5 billion people, many of whom are just beginning the process of economic development, are a force with significant inertia, and the idea that climate, like all major environmental systems, won't change as a result is untenable.

This point is reinforced by looking at just one case study, the important coupling between the anthropogenic carbon cycle, and another critical cycle, the nitrogen cycle. An element that was identified only about 200 years ago, nitrogen is, of course, a fundamental part of nucleic acids and proteins, and critical for all life. While there are

---

[3] Science fiction such as Robinson's trilogy, *Red Mars* (1993), *Green Mars* (1994) , and *Blue Mars* (1996) has long dealt with the subject of terraforming (in somewhat ironic parallel to today's terraformers of Earth, in fact, Robinson's Mars has the "Reds," who want to keep Mars "wild" and unterraformed, and the "Greens'" or the developers). Scientists and engineers in NASA and elsewhere, however, have also explored terraforming, especially of Mars (Zubrin and Wagner, 1997; Oberg, 1999). Keith (2000, at 254) comments that "the terraforming community has generated a more robust debate about ethical concerns than exists for geoengineering," perhaps implicitly confirming the point that it is easier to evaluate and judge hypotheticals rather than our own (terrestrial) behavior, even when the latter is in front of our eyes. One is tempted to argue, in fact, that the interest in terraforming other planets is a sublimation of the "illicit" knowledge that we have done and continue to do precisely that to our own planet.

[4] It is not clear that the public is as aware as the experts that implementing Kyoto would have so little effect on the evolution of the climate system, and that significant next steps would be necessary (Schneider, 2002). Moreover, a more subtle point is that, until about a decade ago, the concept of "climate system" didn't even exist; while everyone obviously knew what "weather" and "climate" were, the idea that the system was an integrated whole, and should be managed as such, is a relatively modern invention arising from, among other things, greatly enhanced ICT (information and communication technology) capabilities. "Climate system" is, in other words, a technologically mediated construct, although almost no one, including those in the climate change community, understand it as such.

substantial amounts of nitrogen in the earth's crust and atmosphere, it cannot be used until it is "fixed," or incorporated into reactive compounds. For example, most atmospheric nitrogen is in the form of N_2, and, because of the strong bonds in that molecule, unavailable for use until split into atoms that then recombine into ammonia or nitrogen oxides of various kinds (known generically as NO_x).[5] Prior to substantial human involvement with the system, major mechanisms by which nitrogen was fixed included atmospheric phenomenon, especially lightning, and biofixation by, e.g., legume and soybean systems.

The nitrogen cycle, like the carbon cycle, is a classic case where anthropogenic effects are virtually undetectable in terms of stock, but have significant impact in terms of flows.[6] 80% of the atmosphere is N_2, and any human activity pales in comparison (Smil (1997, at 111) points out that the nitrogen content of the human population is about 3 Mt, which is about a billionth of the atmospheric nitrogen stock). However, human influence on that small part of the nitrogen cycle involving fixed – biologically active – nitrogen is far more dramatic: in the late 18th century nitrogen was identified as an element; by the middle 19th century nitrogen was recognized as critical for crop production; and by the late 20th century humans had grown to dominate the rate of nitrogen fixation, primarily as a result of the Haber-Bosch process creating fixed nitrogen primarily for fertilizer, and as a byproduct of fossil-fuel combustion (Galloway and Cowling, 2002).[7]

The impacts of anthropogenic perturbation of the nitrogen cycle as a result of agricultural activity are varied and potentially significant (Socolow, 1999). Some fixed nitrogen compounds have substantial impacts even at trace levels on atmospheric chemistry and physics, in particular by contributing to the depletion of the stratospheric ozone layer or acting as greenhouse gases; nitrous oxide (N_2O), for example, is about 200 times as potent on a per molecule basis as carbon dioxide in contributing to global climate change. On a more regional basis, anthropogenic nitrogen compounds contributes to photochemical smog and acid rain. Nitrate ions in drinking water can bind to and inactivate hemoglobin, causing "blue baby" syndrome and, at the extreme, infant death. Fertilizers almost never stay just where they are applied, and, as fixed nitrogen is frequently a limiting factor in non-agricultural ecosystems, the result is their unintentional fertilization with concomitant loss of species and shifts in community structure. On a regional basis, the flow of nitrogen from agricultural operations can have significant impacts, especially in estuarial systems. Perhaps the best known example is

---

[5] Smil (1997, at 111-139) provides an excellent and accessible review of reactive nitrogen and human impacts on the nitrogen cycle.

[6] Indeed, Socolow (1999) turns this relationship to good use by suggesting that the history of human management of energy and carbon cycle impacts can be useful in suggesting ways to manage nitrogen, especially related to food supplies.

[7] As Socolow (1999, at 6002) notes:

> The rate at which nitrogen is being fixed on land today is approximately 3000 Mt(N)/yr, roughly double its preindustrial value. Thus, the incremental fixation today from the global industrial and agricultural system of human beings is roughly equal to natural fixation in preindustrial times. This startling result captures the essence of the human impact on the nitrogen cycle.

the "dead zone" that appears in the Gulf of Mexico every year as a result of oxygen depletion on the Gulf floor resulting from the decomposition of zooplankton, whose population explodes because of a phytoplankton bloom which, in turn, results from the flow of nitrogen from agricultural operations in the U.S. Midwest. This is not a trivial phenomenon, as the dead zone, and accompanying kill of bottom dwelling species such as crab and snails, is as large as the state of New Jersey in many years (that is, about 20,000 square kilometers).[8]

In this light, then, consider policies which would address climate change concerns by greatly increasing the use of biomass, which captures atmospheric carbon as it grows and thus, used as a substitute for fossil fuel (e.g., biodiesel or ethanol/gasoline mixtures) is "carbon neutral."[9] In fact, in 2001 the U. S. government explicitly adopted the goal of tripling the use of "biobased products and bioenergy" by 2010, establishing a Biomass Research and Development Board including the relevant Federal Agencies and Departments to oversee the effort. The Board enthusiastically declared that (BRDB, 2001, at 3):

> A revolution spurred by expanded use of renewable biobased products and bioenergy will have enormous impacts in the 21st century. Today, America depends on biomass to provide 3 percent of its energy and more than 300 billion pounds of products annually. Yet, propelled by advances in biological and physical sciences and engineering, America has the opportunity to greatly accelerate the use of biomass.

It is not surprising that one of the goals given for the program was to "improve the environment" (BRDB, 2001, at 2), since it is "common knowledge" that biomass is a renewable source of carbonaceous material and energy, and is therefore preferable to alternatives. But the truth is, of course, that expansion of agriculture for purposes of producing biomass may be carbon neutral, but it is not nitrogen neutral, nor is it environmentally unproblematic by any means.[10] The point is not that biomass energy

---

[8] As Ferber (2001, at 968) notes, "the gulf's woes can be attributed primarily to the 1.6 million metric tons of nitrogen, much of it from Midwestern farm fields, that wash out of the Mississippi and Atchafalaya rivers each year," although animal manure, sewage treatment plants, airborne nitrogen compounds and industrial emissions also contribute. Nonetheless, nitrogen in agricultural runoff remains the main culprit, as it is in similarly affected areas such as Long Island Sound in the United States, the Kattegat strait between Denmark and Sweden, the Baltic and Adriatic Seas, Chesapeake Bay, Hong Kong Bay, Japan's Seto Inland Sea, and elsewhere. This interpretation was reinforced by the experience of the Black Sea, where the hypoxic zone, which began developing in the 1960's, was even larger than the Gulf of Mexico's at one point, but shrunk considerably when the Soviet Union collapsed in 1990 – along with Soviet agriculture, with chemical fertilizer use falling by more than half (Pelley, 1998; Ferber, 2001).

[9] The most notorious US policy in this area is the support for corn-based ethanol implemented by the Bush Administration, which as of winter 2008 gave preferential treatment to domestic, corn-based ethanol by imposing a 54-cent-per-gallon tax on imported ethanol (aimed explicitly at the more efficient Brazilian producers of ethanol from sugar cane), as well as a 51-cent exemption from the federal excise tax on gasoline for fuel mixed with ethanol.

[10] This discussion focuses on the relationship between the nitrogen and carbon cycles, but of course increased biomass production has a number of other implications, especially for biodiversity, food economics, other elemental cycles such as phosphorous and sulfur, and hydrologic and land use patterns.

and material production is not potentially worthwhile; rather, it is that the obvious connection between the carbon and nitrogen cycles implicated in biomass production has been so thoroughly absent from public policy formulation (more technically, it also involves the question of when biomass production of various kinds goes seriously non-linear, thus producing unanticipated and potentially significant unintended consequences).

This example illustrates several themes. First, it introduces the important truth that when one is dealing with complex adaptive systems, one is dealing with information structures that are too complex to be understood from any single perspective. What one perceives of the overall system is in fact a subsystem defined by the query posed to the system. Thus, the query posed to the larger system will define the relevant scale and components of the appropriate sub-system. The reason that one is interested in the nitrogen cycle, for example, will identify those parts of the systems, including linkages with other systems, that are relevant to the query.

Second, the emergent systems behavior arises not from any particular locus – the inherent dynamics of the carbon or nitrogen cycles, for example, or the politics and ideology (and therefore culture) driving the particular policy, or the technology systems through which much of the coupling occurs. Rather, it emerges from the system as a whole, and rational responses to even subsystem elements (such as, e.g., biomass as a partial solution for global climate change forcing) require some knowledge and sensitivity to the system as a whole. The existence of often-acknowledged "unintended consequences" is, in fact, an important indication of the gap between subsystems called forth by query, and the overall system and its responses.

Third, even policies which claim a basis in "science," especially in the environmental domain, are usually highly normative, and the conflation of ideology, myth, and lack of data that often lie behind them lead to solutions that, because they fail to contemplate the scale and complexity of the relevant systems, reflect that particularly dangerous human attitude of uninformed self-satisfaction about which Heidegger warned. Increased reliance on biomass, at least to a degree, may not unduly perturb the nitrogen cycle, but that should be investigated prior to policy formation, rather than afterwards.[11] And finally, of course, it is noteworthy that human technology and economic systems, in this case involving the energy and agricultural sectors, are often the mechanisms by which system coupling occurs, not just between relevant human systems, but between "natural" systems, in this case the carbon and the nitrogen cycles, as well. To understand the Anthropocene without understanding technology is, simply put, impossible.

Consider another important example of a "natural" system that is increasingly anthropogenic, biology. That the dynamics and structure of biological systems at all scales are increasingly determined by human activity is apparent. It has been a long time since humans were just another species in an ecosystem. That may have been true of

[11] For example, growth of algal biomass is sometimes used to soak up excess nitrogen and phosphorous from wastewater. In such a case, benefits for the carbon, nitrogen, and phosphorous cycles might outweigh whatever other risks there might be (such as, perhaps, allowing continued production of the wastes, rather than eliminating them at the source).

hunter-gatherer societies, although even that romanticized oversimplification is questionable given current research on the extinctions of megafauna. Thus, it now appears probable that humans played a critical role in the elimination of megafauna in Australia and North America (Roberts et al., 2001; Alroy, 2001), given that three-quarters of North America's large mammals, including mammoths, mastodons, giant ground sloths, and saber-toothed tigers, went extinct over 10,000 years ago when humans first appeared on the continent. While some have argued that climate change was a causal factor, it now appears that climate shifts occurred too late to have had a major role. Similarly, studies involving Australia, New Zealand, the West Indies, Fiji, Madagascar, Cyprus, and other areas have shown that human arrival is closely correlated in time with the extinction of indigenous megafauna in those cases as well (Kerr, 2003).[12]

It was, however, the rise of agriculture that clearly accelerated the impacts of humans on other biological systems, and began to differentiate the scope and scale of one species from all others. The beginning of food production based on domesticated plant and animal species, probably in no more than nine centers around the world starting around 8500 B.C., was in many ways the beginning of cultural and technological evolution, both uniquely human system dynamics, as well (in part because agriculture strongly accelerated cultural and technological evolution, it played a critical role in creating an entirely different, and much more rapid, evolutionary dynamic for humans than for other species). Agriculture led to settlements and then cities: the domestication of plants and animals was also the domestication of entire landscapes (Mumford, [1961]1989; Redman, 1999).[13] Thus, it is no coincidence that the rise of agriculture in North Africa and Europe

---

[12] Taken another way, these extinction events can be thought of as the first expressions of the extraordinary will-to-power which characterizes the human species.

[13] Interestingly enough, as soon as agriculture supported the evolution of urbanized settlements, the inhabitants began looking back to their rural past as a "golden age," a psychological pattern that continues to this day. Mumford ([1961]1989, at 50) notes that "[t]he early Sumerian bards looked back to a pre-urban golden age, where 'there was no snake, no scorpion, no hyena, no lion, no wild dog, no wolf': when 'there was no fear, nor terror; man had no rival,'" concluding that (at 53) early man looked back to the period *before* the city as the Golden Age . . .". The appearance of the same archetypal pattern in modern environmentalism in particular is notable.

That agriculture and urbanization go hand in hand is apparent, and, indeed, the relationship between the two institutions is not causal, but co-evolutionary. Mumford ([1961]1989, at 30; see also Cronon (1991)) notes that agricultural civilizations gave rise to cities with all their implications – including the development of far more powerful agricultural technologies (a classic example of the auto-catalyzing nature of technological evolution):

> This new urban mixture resulted in an enormous expansion of human capabilities in every direction. The city effected a mobilization of manpower, a command over long distance transportation, an intensification of communications over long distances in space and time, an outburst of invention along with a large scale development of civil engineering, and, not least, it promoted a tremendous further rise in agricultural productivity.

And, of course, the Industrial Revolution was an integration of agricultural, manufacturing, and demographic revolution, producing discontinuous shifts in supply, demand, technology systems, and, concomitantly, the economic and cultural systems which they were simultaneously both embedded in, and profoundly affecting.

coincided with initial deforestation, and concomitant contribution of carbon to the atmosphere, albeit at a much lower level than current fluxes (Grubler, 1998; Williams, 2003).[14] Agricultural societies gained a significant competitive advantage over others, with the result being their massive expansion. As Diamond and Bellwood note (2003, at 597):

> Because food production conferred enormous advantages to farmers compared with hunter-gathers living outside those homelands, it triggered outward dispersals of farming populations, bearing their languages and lifestyles. Those dispersals constitute collectively the most important process in Holocene human history.

Moreover, it was agriculture that generated surplus food and goods, and therefore technological evolution and urbanization, and the development of trade and transportation networks, with all their associated cultural patterns and technology systems. The long evolution of agriculture as an important factor in increasing human dominance of natural systems is both apparent, and frequently overlooked, because it is so mundane and common to virtually all societies (Redman, 1999). Moreover, it is agriculture that has provided the economic incentives that drove much of the most fundamental change in the relationship between humans and biological systems, the development of genetic engineering, at first through "natural" methods such as interbreeding various strains of particular species, and more recently through modern manipulation of genetic material across species.

Perhaps for this reason, deep greens occasionally equate the beginning of agriculture with the fall of humanity from grace (Quinn, 1992; Broody, 2000). The founder of Earth First!, Dave Foreman, says that, "with irrigation ditches, crop surpluses, and permanent villages, we became *apart from* the natural world." (Quoted in Cronon, 1995, at 83). Note that from Foreman's perspective, even agriculture is not "natural," an interesting example of the use of the word "natural" as a moral filter (that which is "natural" is good, and, by extension of Foreman's use of the term, anything human beyond hunter-gatherer is fallen, not good, not "natural").

Genetic engineering and the broader field of biotechnology are, however, far more extensive than any single economic sector. At the genomic level, the human genome has been mapped, as has that of increasing number of bacteria, yeast, plants, and other mammals. At the organism level, genetic engineering of species to, among other things, increase yield; reduce pesticide consumption; reduce demand for land for agriculture and energy production; enable plant growth under saline conditions, thereby conserving fresh water resources (Travis, 2001); produce new drugs; reduce disease; increase hardiness; and support a healthier human diet, is proceeding apace. Indeed, a

[14] Williams (2003) notes that deforestation has been going on for many centuries, with roughly half of all deforestation occurring before 1950. The obvious implication, of course, is that there has been a significant acceleration of deforestation, since about half of all historical deforestation occurred only in the past 50 years. In this, deforestation is like many earth systems perturbations: it has a long history, but the scale of impact accelerates dramatically in the past 100 years or so (Turner et al., 1990; McNeill, 2000).

new field called “synthetic biology” is arising. Sometimes referred to as “plug and play biology,” synthetic biology merges engineering with biology by creating standard biological components that can be mixed and matched in organisms to provide desired functions. This allows researchers to create biological components, circuits and potentially replicating organisms from scratch, and extend beyond existing biological systems in new and completely anthropogenic ways, such as creating life based on different genetic codes than those found in the wild. It is a nascent field of study, but even so progress is significant: MIT, for example, has established a Registry of Standard Biological Parts (“BioBricks”) that can be ordered and plugged into cells, just like electronic components (Ferber, 2004; Check, 2005). Substantially increased interest in bioterrorism research has resulted in controversial breakthroughs such as building the 1918 flu virus, and the polio virus, from scratch (Kaiser, 2005; von Bubnoff, 2005). Other researchers have engineered the genes of *Escherichia coli* to incorporate a 21st amino acid, opening up an option space for design of biological organisms that has been unavailable for billions of years (Service, 2003).

At larger scale, the degree to which humans have created anthropogenic landscapes is somewhat disguised by people’s strong cultural and psychological tendency to interpret landscapes with which they are unfamiliar, and which do not display the technological artifacts they are used to, as “pristine” and “natural,” despite the fact that virtually all landscapes at this particular point in the evolution of our species are products of human intentionality.[15] In fact, at virtually all scales, few biological communities can be found which do not reflect human predation, management, or consumption. As Gallagher and Carpenter (1997, at 485, emphasis added) remarked over ten years ago in introducing a special issue of *Science* on human-dominated ecosystems, the concept of a pristine ecosystem, untouched by human activity, “is collapsing in the wake of scientists’ realization that there are *no places left on Earth that don’t fall under humanity’s shadow*.” Initially trade, and then transportation systems of various kinds have distributed invasive species around the world; as Kaiser (1999, at 1836) notes, “The world’s ecosystems will never revert to the pristine state they enjoyed before humans began to routinely crisscross the globe . . . .” Even those considered “natural” almost

---

[15] For example, even though arriving Europeans perceived the Amazon as “wild” and unaffected by the endogenous tribal cultures, research increasingly demonstrates that, in fact, large areas had been transformed through the construction of raised fields, large settlement mounds, and earthen causeways and fish weirs, and that large settlements existed in the Amazon well before Europeans arrived (Erickson, 2000; Mann, 2008). In the case of Hawaii, as with many previously inhabited landscapes "discovered" by Europeans, the human restructuring of Hawaiian ecosystems began well before Europeans reached Hawaii; it was their Enlightenment Romanticism that perceived that island, long modified by human action, as "natural" (Redman, 1999, at 70-73). In fact, Europeans often labored under (Redman, 1999, at 12-13) "a widespread and important misconception [that] a natural landscape, untouched by human hands, exists; and that societies before European contact lived in a utopian paradise guided by an unselfish conservationist ethic. This European premise that an Eden-like nature existed was based largely on the belief that native peoples, particularly in the Americas, did not share in the biblical fall from grace." For example, Redman (at 196) cites research that "suggests that the North American landscape at the time of Columbian contact was almost everywhere a humanized landscape and that the view of it as pristine was to a large extent an invention of nineteenth century romantic writers." In short, "wilderness" is not a characteristic of “natural” environments, but a projection of a mental model arising from the Enlightenment Romantic tradition (Abrams, 1971), informed in particular by the emotionalism of the Rosseauean "noble savage."

inevitably contain invasive species, frequently in dominant roles.[16] Modern technological systems continue to increase the scale of these impacts: writing in *Science*, Palumbi notes that (2001, at 1786) "[h]uman ecological impact has enormous evolutionary consequences . . . and can greatly accelerate evolutionary change in the species around us . . . technological impact has increased so markedly over the past few decades that humans may be the world's dominant evolutionary force."

But perhaps the most powerful force now affecting biological systems is not transportation technology and networks, but intellectual property law, which, in combination with powerful economic forces, is determining how biological systems - especially through explication of their genetic and metabolic pathway information - are translated from expression in wetware (protoplasm), to the underlying genetic and proteomic systems, to information, to commodity. The implications of this coupling of the biological (natural), biotechnology and genetic engineering (technological), and market capitalism (economic) systems are huge, and it is a clear indication of the inability of current institutions to perceive them that they are so poorly understood.

Take the most obvious issue, biodiversity. Most environmentalists and conservation biologists believe that there is currently a crisis in biodiversity driven primarily by extinctions resulting from human activity. Current extinction rates are estimated to range from 100 to 1000 times prehuman rates, and humans are blamed for causing the extinction of from 5% to 20% of the species in many groups of organisms (Chapin et al, 2000; Lovejoy, 2002). Precise numbers are controversial for many reasons, the most fundamental being our limited grasp of how many species even exist, especially in the microbial realm, but the Millennium Ecosystem Assessment accurately sums up the current view succinctly in concluding that human activity, especially over the past 50 years, "has resulted in a substantial and largely irreversible loss in the diversity of life on Earth." (MEA, 2005) Certainly as noted above it is clear that there are a number of extinctions attributable at least in part to human activities, dating from megafauna extinctions thousands of years ago. But the explosion in biotechnology suggests that what appears to be a crisis may be in fact simply a transition in the mechanisms by which biodiversity is produced: from "evolutionary biodiversity" to "designed biodiversity". This line of thought would argue that a century from now, there may well be more, not

[16] The impact and scale of invasive species, particularly on islands, is sometimes staggering. Thus, for example, of 21,368 identified species in Hawaii, 4,258 are non-native (immigrant and purposefully introduced species), and another 8,343 may not be endemic (status unknown) (Mlot, 1995). The human introduction of invasive species – along with habitat destruction, overexploitation of indigenous species by humans, and secondary extinctions (the so-called "Evil Quartet" of extinction causes) is a major reason that some 80% of known mammalian extinctions during the last half millennium have been among endemic island species (Gittleman and Gompper, 2001). It was not just the historical human migrations, such as the Polynesian and European episodes (and, more specifically, the transportation technologies and human tendency to import their familiar landscapes to new territory), that generated great waves of invasive species, however. In fact, such activity continues today at a less visible but perhaps even greater pace as a result of continuing trade and tourism. For example, there is significant transfer of microorganisms, plankton and larvae in ballast water for ocean shipping (each year U. S. water receives more than 79 million tons of ballast water from overseas, much of which is heavily populated by potential invasive species) (Ruiz et al., 2000).

less, biodiversity – but that biodiversity will be the result of human engineering of genomic systems, not the result of traditional biological evolution.

To consider this argument is not to say such a development is "good" or "bad"; merely to ask whether current disciplinary or institutional structures are competently perceiving, much less understanding, the implications of current trends. Certainly, such a transition raises difficult questions. For example, one of the advantages of "evolutionary biodiversity" is that it reflects the context within which it occurs, and it therefore leads to relatively stable and resilient systems. "Designed biodiversity," however, may reflect economic and cultural pressures, and short term industrial goals, that are not necessarily integrated with other components of the physical and biological world, and thus result in a biodiversity that is fragile and even dysfunctional. Moreover, for many who equate "nature" with the "Sacred" (see, e.g., McKibben, 1989), the idea of biodiversity arising from human intentionality verges on blasphemous, despite the fact that existing patterns of biodiversity already reflect human activities, and have done so for a long time. But even a cursory analysis of the systems involved, and the relevant economic and technological trends, indicates that such a transition to "designed biodiversity" is at least probable. And if that is the case, there is a high cost to refusing to perceive, or consider the implications of, the possibility that biodiversity is not in crisis, but in transition. If this trend is real, there are many profound consequences, from the religious and the ethical to the severely practical (e.g., how can humans purport to create anthropogenic biodiversity when we have so little knowledge of the structure and dynamics of the systems involved?). Such implications require considered thought and dialog from a number of perspectives, not just the technical. Moreover, there are systemic issues: does the purported trend exist, and, if so, how rapidly it is occurring? And how should it be measured? And since, if it is true, it implies continuing integration of biological and industrial systems, what will biology itself mean in the future? More profoundly, whether there is a crisis in biodiversity depends to a large extent on which discourse – say, conservation biology as opposed to biotechnology engineers - gets to define "biodiversity." As will be discussed in more detail below, an ability to define the language can easily become an ability to define a single ontological perspective, creating oversimplifications that are not just wrong, but dysfunctional. A failure to perceive the actual dimensions of biodiversity is necessarily a failure to understand the critical dynamics of the world as we have created, and are creating, it.

I.B. *Economic, Technological and Demographic Aspects of the Anthropocene*

As the biodiversity example suggests, the couplings among natural, human and built systems are both powerful, and clearly apparent by even a cursory inspection of the evolutionary patterns of our species. As Table 1 illustrates, human population growth over time, linked to technology state, has been steadily upwards (allowing for the usual perturbations) (Cohen, 1995; Graedel and Allenby, 2003).[17]

---

[17] Figures are from Appendix 2 in Cohen (1995, at 400-401), an excellent tabular compilation of human population estimates from various sources, from a million years ago to the present. Needless to say, such numbers are estimates with fairly wide error bars; moreover, as Cohen properly notes, the curves usually fitted to such numbers are only approximate as well, and can be misleading if not interpreted accordingly.

Human Population Growth

Age	Population level (in millions)	Global Technology State (Core)
1,000,000 BP*	.125	None
10,000 BP	4	Beginning of Agricultural Revolution
2,000 BP	100	Agricultural
1,000 BP	300	Agricultural
1500 AD	450	Enlightenment; Beginning of Modern Science and Technology
1900 AD	1,600	Heavy Engineering (e.g., Railroad)
1950 AD	2,500	Mass Production and Consumption (e.g., Automobile)
2000 AD *⌋ Before Present	6,000	Information/Biotechnology Society

However it is modeled, human population growth clearly accelerated strongly with the advent of the Industrial Revolution, which essentially created unlimited resources for the expansion of the human population (not unlike yeast in a new growth medium) (Cohen, 1995; Allenby, 1999).

Moreover, human settlement patterns have evolved from primarily rural to primarily urban over time, beginning with the availability of agricultural surpluses, an evolutionary path which has among other things extraordinary cultural implications, a point discussed in more detail below. Developed countries are already highly urbanized, and the UN estimates that the urban populations of Africa, Asia and Latin America will double over the next 30 years, from 1.9 billion in 2000 to 3.9 billion in 2030, when over 60 percent of the world's population will live in cities (NRC, 2003). Such substantial growth and shift in living conditions, particularly combined with technology-enabled extension of humans' control over their environment, has enormous implications for understanding and managing anthropogenic planetary systems. For example, as more humans grow up in urban environments, and are increasingly coupled to synthetic realities and information systems, will they lose interest in the "natural" environment and environmentalism itself?

Technology state equates to the "long waves" of technology constellations familiar to economists (Freeman and Louca, 2001).

Economic data illustrate similar growth patterns on both a global GDP and a per capita basis (Table 2, based on McNeill, 2000).

Global Economic History: 1500 - 1992

Date	World GDP (indexed to 1500 = 100)	Per Capita World GDP (1990 dollars)	Per Capita (indexed to 1500 – 100)
1500	100	565	100
1820	290	651	117
1900	823	1,263	224
1950	2,238	2,138	378
1992	11,664	5,145	942

This overall growth is not homogenous, of course: it consists of different technology clusters, with different patterns of interaction with co-evolving natural systems. For example, early industrialization depended heavily on mining, while the latest technology cluster, bio- and infotechnology, depends much more heavily on intellectual capital and knowledge (Grubler, 1998; McNeill, 2000; Freeman and Louca, 2001). While it is apparent that regional trade has existed since ancient times (e.g., the famous "Silk Road"), it is also clear that the evolution of the European state, and consequent evolution of global transportation systems (ships for oceanic trade, and railroads for overland internal trade), and finally the shift to air, have resulted in unprecedented and accelerating levels of trade and concomitant globalization of transport, resource consumption, and financial networks (Hugill, 1993; Castells, 2000). These networked structures, which increasingly integrate across not just the physical landscape but cyberspace as well, are both indicia of, and the infrastructure for, the anthropogenic earth. They not only support the continuing and accelerating evolution of systems of dramatically greater complexity, but, as more previously "natural" systems are integrated into global economic activity, become dominant information storage and transfer mechanisms, and decentralized control nodes, in the Anthropocene (Castells, 2000; Allenby, 2005).

The profound impacts of technological change are often overlooked, primarily because most people are so immersed in technology that it is essentially invisible to them. Consider the familiar, even banal, technology of railroads. Railroads did not just revolutionize transportation. They created modern industrial time, and modern communication networks (in this case, the telegraph), for both are required to manage a regional network in real time (Rosenberg and Birdzell, 1986; Schivelbusch, 1977). Railroad firms needed far more capital than the simpler factory capitalism they replaced; they thus required, and shaped, modern capital and financial markets (Freeman and Louca, 2001); managing a railroad was qualitatively more complex than managing a factory or local business, and thus generated modern managerial capitalism. The railroads created scale economies across national markets, and thus led to the restructuring of the economy from local and small regional business concentrations to trusts - Big Sugar, the Tobacco Trust, Standard Oil. With the railroad, economic power passed to industrial firms from agriculture; more subtly, so did cultural authority (Marx, 1964; Nye, 1994). They transformed landscapes at all scales: Chicago existed, and structured the Midwest economically, politically, physically and environmentally, because of railroads (Cronon, 1991).

Like the railroads, all powerful technology systems are similarly destabilizing of the status quo. It is thus worth remembering that we now face not one, but five, rapidly evolving new core technologies: nanotechnology, biotechnology, robotics, information and communication technology (ICT), and applied cognitive science ("NBRIC"). In some ways, these technologies are themselves a culmination of the process that has led to the anthropogenic Earth, for they are the logical end of the chapter of human history that began 2,500 years ago with the Greeks. Nanotechnology is the culmination of material science and chemistry, in that it extends human will and design to the atomic level. As for biotechnology, McNeill notes that (2000, at 193-94):

> By the twentieth century, our numbers, our high-energy technologies, and our refined division of labor with its exchange economy made us capable of total transformation of any and all ecosystems. . . . In the twentieth century we became what most cultures long imagined us to be: lords of the biosphere.

Robotics continues to expand its exotic menagerie; national security agencies are developing robotic insects that can be used for surveillance, while hybrid robots – hardware robots guided by hybrid rat neuron/chip configurations – undergo testing in the laboratory (in the instant case, some 300,000 rat neurons in a soup – the image is of the proverbial brain in a vat, only it's real and running a robot (Marks, 2008)). Military use of robots is expanding greatly, from weapon platforms that are manipulated at a distance to jet fighters that are designed so they can either be flown directly by a pilot – or from a distance. ICT gives us the ability to create virtual worlds at will, and facilitates a migration of functionality to information rather than physical structures. Thus, money used to be coins and paper bills, themselves mere symbols of value, but now even that physical premise is gone. Money is electrons somewhere in cyberspace, and financial instruments have become so mathematical that no one can figure out anymore which shell the risk is hidden under. But ICT has more subtle implications. Consider, for example, how Google™ enables real time recovery of virtual any fact on the Internet – or, put another way, how memory as a cognitive function has now been distributed across the Web, just as in earlier eras poetry and religion, upon being printed, became available to everyone, not just elites. And then there's cognitive science, which is particularly challenging in that it affects not just external systems, but the human itself. When previous technology systems like the railroads may have made fundamental changes, at least they were external to the core concept and physicality of human. Cognitive science on the other hand accelerates the process of modifying (or designing, or actively intervening in) the human itself. But it is not just that each NBRIC technology system is powerful; it is that they are combining in unexpected ways that are both beyond any single technological domain, and very potent.

An easy to understand yet often overlooked example is the probability that substantial extensions of average lifespan, with a high quality of life, are achievable in the next few decades (DeGrey, 2004). For example, the IEEE *Spectrum*, a mainstream technical journal, ran a series of articles in 2004 on engineering and aging which concluded that using "engineered negligible senescence" to control aging will allow average ages of well over 100 within a few decades. Others, while not rejecting the possibility, are more skeptical (Vijg and Campisi, 2008). Historically, substantial increases in lifespan are not unprecedented; before 1800, life expectancy virtually everywhere was only 30 to 35 years; South Korea has seen a 30 year jump in lifespan since 1960 (Clark, 2007; The Economist, 2008).

But what makes radical lifespan extension interesting is not just the integration of technological domains – complexity and network theory, genetics, biotechnology, electrical engineering theory and methodology, and much more. Rather, it is how unaware virtually all policymakers and the public generally are of the possibility. This is even more bemusing because of the obviously challenging implications (for pension and old-age systems, reproductive freedom and demographic trends, material and energy consumption patterns, and impacts on natural systems and cycles, for example). To add to the conceptual challenges, radical lifespan extension is only a small, albeit emotionally potent, area of human enhancement research; taken together, the suggestion that "the human" is in the process of becoming a new arena of systemic design is not implausible, although of course specifics are unpredictable (Garreau, 2004; Kurzweil, 2005).

I. C. *Cultural Aspects of the Anthropocene*

Institutionally, culturally, and economically, the world today is predominantly a product of the Greco-Roman-Judeo-Christian European experience as filtered through the Reformation and the Enlightenment.[18] The dominant form of political organization – and

[18] The usual phrase, "Judeo-Christian," understates the degree of integration of Greek philosophy into Christianity, via, among others, Avicenna (980-1037 A.D.) and Averroes (1126-1198 A.D) (Russell, [1945] 1972). More subtly, technology was unquestionably a major theological project of Christian Europe, but it too has its roots in Greek philosophy and rationalism (Barrett, 1979). The Roman influences of law and engineering (especially civil engineering as a critical infrastructure competence for empire) are also important foundations for the subsequent evolution of the European Enlightenment.

the only sovereignty recognized internationally - is the nation-state, whose status is a product of the Peace of Westphalia (more specifically, the treaties ending the Thirty Years' War signed in Osnabruck and Munster in 1648) (Mathews, 1997). The market-driven capitalist form of production that dominates world economic activity is a product of the West, as is the scientific and technological culture that accompanies it. As Giddens[19] comments:

> [Modernity] is institutionally based on the nation-state and systemic capitalist production . . . Both have their roots in specific characteristics of European history and have few parallels in prior periods or in other cultural settings. If, in close conjunction with each other, they have since swept across the world, this is above all because of the power they have generated. No other, more traditional, social forms have been able to contest this power in respect of maintaining complete autonomy outside the trends of global development. Is modernity distinctly a Western project in terms of the ways of life fostered by these two great transformitive agencies? To this query, the blunt answer must be 'yes'. . . . The modes of life brought into being by modernity have swept us away from *all* traditional types of social order, in quite unprecedented fashion.[20]

These observations should not be read as cultural triumphalism, or as denigrating the scientific and technological developments of other cultures, such as Islam during the early middle ages or the well-documented Chinese innovations in technology (Needham, [1956] 1991), nor of the contributions to Eurocentric culture made by many other societies, cultures, religions, and belief systems. But it was in Europe, especially the rationalistic and scientific Europe of the Enlightenment, where the threads of institutional evolution, religious conviction, scientific and technological capability, cultural systems, and economic

---

[19] Giddens, 1990, at 174, 136; see also Diamond, 1997, at 13, 67-81; and Landes, 1998.
[20] As Giddens (1984, at 183) observes, "Modern capitalism is not one type of 'civilization' among others . . . [As] the first genuinely global type of societal organization in history, it has its origins in a double discontinuity in the development of the West . . . . [the first being the] intertwining of political and industrial revolutions . . . [and the second the] expansion in administrative 'reach' and surveillance of the state." Bertrand Russell ([1945] 1972, at 399-400) holds that the Eurocentric "superiority since the Renaissance is due partly to science and scientific technique, partly to political institutions slowly built up during the Middle Ages," and adds the important observation: "It seems not unlikely that, during the next few centuries, civilization, if it survives, will have greater diversity than it has had since the Renaissance." As discussed further in the text, an important component of the Enlightenment project is precisely that it allows - even encourages, by the constant questioning and dissonance enabled by the focus on rationality - emergence of conflicting and challenging worldviews. Thus, not only is Russell correct, but it can be argued that only a culture which had its own obsolescence built in could possibly have become a global culture. To put the matter in dialectic terms, only a culture which encouraged the development of antitheses to each thesis, and thus the achievement of continually broader syntheses, could evolve into a global system. To the European Romantics, for example, the success of European civilization represented a victory of a specific teleology (derived in various forms from Christian culture) and a movement towards "the end of history" (a very Christian concept) (Abrams, 1971), but, it is the process itself that is dynamic and, for a number of reasons, dominated other more static cultures. The cognitive systems of the West grew more complex, more broad, and more auto-catalytic than those of other cultures, giving Eurocentric culture a powerful advantage over more traditional rivals.

theory and market development, all came together. The result was not just the development of ad hoc technologies or scientific discoveries, but the generation of a cultural juggernaut – a set of uniquely powerful networked cognitive systems - which swept over the globe. The most powerful challenge to this structure in the past 150 years has been Marxism – and, of course, Marx himself was a quintessential Enlightenment figure.

But two critical observations temper this potentially triumphalist story. The first is that, as even superficial observation indicates, it is a profoundly multicultural world. The Westernization of the world has not occurred explicitly in many cases, but at a more subtle level. Thus, Eurocentric cultural constructs are generally not explicit, but embedded in institutions and practices which, on the surface, appear to be culturally neutral: the idea of progress, time as a linear structure, the technological and scientific underpinnings of modern life, the market economy, the idea of individual human rights. This is necessarily the case, for explicit cultural imperialism, apparent to those whom it challenges, can be fought directly. When implicit in otherwise appealing discourses – economic development, material well-being as a result of adoption of modern technology – it is both harder to perceive and harder to fight. For example, if Christianity were to directly challenge Islam, the cultural conflict would be – and sometimes is – clear, and can involve significant violence. But Christian eschatology embedded in the globalized technological culture is far harder for Islam to both identify and resist.

The second is that the Enlightenment as global culture has succeeded, ironically, because it uniquely carries within it the seeds of its own negation as a uniquely "true" or "valid" culture. For example, Rorty (1989, at 57) notes that an Enlightenment liberalism appropriate to the modern world, as created by thinkers such as John Dewey, Michael Oakeshott and John Rawls, represent "the self-cancelling and self-fulfilling triumph of the Enlightenment. Their pragmatism is antithetical to Enlightment rationalism, although it was itself made possible (in good dialectical fashion) only by that rationalism." And, indeed, the strongest critics of the Enlightenment have been internal, from Rosseau (whose criticism has become internalized to much of the environmental discourse), to Marx, to the postmodernists of all stripes. Thus two paradoxical observations:

1. Only a structure which, like the European Enlightenment, contained its own critique and negation within itself could possibly become the basis for a globalized cultural framework in a multicultural world; and,

2. The Enlightenment framework succeeds only to the extent it negates itself as a unique source of "truth."[21]

---

[21] There are many different flavors of negation. The Nietzschean flavor is somewhat nihilistic and conceptual; the Marxist, on the contrary, is if anything too naïve in its utopianism and faith in the goodness of human nature. The scientific negation, from Freud to Newton, tends to reflect the passage from a

It is worth noting that the mixture that came together in Europe produced modernity as an emergent characteristic not just of culture, or of economic growth, but of the entire package of European experience. It is highly doubtful that in the early 1400's Portuguese sailing technology could have bested the Chinese, but that test was never made, as the Chinese abandoned their exploratory efforts (an abdication of technological competence that modern China is highly unlikely to repeat). The displacement of the Portuguese by the Dutch was not predominantly technological, but cultural and even theological (Hugill, 1993, at 22): "It was an ideological innovation (Calvinism) that allowed the Dutch to lower the cost of financing ships and to develop the first reasonably modern banking system. They improved risk management by taking shares in ships rather than owning them outright." Subsequently, the British displaced the Dutch through differential social structures and policies (Hugill, 1993, at 23): "The advantage England came to enjoy may have lain more with internal social structure than with technical systems. England proved more adept [than the Dutch] at alienating labor from the land in the later seventeen century."

II. *Integrative Cognitivism: Initial Observations*

The anthropogenic world broadly outlined above raises fundamental and unavoidable questions about the adequacy of current conceptualizations of human agency, rationality, and cognition, at both the individual and institutional level. If, for example, the paths of powerful technology systems such as nanotech or biotech are not susceptible to meaningful management and regulation, many current research and policy programs are essentially moot. Does individual intent, and action, make a difference and, if so, is the result of the action predictable? Is there such a thing as free will, and, if so, how can it be exercised in a world where coupled global systems create level upon level of structure and dynamics, most of which are poorly understood or even perceived? Indeed, implicit in most proposed management methodologies, from systems engineering to adaptive management to earth systems engineering and management is the assumption that it is possible to perceive, understand, and rationally and ethically act in, an anthropogenic world (Allenby, 2007; Gunderson et al., 1995): is that simply a fantasy?

The usual ways of thinking about such phenomenon implicitly assume a world of simple systems, ruled by cause-and-effect relationships, linear input-output responses,

---

pantheistic worldview and explanatory structure to the rationalistic tone characteristic of the Enlightenment; it is a negation because of its highly corrosive effect on existing myths (and its concomitant creation of new myth: the universe as mechanism, for example). Perhaps the latest negation is postmodernism, which is intentionally corrosive of any prior discourses – at least to the extent they pretend to any authority, which is, of course, a major rationale for any discourse in the first place. In each of these cases, however, the Enlightenment tradition has not only been the source of the negation, but has itself been transformed, transcended, and made more universal and encompassing, by the negation. This dialectical process, perhaps most closely associated with Marx and Hegel, is itself an important and self-conscious facet of the Enlightenment; in fact, much Romantic thought, with the important exception of Rousseau, saw the dialectic as the process by which human progress towards a reintegrated high civilization (in religious terms, recovery from the Fall, which was itself seen as introduced by intellectualization) occurred (Abrams, 1971).

and meaningful and obvious causal connections. Indeed, this is still a valid and broadly useful approach; because most systems are bounded in some way - legally, culturally, situationally, or whatever – ideas appropriate for simple systems are still valid. Increasingly, however, the critical questions – involving global development, production and consumption; technological convergence; shift in biodiversity from evolved to designed; climate change and other earth systems phenomenon; evolution of cyberspace; management of urban systems – arise as emergent behavior from complex adaptive systems, often integrating elements of human, natural and built systems. In such cases, it is obvious that the intellectual heritage we have accreted so far largely fails.

This leads to an initial observation that the dominant metaphors we create for reality are contingent and, especially in periods of rapid change, can quickly become inadequate and even dysfunctional. The "universe as mechanism" metaphor which grew from the early Enlightenment and Newtonian physics helped structure the scientific revolution, but proved too limited for modernity because mechanism is a simple system. The "universe as ecosystem" metaphor which is dominant now, and ripples through such concepts as the "eco-city" or sustainable development, is also rooted in the Enlightenment, and, because it is based on biological and ecological mental models, enables perception of more complexity. Nonetheless, it is itself inadequate for the Anthropocene because among other things it fails to enable recognition of intentionality, culture, and transformative technology, and virtually by definition rejects the reality of the anthropogenic Earth. It reflects more complexity than the mechanism metaphor, but it is still too simple.[22] The metaphor towards which I suspect we will move after the infatuation with the biological metaphor wears off will be one of evolving networks of networks, which can capture the biological, cultural, and other relevant dimensions of complexity. Still, it must always be remembered that all such metaphors are essentially cognitive tools, enabling perception and a metastructure for cognition; they arise from our efforts to structure complexity, not from complexity itself. Accordingly, there is a

---

[22] Gandy (2002, at 9,10) notes that:

> Over the last twenty years there has been a growing interest in the "ecological city"' as an alternative to the environmentally destructive, violent, and socially divisive characteristics of contemporary urbanism. The "ecological city" draws together a series of interrelated themes: the use of nature as a "blueprint" or set of rules for the organization of human society; an organic conception of the regional economy as a largely self-contained form of social organization; an aesthetic predilection for the "urban Pastoral" rooted in nineteenth-century romanticism and a belief in the "curative" and "regenerative" powers of nature; and an elision between the ecological world view and a wider critique of modernist thought and design.

But he severely criticizes the failure of this model to account for the human, particularly the cultural (2002, at 10-11):

> . . . the ecological view is critically deficient with respect to the social production of nature. . . . explanation [of urban systems] in the physical and biological sciences is rooted in metaphors that are social and cultural in origin, even if the phenomena under investigation have an ontological status of their own. To call for an ecologically based urbanism is to replace the historical analysis of social change with an arbitrary alternative.

boundary of validity implicit in the choice of any such metaphors, and careful attention is required near those boundaries to ensure that the metaphor is not forced beyond its functional point. That is, in fact, what happens when ecological metaphors are applied to human systems such as firms or cities; careful observation and analysis might provide new insights, but the metaphor is prima facie inapplicable to the complexity of such systems.

II. A. *Networks*

Networks – essentially combinations of nodes or hubs, and connections – are proving to be increasingly useful models in all fields of research. Network theory is a rapidly growing area of research, driven in part by its applications in biology, communication and information systems, business operations, and social networks.[23] A complete survey of this literature, while interesting, would be well beyond our interests, but a few salient observations about networks in general may make the discussion of integrative cognitivism more understandable.

To begin with, it is important to realize that much of a network's behavior and characteristics arise not from its substantive content, but from its structure and dynamics. This is counterintuitive for a species that puts heavy emphasis on its intentions and desires. For example, it appears that at least some behaviors that one might ascribe to intentionality can arise, at least in theory, from inherent systems dynamics.[24] Thus, dense networks – ones with many interconnections, and where the interconnections are relatively strong – have a high potential for emergence of large scale phenomenon via self-organization. As Fewell (2003) notes with regard to social insect networks:

> As dense networks, social insect colonies have a high potential for the emergence of large-scale phenomena via self-organization. . . . What is perhaps most important about self-organization in social insects is that it is not based on derived characteristics unique to the taxon. Instead, it is driven by a limited set of nonlinear dynamics that should occur across social systems, from insects to humans.

---

[23] Barabasi (2002) is an excellent and approachable general text on networks and network theory, and both *Science* and *Nature* have run major special sections on complexity, networks, and biological systems (Gallagher and Appenzeller, 1999; Surridge, 2002). Nagurney and Dong (2002) provide a more technical treatment of networks, with a focus on economic applications. Castells (2000 a and b, 2001) discusses the importance of networks in sociological, financial, industrial and professional systems in great detail.

[24] The observation that in many cases consciousness of a decision appears to trail, not lead, changes in brain state indicating that the action has already been set in motion is among many that call into question the intuitive explanation of consciousness alone as a source of expressed behaviors (Dennett, 2003). On a different scale, the events of "Black Monday," October 19, 1987, when the U.S. stock market fell by 22.6% in one day, have been attributed to the dynamics of an uncoordinated network of stock trading computers set up by different brokers and linked by their relationships to the market and subsequent shifts in "market psychology," especially since there were no changes in market fundamentals that seemed to warrant such an adjustment. In other words, the argument is that the crash was precipitated by network dynamics (software/computerized trade and psychological responses through human networks) rather than substantive fundamentals (although there is no final agreement regarding fundamental causality).

However, the more dense and interconnected a network structure is, the more conflicting constraints exist, and the more difficult smooth evolution will be. Thus, for example, it is relatively easy to make a change to an end-of-pipe pollution control technology, because it is only weakly associated with operations in the facility. On the other hand, it is frequently quite complex, and generates significant ripple effects across a system, if a change is made to an important manufacturing technology, because it is tightly coupled to other manufacturing operations, product and process design, and the economics and performance of a product.

The spectrum of possible densities of network structures establishes an important space (Kaufmann, 1995). As a network becomes more interconnected, it becomes more stable and homeostatic; at the limit, the interconnected network structure renders any change (except, perhaps, complete destruction of the network) impossible, and the system becomes static and unable to evolve. If, on the other hand, there are not many linkages and the ones that exist are weak, evolution is impossible because transmission of information to future states is impossible: some order and structure are required for evolution. Accordingly, evolution occurs in the domain between order and chaos, because the evolving network must be able to both coordinate complex activities (requiring structure) and evolve (requiring some degree of freedom) (Kaufmann, 1995).

The metaphor this provides for the Anthropocene, therefore, is that of a structure of networks of networks operating at many different and interpenetrating levels, some of which are changing, some of which are locally stable, and many of which exist in overlapping but not identical phase spaces.[25] There is both structure and chaos in such a system; as Kaufmann notes (1995), both are necessary and either, if it becomes too dominant, restricts the ability of a system to function and, at the limit, destroys it. Moreover, any particular network can go through periods when it is susceptible to change (relatively weak linkages among nodes, little interconnection to other networks), and periods when it is exceptionally stable, and thus resistant to change. An obvious example of this occurs in industry: a firm at the peak of its success – tightly coupled to its markets, its customers, and internally aligned in a way which has both supported achievement of success, and resists efforts to change - seldom changes dramatically; the opportunity for significant change exists when a firm is struggling, or the stable market configuration for which it has been optimized suddenly and fundamentally shifts.

The question of when networks and complex systems are stable, and when they are not, is a vexed one, especially as in any reasonably complex network the subnetworks

---

[25] The concept of a phase space was introduced by Willard Gibbs in 1901. It is a multidimensional space where all possible states of a system can be represented, with each possible state corresponding to a unique point. The number of dimensions a phase space has therefore depends on how many degrees of freedom or different parameters are necessary to define a regime such that each state can be differentiated from any other state. Although the concept originated in the physical sciences, it is interesting, and challenging, to extend it to human systems and, even more challenging, to the integrated human/built/natural systems that characterize the anthropogenic Earth.

will be shifting and evolving at different rates with different dynamics. As cognitive networks become more reliant on ICT, for example, creating nested networks of signifiers linked by information codes, the arbitrary nature of those codes means that in some cases global commands can change system states across many scales. This gives quite significant power to even small changes (Hayles, 1999) – but only to certain "privileged" ones. Referring back to the archetypal image of a butterfly flapping its wings and thereby generating a storm, Kaufmann (1995) notes that if every time any butterfly flapped its wings, major systemic effects ensued, unmitigated chaos and disorder would result. Lanier (2002, at 219) raises the critical issue: since every butterfly flap does not create a storm, what differentiates the few that do from the millions that don't:

> [E]ven if it's true once in a while, there aren't enough storms to account for all the many butterflies. Measurable bits might be said to have different "causal potentials." . . . In order for a bit to be important – that is, to have high causal potential – it must be read; it must be a critical part of a system.

In short, the good news is that networks provide a viable means for conceptualizing interacting complex adaptive systems; the bad news is that even some of the fundamentals of their dynamics, especially when they involve human systems that deliberately generate new information and display intentionality and reflexivity, are not well understood.

The implications of this network of networks model of complex reality in the Anthropocene are non-trivial. For example, it explains to some extent why the argument between relativism and absolutism is obsolete (in fact, unintelligible); in large part, it simply represents a category confusion, an inappropriate attempt to extend concepts valid for simple systems to complex adaptive systems. It is reasonable that within a particular network that is locally stable, certain rules, ethics, ontologies and patterns of behavior may be absolute. Indeed, they may be important defining parts of the network. Common religious beliefs, clan relationships, and many belief-based Internet communities suggest such a dynamic. But it is also the case that once the boundaries of that island of stability have been passed, there is no particular reason why they should continue to be absolute; indeed, it is likely they will not be. There can be absolute truth, and there can be relativism, and they co-exist; it depends on the structure of the network within which one is operating, which in turn depends on the basic set of queries that has generated the particular structure in response.

Equally interesting, the convergence of a number of potent technologies on the biological, cognitive, and other aspects of the "human" have destabilized that cultural construct as it has not been for centuries. It is not just that the physical and biochemical dimension of human beings is becoming a design project; it is also that the rapid deconstruction of the human as Cartesian artifact, and its reconstruction as a networked cognitive system across many new technologies, is having profound effects on critical components of our self-definition. In particular, the constructions of "human," "self," "cognition," "cognitive capacity," and "intentionality" are increasingly understood not as representative of foundational verities, but as contingent constructs that arise from the systems states underlying them. They are, in other words, network functions. That we reify them is, in most cases, a harmless and even useful oversimplification of otherwise complex conditions; but when we seek to understand the anthropogenic world, such oversimplifications can be both misleading and dysfunctional. It's a little like Newtonian versus quantum physics: in most cases, the simpler Newtonian model of the world is perfectly adequate; but if one is after deeper questions of physical reality, Newtonian physics fails.

It is also important to remember that every network is inherently arbitrary, in that it reflects particular structures in a complex adaptive system that are relevant to the query posed to the system. Any query, or discipline, or ontological stance structured enough to exist as a network will call forth a responsive network from a complex adaptive system, but the latter will always be contingent on the former. That there is no privileged access to reality, therefore, arises from the nature of complexity and reason: it is not a reflection of a failure on the part of the cognitive network, but is an irreducible result of the behavior and essence of complexity.[26] This does not mean that there are not more or less functional ways of conceiving particular problems, or defining the phase spaces within which one is functioning, but it complicates the question of relativism. It does not mean that there are no totalizing discourses, no totalizing ontologies; only that they exist within a bounded network that is, itself, contingent. Thus, there are no globally valid discourses or ontologies, but there are local ones, if the local system is stable enough to support them.[27] In fact, we can go further: since the creation of local order tends to reflect particular networks and resultant identification of reflective networks from external complexity, it is likely that local systems will, in fact, reflect and generate particular

---

[26] In this, the relationship between query and responsive network, against the backdrop of a complexity that cannot be captured in any single network, is reminiscent of Lau Tzu ([circa 550 BCE]1991):

The tao that can be told
is not the eternal Tao.
The name that can be named
is not the eternal Name.

The unnamable is the eternally real.
Naming is the origin
of all particular things.

The difference is that the Tao as so defined is understood as a mysterious quasi-religious entity; the complexity that characterizes our current environment is inherent in its structure, and may be understood, although not reduced or eliminated, by future exploration. Certainly, we understand a lot more about complexity than we did twenty years ago, and there is no reason to believe such intellectual progress will not continue.

[27] Those disciplines that focus on information generation from "physical" systems such as chemistry or physics will tend to have ontologies emphasizing the independent reality of physical systems; those that focus on reflexivity in human systems, such as sociology or literary criticism, will tend to have ontologies emphasizing the contingent and constructed nature of reality as perceived and changed by the activity of cognitive systems.

discourses or ontologies. The mistake is in misconceiving such local structures as valid globally.

As an additional observation, since generating queries and stances is a creative act that calls forth unique responses from the queried system, the need to understand intentionality in a world characterized by complexity is even more critical, for that world is built upon the reification of the continual dialog between cognitive networks and the greater background of complex adaptive systems. The need for integrative cognitivism, in other words, arises not just because changing relationships between humans and their planet require an updated philosophical approach, but because the cognitive networks that we are, and create at many different scales, become reified in the complex adaptive systems within which we function, and with which we, in turn, co-evolve.

Accordingly, history matters – as do legacy networks.[28] In particular, the network structures that characterize the anthropogenic world reflect their past paths in their internal structure and dynamics. Moreover, since their ability to react to changes in external and internal states is a product of their current state, their past affects their future. Such networks, in other words, have an arrow of time. This sounds like a trivial observation, but it is often overlooked. Consider, for example, all the dialogs about restoring the Everglades, or the Baltic, or the Iraq Marshes to their previous pristine states. This is simply impossible. We can choose to design the systems to create a state that includes flora and fauna we find desirable, and that may include organisms that lived there before and can live there again; but we can not reverse the paths of these networks. Thomas Wolfe was right: you can't go home again.

II. B. *Integrative Cognitivism*

In order to lay the necessary groundwork for understanding the anthropogenic Earth, it is necessary at this point to structure a conceptual framework that, even if quite preliminary and somewhat speculative, provides one way (certainly not the only way) of thinking about the anthropogenic world.

In broad overview, then, the anthropogenic world is one where the sum total of human behavior and cognition, including emergent behaviors and characteristics at various levels, is reified, in a process that is neither predictable nor teleological nor understood, but clearly reflects human activities. Consider a simple thought experiment: visualize an alien, seeing the Earth for the first time. Such a visitor would see evidence of order, and planning, and design, and management in virtually every dimension of the Earth, from land use and agricultural patterns; to emissions spectra including radio, television, and visual frequencies; to restructuring of biological and ecological systems;

---

[28] As networks evolve, some of their subnetworks will be more stable than others, creating legacy systems. One of the more difficult tasks facing the engineers who work on telecommunications systems, for example, is ensuring that necessary legacy systems are not unintentionally disturbed by frequent technology and software upgrades. This becomes particularly challenging given the frequent merger and acquisition activity that characterizes the industry, when incompatible networks, including substantial legacy systems in many cases, must be integrated and modernized.

to deployment of technologies; to climate dynamics. If our alien were not familiar with our patterns of thought, it might well take the objective evidence before it as representing the conscious intent of the species taken as a whole, including, of course, cognitive networks scaling from the individual human entity and human institutions at different scales, to the global scale. A planet such as the Earth, which is evolving into a monoculture support system for one species, clearly exhibits at a planetary scale the appearance of planning and intelligence, and is thus the physical expression of the "diversity in unity" of shifting hierarchies of cognitive networks – what earlier thinkers might have expressed by the concept of "Mind". The analytical framework is not, however, one of explicit global intent as the concept of "Mind" might suggest, but one of complexity and auto-catalysis, marked by accelerating networking within and among systems at differing temporal and spatial scales, and the unpredictable but significant creation and integration of vast new information structures – particularly markets, the growing content of the Internet, and the conversion of the genetic and proteomic basis of life to a human information system (and from thence into an economic commodity).

It thus becomes critical to attempt to understand how such apparent evidence of intent and planning at global scales can be juxtaposed with individual characteristics from which it seems to arise, which at the least operate at very different scales, and are highly contentious to boot. In fact, in beginning the attempt to understand cognitive networks, I will begin by bracketing the vexed question of "consciousness" as being an unnecessary distraction, for several reasons. Perhaps most obviously, there is no agreement about what consciousness is.[29] Rowland (1999, at 2), for example, states that "the problem of consciousness is one that needs dissolution rather than a constructive solution," suggesting that what is faulty is the mental model of the mind that Cartesianism has bequeathed to us. I suspect, in fact, that much of the confusion about what "consciousness" is, or for that matter whether it actually exists at all, results from a failure to clearly define the sets of phenomena one is including in the term.

This leads to the second reason I shall not define "consciousness": it is unnecessary for our purposes. Following Rowland (1999), I will therefore substitute for "consciousness" the concept of "cognition." Cognition obviously includes the process of perceiving and processing information; it thus encompasses, for example, information storage as memory. However, depending on how one defines these terms, a computer or biological community arguably performs such information detection and manipulation functions, so such an instrumental definition is too inclusive for our purpose. Somewhat oxymoronically, it is also too narrow in that it lacks the element of intentionality and deliberate design that continues to separate human from non-human systems. In order to properly understand how cognition operates in an anthropogenic world, we must therefore add to information processing a second function, "intentionality." These concepts are discussed in more detail below; for now, it is sufficient to note that neither information perception and manipulation, nor intentionality by itself, are adequate to

[29] Harnad (2001), for example, makes this point in a review of recent literature on the subject. Marshall (2001) in making the same point approvingly quotes the English philosopher and scientist George Lewes, writing in 1878: "[consciousness] designates an ultimate fact, which cannot therefore be made more intelligible than it is already."

define a cognitive network: there must be both. Moreover, the combination of intentionality and information processing leads to a third characteristic of cognitive systems: they generate new information. It is the second function, intentionality, that in part makes human systems contingent; it is this third function that leads to an additional characteristic of cognitive networks, their reflexivity, for cognitive networks constantly incorporate into their operation the information they, as well as other coupled cognitive systems, have and are generating.[30] This dynamic is, of course, the source of the auto-catalysis that characterizes human complex systems – particularly technological systems.

The third reason to avoid the reliance on the concept of "consciousness" is apparent from the importance that complexity and systems play in the anthropogenic world at all scales, including that of the self. Traditionally, "consciousness" has generally been associated with the human individual, both in philosophic tradition, as in the writings of Descartes and Kant, and, more pertinently perhaps, as a phenomenon each of us believes we directly access within ourselves. Where it is applied to systems higher in the hierarchy – States (Kant and Hegel), classes (Marx), firms and organizations (Senge), and the like – it carries with it the faint odor of analogy, but not the rigorous assumption that such systems are "conscious" in the same way that an individual human is – with, for example, the same sense of "self" that an individual perceives. On the other hand, by identifying a set of functions associated with cognition – perception, information processing, information storage (memory), judgment (reasoned choice between alternatives), creation of new information partly through the exercise of intentionality – and determining whether such systems exhibit those functions, one can fairly credibly determine whether they are cognitive systems.

Indeed, this is the approach taken by Descartes, who said ([1641] 1998, at 66):

> But what then am I? A thing that thinks. What is that? A thing that doubts, understands, affirms, denies, wills, refuses, and that also imagines and senses.

But this Cartesian phrasing carries a subtle assumption, in that it reifies "self" as a "thing" with certain characteristics, such as "will". Increasingly, this positioning of "self" as a foundational reality upon which other constructs can be based, as opposed to

---

[30] Some have suggested, in fact, that the raison d'ete of the "self" is to provide a mechanism by which internal as well as external reflexivity can be tamed (Damasio, 2003, at 227):

> The value of such a symbol [the "self"] is that it serves as a reference for other contents of the mind, such as representations of the objects with which organisms interact, and of the events in which organisms participate. . . . the simplest level of self allows us to manufacture the idea that objects and events are perceived from a singular perspective, that of the organism symbolized by the self.

In other words, the "self" is an epiphenomenon required when a certain level of complexity in cognition is achieved that enables one cognitive network (the "individual") to be organized enough to present queries to external reality, thereby generating an external structure within which the organism can function. The self, then, may not be what we intuitively take it to be (my "personal identity"), but it is a critical construct if continued evolution in complexity is to be achieved.

an epiphenomenon of network structure which has been called forth as necessary once a certain level of complexity in cognitive systems evolves, appears to be a convenient but, at least for our purposes, misleading mental model (Damasio, 2003; Hofstadter and Dennett, 1988). As Hayles (1999, at 2)) notes, the redistribution of cognition as a networked function across cultural systems – ranging from written texts and visual representations of various kinds to the Net and portable information devices – has been going on for centuries, and has now reached a point where many individuals in developed countries are so distributed that they cannot function if those technologies fail, for current patterns of cognition "privileges informational pattern over material instantiation, so that embodiment in a biological substrate is seen as an accident of history rather than an inevitability of life." She concludes that "the posthuman subject is an amalgam, a collection of heterogeneous components, a material-informational entity whose boundaries undergo continuous construction and reconstruction" – in other words, the "self" is best understood as a contingent and constantly changing network defined by boundaries that are, at best, somewhat arbitrary.

This profoundly changes the framing of characteristics of the "self" such as will. If the "self" is an independent, preexisting thing, such characteristics are real because they derive from it and, like it, are independent of, and preexisting when considered in light of, transient conditions. If, however, the self is a network structure with "selfhood" arising as an emergent characteristic, then its secondary characteristics such as "will" are by definition dependent on states of the network, both internal and external; and both "self" and its characteristics are distributed across the relevant networks. Moreover, partially as a result of technology (rapidly evolving ICT, for example), such networks are becoming more distributed; it follows that "self" and its characteristics also become increasingly distributed functions as well.

Again, perform a thought experiment. Consider the technology of implanting a wireless transmitter in a human brain, where it couples with neurons to produce a system capable of communicating with, and manipulating, external environments. Indeed, such neural prosthetics have already been implemented with paraplegics and their wheelchairs (Singer, 2006). Now extend forward to the point where the technology enables humans to be interconnected with technology systems, be they local environments, military weapons platforms or grid computer warfare environments, or perhaps complex space platforms operating in conditions hostile to biological systems. Such systems will for neurological purposes feel much the same as a limb, or a finger. In such a case, where does "self" end and "non-self" begin? Is a deliberate attack on the attached system assault and battery, akin to knifing someone in their arm? Is hacking into the software of the attachment the same assault as well? Where "self" and "physical body" no longer correspond, what parts of our relevant current language and cultural structures (e.g., legal systems) still apply, and to what?

Given this background, one can generate a more rigorous definition of cognitive networks as requiring five elements:

1. they are distributed and networked across temporal, spatial, informational, and complexity scales, and exist in many different phase spaces;

2. they act as active perceptual filters, in that there will always be some information in the ambient environment that could be perceived but, by system design or choice, is not;

3. they process and manipulate information;

4. they are reflexive, in that they create new information, which in turn is both internalized to the creating system, and feeds into other networked cognitive systems; and

5. they display intentionality, and the exercise of judgment.

The term "intentionality" is used rather than "will" to avoid the difficult and probably unresolvable argument about whether "will" exists or not (Baer et al., 2008). Concepts such as "will" cannot be understood with reference to a "self" alone, but themselves can only be defined as distributed products of systems states.[31] Moreover, a differentiation is necessary: "will" may still be viewed as a property of a more or less networked "self," but it can be seen, understood, and interpreted only as it is expressed given certain internal and external systems states and dynamics – that is, as highly contingent (much of the philosophic problem of will seems to arise from its reification as an absolute value attributed to the Cartesian individual, rather than its recognition as a contingent property dependent on network state). I will thus refer to "will" as inherent to "self," but make no particular effort to justify this conceptualization, which has been vigorously defended and challenged, because, like "consciousness," resolving it is not necessary to our discussion. It is not "will," but "will as it is expressed given internal and external system structure and dynamics," that is observable and functional in the real world. The latter I will refer to as "intentionality," and it is differentiated from "will" in that it is expressed and its effects observable. Intentionality as an observable phenomenon is thus an emergent characteristic of cognitive networks, and is contingent on internal and external system state; even if, arguendo, it is coupled to the concept of "will," it is generally unlikely that what was willed is the intentionality that is displayed. What has led to the American Midwest being checkerboarded into square mile segments across vast areas of land was not some hypothetical will associated with a hypothetical formulation of self, but human intentionality expressed under particular cultural, political, economic, technological and legal conditions, and summarized across complicated institutional spaces. In short, intentionality is what "will" would look like if it existed given the reality of cognitive networks.[32] Thus, for example, land use patterns generally

---

[31] As Hayles (1999, at 3-4) says:

> The presumption that there is an agency, desire, or will belonging to the self and clearly distinguished from the "wills of others" is undercut in the posthuman, for the posthuman's collective heterogeneous quality implies a distributed cognition located in disparate parts that may be in only tenuous communication with one another. . . . If "human essence is freedom from the wills of others," the posthuman is "post" not because it is necessarily unfree but because there is no a priori way to identify a self-will that can be clearly distinguished from an other-will.

[32] To further expand this idea, it can easily be seen that "will" and "intentionality" are not equivalent in a world characterized by complexity. Consider the restructuring of island biology as a result of the great Polynesian and European colonization movements, or the commoditization of land in the American Midwest enabled by surveying land into geometrically equal figures, neither of which was "willed" by any

reflect not what any particular individual "willed," but a complex expression of historical and cultural forces, legacy systems, physical geography, demography, economic structure, and much more.

Cognitive networks obviously exist at many levels. The unit of subjectivity is not fixed (the "human" or the "self"), and is not biological: as Mitchell (2003) puts it:

> So I am not Vitruvian man, enclosed within a single perfect circle, looking out at the world from my personal perspective coordinates and, simultaneously, providing the measure of all things. Nor am I, as architectural phenomenologists would have it, an autonomous, self-sufficient, biologically embodied subject encountering, objectifying, and responding to my immediate environment. I construct, and I am constructed, in a mutually recursive process that continually engages my fluid, permeable boundaries and my endlessly ramifying networks. I am a spatially extended cyborg. . . . My cyborg self is structured – Linux-like – as a system of nested shells, with carefully articulated and controlled interconnections among the levels.

System levels above the individual (firms, nation-states, non-governmental organizations, and the like) are cognitive networks as well. In this case, however, although the higher system may express the appearance of intentionality, it derives ultimately from the exercise of intentionality by individuals, albeit distorted, complicated, combined, filtered and confused by the complex systems within which it is expressed. As Hutchins (1995, at xiii) comments (with a degree of understatement), "the relationship between cognition seen as a solitary mental activity and cognition seen as an activity undertaken in social setting using various kinds of tools is not at all clear."

In order to clarify the idea of cognitive networks, and their role in the evolution of the anthropogenic earth, the framework concept of "integrative cognitivism" is introduced below, along with a brief discussion of the most critical constituitive properties: freedom, intentionality, and perception, among others. These are broad areas, and this is not a definitive treatment: rather, it is a survey of the landscape to identify a more productive way of thinking about an increasingly human world.

To set the stage for understanding the implications of cognitive networks and intentionality in the anthropogenic world, it is important to recognize, and move beyond,

---

individual, but both of which clearly expressed intentionality. In saying this, I am viewing intentionality "from the outside" – that is to say, there is a clear change in systems state (such as, for example, surveying land into square mile units, or the changes in island biologies that European exploration and colonization created) resulting from specific behaviors that were "chosen" in that they could have been otherwise (land surveys could have been based on drainage patterns, for example; and other societies did not globalize their culture as the Eurocentric Enlightenment culture and Christianity did). Whether any person or cognitive network "willed" such an outcome is dependent on internal states that are not accessible to external decoding, at least at this point. The intentionality, though, is apparent from the relevant changes in systems state. Accordingly, intentionality is not necessarily "will."

the most dominant underlying paradigm of "Mind" in the Western tradition. Descartes in his efforts to foundationally ground modern philosophy not only famously created the mind/body duality, but also located mind, and cognition, internally to the thinking subject – indeed, it had to be internal since its action was the only means by which the existence of the subject could be established (Descartes, [1641] 1998; Rowlands, 1999). This "internalist" approach has continued through Kant and Hegel to the present, characterized by (Burge, 1998) "a broad, inarticulate division of emphasis between the individual and his social environment [which has] marked philosophical discussions of mind."

This underlying mental model, however, has become increasingly questionable. In part this has occurred because of the recognition of the increasing focus on language, and its determinative effects on perception and cognition (Habermas, 1975; Rorty, 1989), and in part because of the broader recognition of the importance of social context and cooperation in determining what individuals can and do think (Giddens, 1990; Burge, 1998). As will become more apparent below, the degree to which knowledge exists external to the individual, and is both accessed as needed, and powers the reflexivity of social evolution, is an important part of this more sophisticated approach to, and reintegration of, the internal and external environments (Giddens, 1990).[33] This approach is the basis for a relatively new school of philosophy called "externalism" which holds that (Ludlow and Martin, 1998, at 3, 1)"the social character of content pervades virtually every expression of our language, and virtually every aspect of our thoughts" and thus:

> the content of our mental states depends at least in part on relations between ourselves and the environment. Externalism is, in other words, a denial of the traditional Cartesian view that holds that the contents of our thoughts are what they are independently of the surrounding world.

Rowlands (1999, at ix) points out that the argument is not just that thoughts are independent of the world, but that innate mental structures in part determine the world that is perceived:[34]

> Philosophy since Kant has been, well, neo-Kantian. . . . Neo-Kantianism is the view that there are activities of the mind whose function is to structure the world. At least some aspects of the world that is presented to us, therefore, are mind-dependent in that they depend for their existence or nature on the structuring activities of the mind. . . . [Externalism] effectively invert[s] this picture of the relation of mind to world . . . . the idea [is] that the contents of the mind are, in some sense at least, *worldly*: they are environmentally constituted.

[33] As Giddens notes (1990, at 53-54): "The production of systematic knowledge about social life becomes integral to system reproduction, rolling social life away from the fixities of tradition . . . . Knowledge reflexively applied to the conditions of system reproduction intrinsically alters the circumstances to which it originally referred."

[34] Note that this argument is different than the observation that the anthropogenic world over time reflects the operation of cognitive networks. The externalism argument refers to the relationship of internal and external systems in the process of cognition; the integrative cognitivism observation applies to co-evolving cognitive networks and complex adaptive systems over time.

But externalism by itself does not go far enough to explain the dynamics of cognitive networks in an anthropogenic earth. This is because, while it may attack the first Cartesian principle, foundational mind/body dualism, it still allows for the second Cartesian principle, internalism. Put another way (Rowlands, 1999, at 41), "philosophical externalism is perfectly compatible with the claim that it is possible to understand the ability of the [sic] an organism to process the information it needs in order to interact successfully with its environment in terms of structures and processes that are purely internal to that organism."[35] What I want to assert, however, is that cognitive function is, in fact, not internal any more in any meaningful way: that the defining characteristic of the anthropogenic world is that cognition increasingly extends throughout it in fact and not just in some vague, "ghost in the machine" sense.

In doing so, I will begin by following Rowlands' argument for a position he calls "environmentalism." I will have to coin another term for my approach, however, to both avoid confusion with my completely different use of "environmentalism" throughout this discussion, and because I extend his arguments considerably in speculative ways, and would not want him blamed for that.[36] Given that this line of argument undermines both elements of the Cartesian position, I will call it "integrative cognitivism": it integrates the internal and the external in the act of cognition, focuses on cognition rather than consciousness, and integrates cognitive networks, technology, and the project of the anthropogenic Earth. In doing so, it provides a basis for understanding some of the philosophic implications of our current situation.

The elements of "environmentalism" as presented by Rolands (1999, at 22) are relatively straightforward:

> *The Ontological Claim:* Cognitive processes are not located exclusively inside the skins of cognizing organisms.
>
> *The Epistemological Claim:* It is not possible to understand the nature of cognitive processes by focusing exclusively on what is occurring inside the skins of cognizing organisms.

---

[35] More technically (Rowlands, 1999, at 40), externalism is compatible with the position that "the capacity of an organism to process the information it needs to successfully interact with the environment can be explained solely in terms of operations defined over representations. Since these representations are viewed as exclusively internal items, the operations defined over them are viewed as exclusively internal operations."

[36] Rowlands is very careful to indicate throughout that he is not trying to *refute* the prevailing internalist paradigm, but to make its nature as mythology clear, and to *unseat* it, to show that it (1999, at 12) "is not how we have to think about cognition." Thus, he does not seek to rigorously disprove internalism, but to demonstrate that (1999, at 12) "[t]here is, in other words, no theoretically respectable reason for thinking of cognitive processes as purely and exclusively internal items." I on the other hand am not merely challenging a particularly stubborn mental model, but attempting to establish "integrative cognitivism" as a necessary tool for understanding and exploring the increasing scale and complexity of cognitive networks, which, at their largest scale, are one and the same with the anthropogenic earth and the reification of human cognition therein.

Cognitive processes, such as those listed by Descartes, are understood as hybrid to their very core: they are composed of internal processes and external structures, the act of cognition requiring (Rowlands, 1999, at 26):

(i) The presence of a structure, external to the organism, which is a *locus* of information.

(ii) The ability of the organism to identify and appropriate this information through manipulation of the structure.

As Rolands (1999, at 29) sums up:

> The metaphysical claim is that not all cognitive processes occur inside the head or skin of cognizing organisms. Therefore, if we assume that the mind of a cognizing organism such as a human being is made up, at least in part, of cognitive processes, the central metaphysical assertion of this book is that the mind is not, exclusively, inside the head. Minds are not purely internal things; they are, in part, *worldly* in character. That is, minds are hybrid entities, made up in part of what is going on inside the skin of creatures who have them, but also made up in part of what is going on in the environment of those creatures.

Rowlands supports his challenge to the internalist position by discussing at length the actions of perception, memory, thought, and language, and demonstrating how the complete act of cognition requires not just activities internal to the organism, but also external sources of information and processing.

Clark (2001) reinforces the insight, critical to integrative cognitivism, that cognition – thinking – is a function that no longer occurs within the human organism, but in an intricate, dynamic network of symbols, information technologies, language, and culture, emphasizing:

> the distinctive way human brains repeatedly create and exploit various species of cognitive technology so as to expand and reshape the space of human reason. . . . creating extended cognitive systems whose computational and problem-solving abilities are quite different from those of the naked brain. Human brains maintain an intricate cognitive dance with an ecologically novel, and immensely empowering, environment: the world of symbols, media, formalisms, texts, speech, instruments and culture. The computational circuitry of human cognition thus flows both within and beyond the head.

Integrative cognitivism does not just assert that human brains rely on external information sources, although that is an important starting point. Rather, it is a stronger claim: cognition under conditions of complexity is a property of networks of brain(s), technologies, culture, and symbols, and mental models. Cognition arises as a network property, not a "brain" property. A few examples may help clarify and support this fundamental assertion. Perhaps the most interesting is that provided by Hutchins (1995), who studied navigation systems on large naval vessels (prior to Global Positioning System technology). He noted that navigation as a cognitive activity had been substantially enhanced by determining where the world was invariant, and then building those invariants into physical navigation technologies (such as the way the charts are structured, and readings taken on various instruments). Moreover, none of the humans involved in the navigational process on a particular ship knew it as a comprehensive whole; rather, navigation arose from the integrated system of humans and the relevant technologies that converted observations into navigation. As Hutchins succinctly noted (1995, at 200): "An interlocking set of partial procedures can produce the overall observed pattern without there being a representation of that overall pattern anywhere in the system." An important observation is that, in such cognitive networks, technology is not just an aide to more powerful thinking, but becomes a repository of what I will call "congealed cognition" (1995, at 96):

> In the Western tradition, physical artifacts became repositories of knowledge, and they were constructed in durable media so that a single artifact might come to represent more than any individual could know. Furthermore, through the combination and superimposition of task-relevant structure, artifacts came to embody kinds of knowledge that would be exceedingly difficult to represent mentally [cite omitted]. Many of the instruments of Western navigation [such as the astrolabe or the compass] are based on the principle of building computational constrains of the task into the physical structure of the artifact.

It is worth noting that congealed cognition has a number of consequences; in particular, it can create much more powerful cognitive networks, but in doing so, like any system, it necessarily imposes constraints on current cognition. A Western navigator, for example, has a command over location that previous ages could not imagine, but he or she is not "free" to change to a Micronesian navigational process, because that system is based on very different mental models and algorithms than those congealed in existing Western navigational aids. One way of understanding technology, then, is as an important mode of congealed cognition. This will become important as well when we discuss intentionality, for much of the constraints on intentionality arise from past system states – or, in other words, congealed intentionality, like congealed cognition, as a powerful constraint on future paths.

To take another example of integrative cognitivism, consider the development of writing and external information storage devices. These advances enabled the development of (Rowlands, 1999, at 144) "collective memory hardware":

> Individuals in possession of reading, writing, and other relevant skills have access to the 'code' that allows them to plug into this external [information storage] network. They thus become somewhat like computers with networking capabilities; they are equipped to interface, to

> plug into whatever network becomes available. And, once plugged in, their memory capacities are determined both by the network and by their own biological endowments. Those who possess the 'code', the means of access to the external system, share a common memory system. And, as the content of this system expands far beyond the scope of any single individual, the system becomes by far the most significant factor in the memory of individuals.

To take a simple example, my memory of Shakespeare's plays exists not in my mind, but in the system composed of my book containing the complete works of Shakespeare, an index system that I understand that allows me to search that book, and my internal capabilities to process the information. Moreover, memory structured in this way is far more powerful, and capable of storing far more information, than the "episodic" memory characteristic of oral traditions.

Another interesting example is provided by music. Musical notation was first invented in the eighth century, but music itself, as a cognitive system, changed fundamentally in the fifteenth century, with the standardization of notation, and the invention of the printing press (Shlain, 1991, at 275): "written music . . . soon became so commonplace that by the end of the fifteenth century music could challenge Latin as the primary pan-European language." The implications of this change were profound, similar to that represented by the replacement of the oral tradition with written language (Shlain, 1991, at 275):

> Before the Renaissance, European music and knowledge depended for the most part upon an oral tradition that was written on the wind. But in the fifteenth century, what had been ephemeral became permanently transfixed by ink and sight: Music and speech became visible. . . . Musical notation allowed the invisible vibrations of sound waves to be synesthetically converted to black marks on white paper. As a result, an individual versed in this specialized language could compose a piece of music without making a sound other than the scratchings of pen on paper. These transcribed sheets could then be given to another musically literate individual who would be able to reconvert the notations imaginatively, from the visual to the auditory sense, without making a sound. All this could transpire without a single audible note . . . . As a result of notation and the printing press, music could at last break out of the narrow confines of the *here and now*. . . . Printed scores allowed any complex piece to be performed many miles away from, and many years after, the place and moment of its origin. The functions of composer and performer could definitively become separate. . . . Once music could be seen, its transitory, undulating essence could be stilled and analyzed.

In short, in an identifiable period as a result of specific technological innovations, primarily notational and in communications technology (the printing press), musical cognitive networks changed dramatically. They expanded across space and time, gained an analytic dimension that had heretofore been lacking, developed a structure allowing vastly improved memory, became a different practice for both musicians and composers, and became integrated into a far more complex system. Much of the cognitive power required to "make music" shifted from a craft mode (primarily internal cognitive networks of the individual musician, who built the performance from skill and memory) to a technology-rich mode, with much of the cognition now congealed in a formal pattern of symbols, which, in turn, also limited the options open to the musician.[37]

Lest these be thought trivial observations, remember that cognition is power: a more cognitive entity is, all else equal, a more powerful entity. In this light, Diamond's (1997, at 67-81) discussion of the battle at Cajamarca, in the Peruvian highlands, between the Spanish conquistador Francisco Pizarro and the Inca emperor Atahuallpa, is instructive. Pizarro had 168 Spanish soldiers (62 horse, 102 on foot), was fighting in an unfamiliar cultural and physical environment, and had no support available. Atahuallpa, on the other hand, was the absolute ruler of the largest and most advanced state in the Americas. He was in the middle of his empire and surrounded by 80,000 soldiers when he walked into a Spanish trap at Cajamarca, was captured, held for ransom and then, when that was paid, executed by the Spanish. Indian losses were in the thousands; not a single Spaniard was killed. Nor was this unusual: at four similar battles – Jauja, Vilcashuaman, Vilcaconga, and Cuzco - the same pattern repeated.

In any such extraordinary clash of cultures, a number of factors come into play – such as, for example, the Spanish superiority in armament and use of horses. But that alone cannot account for the fact that not just the battle of Cajamarca, but the clash of cultures, ended decisively in favor of the Spanish. Here, Diamond's comments about the disparity in cultural memory are instructive. Atahuallpa had only the information about the Spanish that could be transmitted by word of mouth; the Spanish, on the other hand, belonged to a literate tradition. The amount of information to which they had access, and which they could therefore process, was far greater. Indeed (Diamond, 1997, at 80), "Pizarro explicitly modeled his ambush of Atahuallpa on the successful strategy of Cortez":

---

[37] A number of additional examples have been researched by those studying technological evolution. For example, Gorman (1997) takes an integrative cognitivism approach to the invention of the telephone (although, of course, he doesn't call it that since I just made up the term). In evaluating how two innovators – Alexander Graham Bell and Elisha Gray – invented devices capable of transmitting tones, he illustrates a process of dialog involving different individual mental models, mechanical representations, and heuristics which anchored the cognitive process of invention of the telephone not solely in the individual, or in the external context within which the individual worked, but firmly in both (at 589, 612): "Cognition clearly is both embodied in brain, hands and eyes, and also distributed among various technologies and shared across groups . . . in order to compare two inventors, one needs to understand their mental models and mechanical representations. This kind of understanding is possible only because so much of cognition is in the world . . . ." In other words, Bell and Gray functioned within two different cognitive networks, and the results of one proved superior to the other in enabling an economically and socially relevant function – the transmission of voice over distance in real time. Other examples are provided by Bijker et al. (1997): technological innovation is a fruitful area for case studies in integrative cognitivism precisely because the complexity of developing artifacts and practices which by definition must be functional in a much broader social, economic, and cultural context illustrates quite plainly the coupling between internal and external elements of cognitive networks.

> In short, literacy made the Spaniards heirs to a huge body of knowledge about human behavior and history. By contrast, not only did Atahuallpa have no conception of the Spaniards themselves, and no personal experience of any other invaders from overseas, but he also had not even heard (or read) of similar threats to anyone else, anywhere else, anytime previously in history. That gulf of experience encouraged Pizarro to set his trap and Atahuallpa to walk into it.

From the perspective of integrative cognitivism, what happened in Peru was that two systems with unequal cognitive ability came into conflict, and that with the greater cognitive ability won. This is not an argument for some form of cognitive determinism, for certainly it is conceivable that the battle of Cajamarca could have gone the other way, and the Spanish eventually ejected from the New World. Moreover, it is evident that, as with virtually any other important historical event, there are no simple or linear causalities: the real world is not kind to such assertions. But, in general, that system with the greater cognitive ability will out-compete those with which it comes into conflict. In part, of course, this is because cultures with greater cognitive ability have a suite of associated characteristics – higher technological development, more developed economies, more complex social organization – that taken together also may provide advantages in any competition with other cultures.

This analysis also does not support in any way the quasi-racist argument that the Incas were, in individual cognitive ability or in other qualities such as courage, somehow inherently inferior to the Spanish: there is no evidence for this whatsoever (indeed, this is a major point of Diamond's work). But, as integrative cognitivism would hold, it is not the intelligence internal to the individual human organism that is relevant, but the larger cognitive networks available to her or him – a structure heavily dependent on culture - that determines the overall cognitive ability that each individual has access to. Internal Spanish cognition was multiplied by the cultural structures, such as writing, available to it; the same was not true for the Incas.[38] It is not a question of the superiority of Cartesian individuals (racism), but of the cognitive networks which their culture has enabled, and of which they are a part.[39]

---

[38] As in most cases involving human institutions, no model captures all dimensions of behavior. Thus, while this approach implies an evolutionary model and competition, the same events can also be seen though the lens of a dialectic, with conflict resolved through the achievement of a new synthesis containing elements of both. Indeed, while Eurocentric culture has globalized based in part on its evolutionary advantages, it has also absorbed, and been powerfully changed by, that with which it came in contact. As light is particle and wave, so human history is evolutionary and dialectical – and a lot more. Which model is appropriate depends not just on the factual situation being analyzed, but on the purpose of the analysis – which is in this case to understand the role of cognitive systems, themselves both evolutionary and dialectical.

[39] Ironically, the Cartesian model of cognition enables racism, in that it facilitates assigning to the individual the weaknesses that may exist in the cognitive networks enabled by a culture. Thus, Europeans accurately understood that many peoples they came into contact with did not have their technologies, and thus their extensive cognitive networks; but their Cartesian bias allowed them to attribute this to personal failings, and thus race, not to cultural differences. "The White Man's Burden" arose from poor metaphysics as much as anything else.

This analysis does make apparent, however, what has consistently driven the ever-increasing diffusion of cognition across ever more complex networks: such networks display greater cognitive processing power than simpler ones. Hutchins' (1995) example of the navigational cognitive network of a large naval vessel, composed of human and technological components with complex structural and dynamic linkages from which arose navigation as an emergent property, is a striking and well-researched example. Similarly, Mitchell (2003, at 149) notes in a different context:

> As local and distributed communities competed for mindshare, local began to lose ground; professors and medical specialists often discovered that they had more valuable and satisfying exchanges with colleagues on the far side of the world than with those just down the hall.

Cognitive networks, like all complex network systems, tend to evolve towards greater complexity, and they do so because it enables greater cognitive capability.[40] And, given that the will to power is a major component of the psychological structure of the human species, the drive to obtain greater cognitive capability will be heavily favored in the evolutionary history of humans and their various institutions. This sheds additional light on the integrated cultural juggernaut of Eurocentric capitalist modernity, which has been characterized by continued advances in technology systems enabled by the alignment of Christianity and technological evolution, since technology is an important repository of instantiated cognition.

Rowland's arguments are phrased in terms of individual organisms and their functions, as befits the undermining of an essentially Cartesian worldview based on *cogito, ergo sum.* Significantly, an important element of his argument is evolutionary: that in general it is more efficient for an organism to off-load cognitive functions into its external environment than to attempt to internalize it all. Why have to remember all of Shakespeare internally when one can just as easily remember the much shorter algorithm for deriving such information from books? And then one can remember many more books, and access their information and wisdom on an as-needed basis. Indeed, similar structures are built into efficient software and communications systems everywhere. And, given this efficiency, it follows that evolution would favor those mechanisms, and organisms, that distributed cognition across internal and external components in such a way. But Diamond's example, and the fact that, as noted above, the world today is predominantly a product of the European experience, extends that argument, for it is not just individuals interacting with their world, but the structure of cultures and societies, and the mechanisms and pathways by which they magnify and extend internal processes to far greater temporal and spatial scales, that determine evolutionary success. Whether we wish it or not, cultures compete (Harrison and Huntington, 2000), and it is a useful insight that cultures with a greater systemic cognitive capability – in some meaningful

[40] Hutchins (1995) additionally argues, based on evidence obtained during his study of navigational systems, that distributed cognition also encourages graceful degradation of the system if challenged, and thus at least to some degree enhances the resiliency of cognitive networks (Allenby and Fink, 2005).

sense, a better collective ability to think because of more evolved and complex, and thus more powerful, cognitive networks - have a greater chance of success.

Is it possible to be more explicit? Perhaps. A critical determinant of the cognitive capabilities of a culture is its technological sophistication and the degree to which the culture does not unnecessarily constrain the auto-catalyzing dynamic of technology.[41] As Castells (2000, at 7) writes:

> The ability or inability of societies to master technologies that are strategically decisive in each historical period, largely shapes their destiny, to the point where we could say that while technology *per se* does not determine historical evolution and social change, technology (or the lack of it) embodies the capacity of societies to transform themselves, as well as the uses to which societies, always in a conflictive process, decide to put their technological potential.

Integrative cognitivism thus strongly suggests that a fundamental role of technology is to increase the cognitive capability of the culture or society within which it exists.[42] To an important degree, the evolution of technology is the evolution of cognition – and the evolution of human biology, culture, and technology become an entwined evolution of cognitive networks of increasing complexity and power. This dimension of technology is particularly evident as regards information technology, from the *kvinus* (knot memory system) of Peru and elsewhere; to written information; to communications systems that facilitated longer range, instantaneous transmission of information; to modern information storage and transmission systems and the worldwide

---

[41] Again, it must be emphasized that the technological sophistication of a culture, which is correlated to a significant degree with the cognitive capabilities of that culture, is not determinative of success in itself: indeed, technological sophistication and evolution within a culture is an integral part of a much more complex context which may include, *inter alia*, educational processes, tax and economic structures, cultural approbation of innovation, individualism and entrepreneurial activity, and governance structures of all kinds. Thus, Castells (2000, at 5) remarks that:

> The technological blossoming that took place in the early 1970s [in Silicon Valley, California] can be somehow related to the culture of freedom, individual innovation, and entrepreneurialism that grew out of the 1960's culture of American campuses. Not so much in terms of its politics, since Silicon Valley was, and is, a solid bastion of the conservative vote, and most innovators were meta-political, but with regard to social values of breaking away from established patterns of behavior, both in society at large and in the business world.

More fundamentally and perhaps somewhat controversially, technological competence appears to be associated to some degree with capitalism, individual liberty, and democratic institutions (Harrison and Huntington, 2000), which are in turn associated with Eurocentric culture and Christianity (the most famous work along these lines perhaps being *The Protestant Ethic and the Spirit of Capitalism*, by Max Weber [1904]1998; see also Noble, 1998). Whether this will continue to hold true in most cases is an interesting question (given, for example, China's rapid economic development).

[42] Technology is thus not only a direct expression of the will to power of a particular culture (which is why its evolution is often associated with military adventures), but also an indirect expression of the will to power, in that it enables more potent cognitive networks that, in turn, increase the power of the technological culture.

Net. But technology is an integrated project, not just a collection of various artifacts, and those cultures that are advanced in information technologies tend to be competent in others as well. Moreover, because technology is auto-catalyzing, the more technologically adept a culture already is, the more technology it is capable of evolving (Grubler, 1998). This implies an important corollary: that cognition, which is correlated with technology, exhibits similar dynamics: the more cognitive a culture already is, the more likely, and easier, it is for the culture to continue to broaden and deepen its cognitive function.[43]

In doing so, the society will become more complex, more fragmented, and simultaneously more integrated, creating deeper and more powerful cognitive networks. Simple belief systems will be challenged and become increasingly dysfunctional. The collapse of space and time boundaries, the ahistorical pastiche so beloved of postmodernists, is, in fact, a reflection of such a culture, but, contrary to pessimistic prediction, need not result in fundamental alienation, either of individuals or of institutions. This is because even if the overall system is highly fragmented, complex and contingent, it is also characterized by patterns of order that are local within time and space, and thus offer safe foundations for both individuals and higher entities. Local hierarchy coexists with networked evolutionary complexity: local truth suffices where attempts to establish foundational Truth become dysfunctional, increasingly atavistic, and finally untenable.[44]

This discussion of integrative cognitivism helps elucidate some of the profound implications of the new foundational technologies discussed above - nanotechnology, biotechnology (including genomics), robotics, information and communication technology (ICT), and applied cognitive science, and their convergence. Each in its own way is an extension of human design and function into a new realm: in the case of nanotechnology, the very small, indeed in some cases molecular, structure of the physical world; in the case of biotechnology, into biological functions from the genetic and molecular to the regional and global (as genetic design changes organisms, and,

[43] The ability of cultures to support technological evolution, however, changes over time. Castells (2000, at 7-8) notes the example of China, which around 1400 is considered by many to have been the most advanced technological civilization in the world, but by 1800 had evolved little further, and had clearly been surpassed technologically and scientifically by Europe. The reasons for this are complex and debated, but at least one seems to have been (Castells, 2000, at 9) "the rulers' fears of the potentially disrupting impacts of technological change on social stability." A similar explanation has been suggested for the differential rates of success of various cultures within Europe, where the dynamic Northern European Protestant countries such as Great Britain and the Netherlands out-competed the more static and rigid societies of Catholic Southern Europe (Landes, 1998). The obvious question raised by such analyses is whether the ideological opposition to new foundational technologies such as biotechnology, arising in Europe from environmentalism and in the U. S. in particular cases from fundamentalist Christianity, will have a similar negative impact on the ability of those cultures to compete with differently constrained ones such as China and perhaps India over time.

[44] In any such discussion, it is apparent that one is speaking of truth in the human and not religious sense. That a multicultural world is complex and confusing, and tends to corrode local truth posturing as global Truth does not logically or otherwise imply that the kind of transcendental Truth characteristic of religion does not exist, merely that human instantiations of it in historical and cultural contexts are contingent and partial.

accordingly, restructures biological communities); in the case of robotics, the integration of hardware, software, and wetware; in the case of ICT, the coupling into networks of previously disparate artifactual and structural systems; and in the case of applied cognitive science, the accelerating integration of human intentionality into increasingly complex systems integrating human, built, and natural systems. In other words, each extends cognitive structure into realms that previously were independent of it . . . human cognition extending into the molecular and, through many couplings, to the global, characterized at all scales by rapidly multiplying and increasingly complex cognitive networks. This wave of technological evolution is, obviously, at the same time an extension of, and reification of, human cognition in the natural and built systems of the anthropogenic Earth.

The nexus between the success of the Eurocentric Enlightenment culture and its characteristic technological and scientific worldviews, and enabling theology, also becomes clearer using an integrative cognitivism analysis. Obviously, this globalized culture has drawn on, and continues to incorporate, many elements of other cultures - Asian, Islamic, Latin American, and African - as well. Nonetheless, technological and scientific evolution, drawing on Greek and Roman roots, was uniquely encouraged by Christian theology in Europe, and, as is the nature of technology (and perhaps the cognitive acceleration which rides on technology), became auto-catalyzing, especially as capitalism, aligned with and driven by Calvinism, co-evolved (Weber, [1904]1998). It was not that Europeans were inherently any smarter, but that their cognitive networks grew faster, more complex, and more robust than those of societies with which they came into contact, and competed with, at least in part because of the alignment of theology and the scientific/technological project that uniquely characterized that culture from the 11^{th} century onwards (Noble, 1998). It was not Europeans as individuals, but their culture, that was in some sense more capable of cognition. This did not mandate that the Eurocentric culture would grow to dominate the world, but it is certainly a significant reason for that outcome.[45]

And it is by a similar process – the evolution of increasingly complex and competent cognitive networks at ever greater and more inclusive scales – that the anthropogenic world has come to reflect the activities, teleologies, and confused intentionality of the human. For, just as European culture was unique in the speed, and scales, at which it fostered the evolution of technology, and thus its systemic cognitive capability, so with the human species: as Rowlands (1999, at 135-136) notes, "on this planet, at least, only *homo sapiens* has been able to develop external representational structures." The importance of this development is significant (at 129):

[45] Again, no single factor can be identified as the reason: any such determinism in human affairs is inevitably an oversimplification. In this case, for example, Diamond (1997) mentions factors such as a temperate climate in the European area, and a pattern of agricultural development that led to economic advances and resistance to many diseases. Sachs et al. (2001) focuses on climate and access to sea trading opportunities. Harrison and Huntington (2000), and Landes (1998) concentrate on culture. All are valid insights to a reasonable extent; they have simply posed different queries to the complexity of the historical record, reflecting their different perspectives, values and ontologies, and called forth different narratives reflecting those positions.

> The great schism in the development of the modern mind was the incorporation of external means of representation. The significant development was not representation *per se.* This can be found in many non-human animals. All episodic experience is representational, at least in the minimal sense that it is *about* other things. What is distinctive about the modern human mind is not representation as such, but the development of *external* means of representation.

And, one might add, the increasing competence of the resultant cognitive networks.

This is the core of the dynamics behind the anthropogenic Earth, and the reason that it is uniquely humans who are creating it, for it is human culture and technology that form the framework for the unprecedented expansion of cognition to the level of global systems that is the defining characteristic of the anthropogenic earth. It also expresses a challenge, for we are not used to thinking in terms of integrative cognitivism: of our thinking process as extended out into, and integral to, the non-human, cultural, economic and technological systems that surround us. Accordingly, the observation that the Anthropocene requires a new way of thinking is more than hyperbole: it requires that we reconsider what cognition is, and how cognitive networks know, and what the ontological basis of intentionality and thought actually is. And the beginning of that process is understanding that technology is not just artifacts, or software, but a mechanism that profoundly changes cognition, and extends it, and thus generates cultural power and fitness.

Integrative cognitivism also makes it clear that saying that the Earth increasingly reflects human cognition is more than a figure of speech. Rather, it is a recognition that increasingly elements of systems previously considered "natural" become integrated into cognition – cognition springing from humans and their institutions, but now spread far beyond the individual, with consequences and implications which are difficult to predict. For integrative cognitivism does not hold that internal human cognition simply becomes more powerful as it is externalized in increasingly complex ways in systems that are themselves evolving; rather, the cognitive process, although still emanating from the individual, becomes different in kind.[46] Cognition and cognitive power emerge not from

[46] Some will, perhaps, object to this realization, and the idea of cognitive networks at this scale, because it appears to them to simply be a restatement of Hegelian *Geist* or perhaps Heideggerian Being, come to consciousness. There are, however, major and important differences. Unlike either concept, the process of expanding cognition over time is not teleological: that is, it ends neither at Hegel's desk with the coming into consciousness of *Geist*, nor with the teleology of the (semi-Taoist Christian?) Being. Cognitive networks not only continue to evolve, but do so in ways that are reflective of systems state, not teleological. People and institutions in cognitive networks may have implicit or explicit teleologies; how those are expressed by evolving systems is not for that reason teleological. Second, the evolution of cognitive networks, and their reification in the anthropogenic Earth, is not a description of an endpoint, or a deterministic system; rather, it is an observed process with certain implications. Thirdly, cognitive networks, no matter how widespread, emanate from and remain based in the intentionality that, however modified by system state, derives from individual human beings: remove humans from the world, and the technologies, built environments, and systems that compose today's cognitive networks collapse. We have not yet – so far as we know - created cognition independent of humans. The intentionality of individual humans, therefore, has yet to be displaced by larger spirits such as *Geist* or *Being*.

individuals, but from the dynamics of networks of artifacts, information systems, individuals, technologies and other elements that now form the operative platforms for cognition.

Looked at from a historical perspective, this is not new and different, for the history of the evolution of the human species is in large measure the process of auto-catalyzing and thus expanding cognitive networks - although the process is arguably accelerating rapidly. Looked at from an intellectual perspective, however, it is more daunting. That this type of cognitive process or structure, exists, much less what its dynamics are, is still beyond the pale of much disciplinary and intellectual thought. How it is functioning to create the anthropogenic earth, including important questions such as where such a process would get its ethical content, is similarly still largely unexplored territory. To shift the locus of cognition from the individual consciousness, whatever it may be, to cognitive networks of whose reality most are still blissfully unaware, raises the complexity of issues of cognition, intent, ethics, justice, and other philosophic concepts substantially. Given the progress, or lack thereof, we have made in these areas to date, this is not necessarily encouraging. But necessity is a harsh taskmaster, and if we have as a species exercised our will-to-power to create the anthropogenic earth, we cannot now refuse the responsibility, or the challenge, as individuals.

As one minor topical example, note how integrative cognitivism undercuts to some degree the arguments of those, like Singer (2001), who argue that, as the title of his famous essay states, "all animals are equal" – with humans being considered as animals – in that they individually have sentient characteristics, and therefore animals should have equal rights to humans. This may be an arguable position if made only at the level of cognitive abilities of individuals (Singer notoriously concludes that experimenters should use orphaned human infants, rather than cats, dogs and other more "sentient" beings, in their experiments, because infants are not as "sentient").[47] But, regardless of other criticisms, Singer's position can be criticized for focusing on the wrong level of the hierarchy – the individual organism - to evaluate cognition (sentience). By dint of access to culture and to technology, virtually every human being to some extent participates in cognitive processes that extend well beyond the innate, whereas virtually no non-human mammal does so unless they have themselves become part of a human cognitive network

---

[47] Singer (2001, at 36):

> If the experimenter is not prepared to use an orphaned human infant, then his readiness to use nonhumans is simple discrimination, since adult apes, cats, mice and other mammals are more aware of what is happening to them, more self-directing and, so far as we can tell, at least as sensitive to pain, as any human infant. There seems to be no relevant characteristic that human infants possess that adult mammals do not have to the same or higher degree.

And to those who would argue that it is the future potential of the infant as an adult *homo sapiens*, Singer offers the mentally challenged (2001, at 36): "this argument [concerning the future potential of babies as a differentiator] still gives us no reason for selecting a non-human, rather than a human with severe and irreversible brain damage, as the subject for our experiments." These positions are of course quite controversial, but unlike many environmentalist writers, at least Singer has the courage to accept the implications of his position.

(as, for example, a primate trained by humans to respond to visual cues, or a much loved pet).[48] Sentience is, in other words, a property of cognitive networks, not of individual organisms. And, to date at least, no other animal but the human has generated cognitive networks, certainly not to any meaningful extent. If there is indeed such a cognitive gulf between humans and other mammals – and that is, at least, arguable given the implications of integrative cognitivism – then the utilitarian approach underlying Singer's theory fails, for it requires an equivalence between humans and other mammals that simply isn't there.[49]

II. C. *Responsibility, Intentionality and Integrative Cognitivism*

It may be useful to consider a relevant example to begin the process of working out the implications of integrative cognitivism, especially regarding the issues of freedom, free will, intentionality and perception. The line of reasoning is this: the anthropogenic planet is increasingly defined as the reification of cognition, which is the integration of cognitive processes, artifacts, and cultural components, and concomitant emergent behaviors within many systems at various levels. Ethical responsibility requires that to the extent possible these cognitive processes are elevated from the implicit and unperceived, to the explicit, for only by doing so can two important cognitive functions be integrated into the evolution of the anthropogenic earth: ethics, and design.[50] Thus, ethically responsible behavior is dependent upon the existence of choice, intentionality and what is classically if over-simplistically called "free will". Responsible action, after

---

[48] It should be noted that humans can participate in cognitive networks either as sources of intentionality, or as components; in the navigation example presented by Hutchins (1995), for example, the function of the cognitive network was not dependent on any particular individual, although several were members of the network as it functioned. Because it is a network function, intentionality like other network functions can be congealed; ships navigate because such behavior is built into the technology, and expressed through both particular ("The Pentagon wants this ship to sail.") and congealed ("Ships sail.") intentionality.

[49] This argument, of course, in no way justifies cruelty to animals, or any infliction of unnecessary pain. It simply challenges the assumption of equivalence between human and non-human organisms that Singer requires to apply his utilitarian approach. Note that this assumption can also be challenged on less sweeping grounds: as Pullam and Scholz (2001, at 367) comment regarding language:

> Human languages exhibit a unique combination of characteristics: first, semantic word-to-world relations that we share with other primates; second syntactic structures as complex and exact as in formal languages; and third, an openness, flexibility and ambiguity that formal languages do not allow.

It is the latter two characteristics that are particularly human. In other words, the claim that there is functional equivalence between humans and other species, sometimes backed up with sweeping references to cognition, sentience, or language capabilities, lumps all three of these functions together, whereas they are both separate, and a differentiator. Complete equivalence between humans and other animals, even at the margins, is wishful thinking (it is comforting to think that we are not alone, and uniquely responsible, for the anthropogenic earth), not factual – a conclusion amply supported by even a cursory inspection of the real world.

[50] Whether God or an equivalent deity is, in fact, designing the earth is a theological issue that I do not reach. Rather, I am making the lesser argument that, regardless of how God may be thought of, or revealed, as the anthropogenic earth evolves, it is unethical for humans not to respond to that which they, acting through extended cognitive systems, have caused and willed, once that relationship is perceived to exist.

all, rests on the assumption that design is possible, and design in turn implies the ability to choose among options that make a difference to the designed system in an intended way. If this is not possible, if there are no actual choices to be made, then responsible action is, at least as commonly understood, illusory, for determinism by any other name is determinism. Moreover, intentionality and free will have traditionally been associated with what Kane (1998, at 4) calls "moral responsibility in the deep sense;" that entity which wills, which originates purposes, also creates for itself fundamental, non-delegable, moral responsibility. Is this a reasonable assumption when dealing with the complex integrated human/natural/built systems that characterize the Anthropocene? Let us begin by differentiating between free will and intentionality.

1. "Free will" is usually understood in a fairly Cartesian way as a property of human individuals (in part because it is a critical, if long debated, theological assumption of major religions such as Christianity and Islam). "Intentionality," on the other hand, also reflects choice and intent, but is explicitly a function of internal and external systems states, and is expressed in detectable change, or lack of change that would otherwise have occurred, in systems states. Reflexivity is the major process by which intent and systems state reciprocally create their future paths.

2. Intentionality is compatible with, but does not require the existence of, free will as classically defined. Patterns of order in anthropogenic system at all scales clearly are evidence of design in that certain options are selected over others for reasons expressed by the agents involved – choice, based on intent – but free will as a fixed characteristic of humans assumes a stability of "self" (and of brain function) that is likely incompatible with the complexity of current, much less future, cognitive networks.

3. The existence of a link between the assumed free will of the individual, and the intention of humans as expressed in their institutions and design choices, and in the paths of complex adaptive systems that humans try to establish, is apparent: how that link is established; whether it reflects unconscious or conscious choice, and how such choice is made and filtered; and how individual intent scales up in complex cognitive networks, is far less clear.

4. Human intentionality is expressed at the intersection of two types of networks that are both necessarily incomplete and unpredictable. The internal networks of individuals – brains, hormonal states, and the like – are fragile and subject to upset (e.g., brain tumors, dementia), as well as significant shifts as external environments shift (e.g., mob behavior, fundamentalist violence). Moreover, human intellect and perception is limited and fallible. External networks are complex and unpredictable. While understanding the discussions regarding free will is useful in creating a foundation for thinking about intentionality, it must always be remembered that any choice or decision in the real world is partial and represents muddling through, rather than the theoretical purity implied by "free will."

5. It is daunting but informative that Jalalu'ddin Rumi, the Persian poet, commented in the twelfth century that "There is a disputation [that will continue] till

mankind are raised from the dead between the Necessitarians and the partisans of Free Will."[51] This suggests that the philosophic purity implied by the idea of "free will" is too simplistic, and that a more nuanced version of agent intentionality, based on evolutionary and psychological theory and observation, leads to a more workable framing: that intentionality is real, but that its expression in most cases (as well as available choices and the like) is severely limited because of perceptual limitations of the individual, external and internal network conditions, and the evolutionary structure of the brain (Baer et al., 2008). It is, for example, highly unlikely that an ability to make limited choices would not characterize the world's most successful species, and thus be evolutionarily favored: as Bandura (2008, at 86-87) observes:

> The symbolic ability to comprehend, predict, and alter the course of events confers considerable functional advantages. The evolutionary emergence of language and abstract and deliberative cognitive capacities provided the neuronal structure for supplanting aimless environmental selection with cognitive agency. . . . Through cognitive self-guidance, humans can visualize futures that act on the present, order preferences rooted in personal values, construct., evaluate, and modify alternative courses of action to secure valued outcomes, and override environmental influences.

Initially, then, evolutionary advantage strongly suggests some choice/intentionality mechanism, balanced by the considerable constraints that brain structure, psychological and cultural patterns, physical environmental structures, and other network configurations place on any exercise of choice. "Free will" is too pure; complex and constrained agency is too good evolutionarily not to be selected for.

Let us begin an exploratory discussion by differentiating two salient concepts of freedom: external (political) freedom, and internal (spiritual) freedom. Thus, in the *Upanishads* and *Bhagavad Gita* freedom (*swaraj*) means two things: the ability to rule over one's own land (political or social freedom; what I would call exogenous freedom), and the ability to rule over one's self, or soul (internal freedom from cravings, fear, ignorance, and illusion; what I would call endogenous freedom) (Dalton, 1998). Broadening this definition, we can say that exogenous freedom deals with the freedom from restrictions imposed by the external environment on a cognitive network, while endogenous freedom deals with the ability (always partial) of the cognitive network to control its internal system state and potential responses to changes in the external environment. Issues of freedom involving political and social freedom are discussed in the section below on governance. At this point, however, two formulations of endogenous freedom are worth mentioning in the integrative cognitivism context.

---

[51] Quoted in Kane (1998, at 3). Kane notes that modern philosophy has tended to move away from the very concept of "will" on the grounds that it, like many concepts such as phlogiston, has no content but rather reflects a state of ignorance that has passed. Kane's book takes the opposite position, as, indeed, do many theologians and some ethicists: although they may not agree on what "free will" is, they recognize a deep connection between the ability to will, and moral responsibility.

The first is that of Sartre (and, more broadly, existentialism): the radical freedom of choice. Sartre argues that humans always have a choice as to how they will respond to events, and to life itself – after all, one can always kill oneself, rather than accept whatever option is presented. More fundamentally, this choice is constant, on-going, and the means by which an individual creates their personal world – and, importantly, not to recognize and embrace this freedom, painful as it might be, is inauthentic: a flight from both freedom and responsibility.

The second form of personal freedom can be called "perverse freedom" (Palmer, 1996). This is the freedom of Dostoyevsky's antihero in *Notes from the Underground*; knowing he is sick, he refuses to go to a doctor, for reason and reality itself are intrusions on his freedom (Dostoyevsky, quoted in Palmer, 1996, at 226):

> One's own free unfettered choice, one's own caprice – however wild it may be, one's own fancy worked up at times to a frenzy – is that very "most advantageous advantage" which we have overlooked, which comes under no classification and against which all systems and theories are continually being shattered to atoms. And how do these wiseacres know that man wants a normal, a virtuous choice? What has made them conceive that many must want a rationally advantageous choice? What man wants is simply *independent* choice, whatever that independence may cost and wherever it may lead.

Note first that these ideas of freedom – which are not, at heart, dissimilar descriptions of human freedom – are not absolute: one may be free to commit suicide, but one is not free to purchase a product that is nowhere made. It is a freedom, in other words, at the individual level.[52] Nor is one free if one has certain forms of mental illness, or is under the influence of certain drugs; this is the contingency of the internal network state, primarily, but not exclusively, the mental processes of the brain. But such a concept of freedom creates an important insight into the dynamics of the anthropogenic world, for a major difference between natural and human systems (using "nature" and "human" as they are commonly understood) is the contingency and reflexivity that, to a large extent, reflects the radical freedom of Dostoyevsky, Satre, and Heiddeger – a

[52] "Freedom" is an enormously complex and powerful idea, with a huge literature. I am merely suggesting here a few pertinent ways in which some of this literature may pertain to integrative cognitivism. Moreover, there are infinite gradations in concepts of freedom: for example, Sartre's radical concept of freedom can be modified to hold that there are *usually* alternatives, or that *under most circumstances* one is free in a limited way to choose. Palmer (1996, at 233) points out, however, one of the important things about the Satre/Dostoyevsky approach: it undermines determinism:

> human nature is such that it can perversely thwart every attempt to make it predictable. If I know that you are trying to predict my behavior, I can incorporate that knowledge into my motivation and behave in ways that will be nearly impossible to predict. There may be some deterministic <u>theory</u> that purports to explain this phenomenon, but the fact is that this phenomenon destroys any deterministic program.

The nice thing about this formulation is the way it integrates the two powerful forces of complexity in human systems: contingency (as a result of freedom) and reflexivity.

radical freedom that springs uniquely from human intentionality. And thus the commoditization of natural systems, and the integration of human/natural/built systems, implies a greater contingency and reflexivity in the anthropogenic world as human dynamics increasingly dominate many regional and global systems.

Bearing in mind the messiness of complex systems, it is here that the concept of "will" is useful, for despite its limitations it helps us understand the intentionality that powers cognitive networks, and that has created over millennia the anthropogenic Earth. While, like "freedom," the term "will" has been used in many ways over the centuries, I will follow Kane (1998, at 22) who defines "will" as "a *set of conceptually interrelated powers or capacities*, including the powers to deliberate, or to reason practically, to choose or decide, to make practical judgments, to form intentions or purposes, to critically evaluate reasons for action, and so forth."[53] Will is a teleological phenomenon: it (Kane, 1998, at 27) "signifies an orientation or inclination toward some objective or end that is desired, chosen, or striven for. . . . different senses of *will* and *willing* represent different ways in which agents may be directed toward or tend toward *ends* or *purposes*." Moreover, will is important because it is usually understood as a necessary predicate for moral responsibility. Thus, Kant noted (quoted in Kane, 1998, at 34) that a "man . . . must make or have made himself into whatever in the moral sense, whether good or evil, he is or is to become. Either [good or evil character] must be the effect of his free choice for otherwise he could not be held responsible for it and could therefore be neither morally good nor evil." This principle, of course, is enshrined in the insanity defense against criminal charges in the Anglo-American legal tradition: a person may not be held morally, and thus legally, culpable for his or her actions where he or she is demonstrably incapable of intentionality by reason of insanity. "The term [insanity] is a social and legal term rather than a medical one . . . [and] is more or less synonymous with mental illness or psychosis. In law, the term is used to denote that degree of mental illness which negates the individual's legal responsibility or capacity (Black's, 1990)."[54]

---

[53] Kane (1998, at 26) further breaks "will" down into three sets of characteristics: what I "*want*, *desire*, or *prefer* to do," "*choose, decide*, or *intend* to do," and "*try, endeavor* or make an *effort* to do." (Emphasis in original.) Note that all three of these categories are not dependent on outcome of action; that is, the act of willing is not voided because the results of the action are not as intended. That is important in the context of the anthropogenic world, where the complexity of the systems involved almost always guarantees that the outcome will not be entirely as intended. Because we assign moral responsibility based at least in part on outcomes, this partial and unpredictable linkage is important: in a suitably complex system, it is not that the outcome *may* not be as intended; it is that it *will* not be as intended.

Another important classic aspect of "will" is evident in the differentiation, dating from Aristotle, between two forms of reasoning, theoretical and practical. Theoretical reason is *intellectus*, perceiving and understanding what exists. *Voluntas*, in contrast, involves judging and choosing what is to be done: it is practical reason, or will (Kane, 1998, as 21-22). This is a relevant dichotomy, for the argument behind ethical responsibility for the anthropogenic Earth is that, first, we are failing to perceive the real state of the anthropogenic world (a failure of *intellectus*) and, as a result, are unable to will what should be done – to design (a failure of *voluntas*) – in short, a failure of both theoretical and practical reason. Cognitive systems require perception, processing of the resulting information, judgment, and choice.

[54] According to Black's (1990, at 794), the most common test in U.S. jurisprudence comes from Section 401 of the Model Penal Code: "A person is not responsible for criminal conduct if at the time of such conduct as a result of mental disease or defect he lacks substantial capacity either to appreciate the criminality (wrongfulness) of his conduct or to conform his conduct to the requirements of law." In brief, criminal responsibility requires intentionality; "intent" is usually defined as (Black's, at 810) "design,

In other words, where network state (in this case, the state of the internal biochemical network of the individual) precludes the ability to perceive reality, or to choose rationally among options, we will not imply intentionality.

But at this point we enter deeper waters, for these formulations of will, and intentionality, are in a very Cartesian way focused on the individual. The systems of concern in integrative cognitivism, and indeed much of the complexities of the modern, arise instead from the operation of systems (such as markets and cultures) and institutions that, while composed of individuals, exhibit far different characteristics, and operate at far different spatial and temporal scales, than the individual. Thus arise discourses about "class (e.g., Marx)," *Geist* (Hegel), Being (Heidegger), the State (e.g., Kant and Hegel), the private firm as "learning organization (e.g., Senge)," and the like. Do such larger systems have a "will" of their own, as implied or even explicitly stated in many cases?

This question is better understood by returning to the understanding of cognitive systems that underlies integrative cognitivism. In particular, consider three of the requirements for the existence of a cognitive system: 1) perception, 2) manipulation of information, and 3) intentionality. It is clear that, in most cases, entities such as cultures, firms, and classes perceive and process information; moreover, they do so in ways that serve as self-definitional and, by including previous output in ongoing information process, are auto-catalytic. Accordingly, in most cases such institutions clearly meet the first two criteria.

Despite the language of subjectivity often used, however, there is little evidence at this point that firms, nations, or institutions exhibit intentionality as a characteristic endogenous to themselves as potential subjects, rather than expressing, in some form or other, the intentionality of the individuals, past and present, who have constituted them. This "congealed intentionality" reflecting past exercises of human intention built into institutional framework, combined with emergent behavior arising from the internal dynamics of complex systems, can mislead one into attributing intentionality to large systems qua systems. But this is illusory: so far as we can ascertain, human individuals alone have ultimate intentionality; institutions exhibit derivative intentionality (from existing human agents) or congealed intentionality (from previous exercises of intentionality, now built into the institution in various ways). Such institutions, for example, would not last long in the absence of the intentionality deriving from the humans engaged in their multiple cognitive networks.

Note, however, the complexity that such institutions create when it comes to intentionality as systems state. Institutions are not just powered by current intentionality, but they represent "congealed intentionality": their structure, derived from intentionality expressed through past cognitive networks, acts as a significant constraint on expressions of current intentionality. As Berger and Luckmann (1967, at 97-98) point out, the institutional reality within which current humans live is socially constructed: language creates knowledge; knowledge creates theoretical propositions which in turn integrate

---

resolve, or determination with which [a] person acts," and "denote[s] that the actor desires to cause consequences of his act, or that he believes that the consequences are substantially certain to result from it."

into an all-encompassing symbolic universe, a set of institutions that significantly constrain current intentionality:

> Symbolic universes are social products with a history. If one is to understand their meaning, one has to understand the history of their production. This is all the more important because these products of human consciousness, by their very nature, present themselves as full-blown and inevitable totalities. . . This nomic function of the symbolic universe for individual experience may be described quite simply by saying that it "puts everything in its right place." . . . the symbolic universe provides the ultimate legitimation of the institutional order by bestowing upon it the primacy in the hierarchy of human experience.

In this, institutional and social structures are similar to technologies; they represent congealed cognition and intentionality which are sources of significant individual and cultural power (because they enable much more powerful cognitive networks), but also heavily constrain possible expressions of intentionality outside the boundaries they have established.

We thus come to a model where, regardless of how complex a cognitive system is, the intentionality that energizes it derives, directly or indirectly, from individual humans, both past and present. Thus, the *ultimate source* of intentionality in a cognitive system is the human individual(s), but the *expression* of intentionality in a complex system context may be – almost always is, in fact - something very different. Language, institutions and society, technology: all represent necessary simplifications of complex adaptive systems that both enable (partial) understanding at the cost of significantly constraining expressions of current intentionality.[55]

It is not hard to understand why. Perhaps when cognitive systems were much simpler – in a hunter-gatherer society, for example – it was easy to follow the dynamics of individual intentionality working through the various systems.[56] But today, when cognitive networks can extend across the globe, and through centuries of time – think of the ongoing human project to dominate and design the carbon cycle through such

---

[55] Legacy networks, mentioned earlier, are a specific example of this general trend.

[56] This is not to trivialize the growth of culture, an extremely complex phenomenon even in the case of such societies. The interrelationship of the development of individuals, their technologies, languages, and their cultures is lost in prehistory, but by the time we can begin to reconstruct it, is already highly complex and human. Put another way, cognitive systems in the case of earlier societies (such as hunter-gather cultures) may have been much simpler than today, but they were not simple. An interesting example is provided by Gorman (1997):

> Micronesians had a very different mental model of the [oceanic] navigation problem than Western observers: the Micronesians viewed their canoes as stationary, and islands as moving. They chart their course by means of imaginary reference islands that are marked by the position of the stars. Using this system, they are able to take long ocean voyages without compasses or other modern technological aids. The Micronesians do rely heavily on memorization, but they have also distributed much of the task outside of the brain.

mechanisms as, e.g., the Kyoto global climate change negotiations and technologies such as, e.g., agriculture, biotechnology and genetic engineering, and ocean fertilization – it appears almost ludicrous to impute the intentionality behind these cognitive systems to the workings of individual wills. The dilemma is in some ways analogous to the way different disciplines and intellectual approaches targeted at the particular level of the hierarchy of concern are required to understand a complex system: a chemist studies atoms and molecules; a cellular biologist studies how these elements operate at a cellular level (including the dynamics emergent at the cellular level); a doctor or physiologist studies the system at the level of the organism; a psychologist studies the behavior which accompanies the organization of a human organism and its expression of mind; and a sociologist studies the emergent properties of complex groups of humans. Certainly there are interrelationships among the levels: a psychologist, for example, may be very interested in the behavioral effects of introducing certain molecules into human organisms. But at each level, different emergent characteristics require different disciplinary approaches.[57] What is lacking is the ability to understand emergent behaviors at a high level by challenging the predefined limits of existing institutions.

And this is the core dilemma of the anthropogenic world: as a species, we are now operating at levels of the system where we have yet to develop the understanding – indeed, even the language – that allows us to understand and manage the expression of intentionality in highly complex and broadly scaled cognitive systems. The congealed intentionality of our institutions, social structures, constructions of reality and languages increasingly constrain efforts to perceive, much less rationally and ethically intervene in, the complex adaptive systems that characterize the current era.

It is not that we need to stop trying to understand these cognitive systems at the level of the individual as we are now trying to do. Rather, it is that we *in addition* need to develop new approaches, new ways of thinking, that define these systems differently, and are scaled to the appropriate levels of the hierarchy and the concomitant emergent behavior. Thus, we should continue the study of, for example, various genetic engineering technologies, and their impacts – but we should also learn how to study the anthropogenic carbon cycle, in all its human and physical complexity, which will require different tools and different approaches. Moreover, in doing so we cannot only look at

[57] In fact, each level may require different ontologies. Many physical scientists, for example, assume without question the existence of an external physical world which they attempt to characterize and understand; at the other extreme, many social scientists assume the world is significantly structured by humans and human intentionality, the extreme being those who hold that the world is entirely constructed by human intellect. The need for different ontologies for working with different parts of the system is quite clear: one would not want, for example, a literary critic who was convinced that the world was as he decided it should be, to design an airplane; conversely, most engineers would not be good at deconstructing a contemporary novel to understand its relevancy in building new social constituencies. Extending the postmodernist critique to conclude that there are not only no absolute, foundational discourses, but no absolute, foundational ontologies, is not only appropriate, but necessary, at this stage of the intellectual development of the species. Reality is always too complex for capture in our languages, our philosophies, and our ontologies – sometimes light is a particle, and sometimes it's a wave: sometimes reality is physically absolute, and sometimes constructed. The challenge is to evolve philosophies, ontologies, and understanding that enable continued evolution in the context of an anthropogenic world too complex for existing approaches.

the science, the technology, or the existing policies, most of which are appropriate for their scale but almost by definition fail at the level of the carbon cycle itself, nor just rely on heavily ideological discourses, for they also fail at this scale. We also need to understand how intentionality, design, and moral responsibility function on such a scale: how, for example, should theological systems that have heretofore focused on the individual evolve to provide guidance at the level of the carbon cycle?

Perhaps an example will help illustrate this dynamic. Consider a European shipbuilder who is building a unique design of sailing ship, one that will enable Europeans to sail around the world, colonize much of it, and, at the end of a long process, create a globalized culture derived from the Enlightenment. His intentionalityl is expressed directly in his design, the ship, which is part of one relatively limited cognitive system (the ship design; relevant ship manufacturing and sailmaking capabilities; known characteristics of the oceanic and weather systems; navigation capabilities; sailors' skill sets; and the like (Law, 1997)). He directly intends the ship to sail open oceans, and to do so as well as his design capabilities and the state of technology allow. Moreover, should the ship sink in calm weather, we would feel justified in criticizing his design, and possibly in moral reproach as well, should the design have been obviously and negligently flawed. In other words, at this scale and within this cognitive system intentionality is expressed simply and directly, and not only implies relatively free choice (that is, within existing network states, such as existing shipbuilding technologies), but also moral responsibility.

But with our centuries of hindsight, we can see that this particular technology carried within it implications unknowable to our ship designer. To take only one, once the European nations, in competition with each other, began their period of global exploration and migration, virtually every island biology was changed. Species such as the dodo were exterminated; rats were transmitted to other islands; European landscapes traveled with new settlers. In this instance, there is obviously a gap between the intent of the shipbuilder – to build an oceangoing vessel – and the results of the implementation of that technology. Even if the technology worked as planned, some might criticize it on the grounds of the unpredicted effects it generated, but most would hesitate to hold the shipbuilder morally responsible for the results, for at least two reasons. First, there are intervening human and institutional intentionalities, both current and congealed, contingencies, and the like that greatly complicate the ability of the shipbuilder to perceive, or predict, these more general effects (the sailors that choose to kill the last dodos, for example). Second, it is unrealistic to impute to the shipbuilder the knowledge, and thus the intentionality, appropriate to the scale and complexity of the cognitive system that encompasses the expansion of European culture and presence around the world.

At this largest stage of cognitive systems, then, does the model of human intentionality, combined with technological and cultural systems that vastly extend the cognitive activity of the individual mind, break down? The model, I think, does not; rather, the issue is that the complexity of the cognitive networks, at heart energized by the intentionality of individual humans, has become so great that the emergent behaviors at higher levels appear completely disconnected from the individuals constituting the system – put another way, the dynamics of these complex systems are such that it appears that single individuals are unable to exercise any intentionality at all within them. If true, this would negate much effort to "improve" the world (always depending on how one took that term), but it probably is not. Rather, it again confuses two scales of intentionality: that of the Cartesian individual, and that of the individual as a component of a large set of complex cognitive networks.

At the individual level, it is apparent that limitations on both knowledge and perception are pervasive in individuals.[58] Humans have very different mental models regarding reality, and those models control perception.[59] More subtly, the same limitations are also apparent in actors at higher levels: firms, NGOs, nation-states and others are also characterized by limited perception and lack of complete knowledge. In fact, much of the paraphernalia of modern life, from last names to property ownership and registration systems to licensing and permitting systems, is intended precisely to allow governments and other institutions to map, and therefore perceive, individuals (and, concomitantly, to exercise control over them; one cannot control what one cannot perceive (Scott, 1998, at 183: "Legibility is a condition of manipulation."). In the commercial realm, a primary function of brands is to aid customer perception of quality and value. Even in theory, perception necessarily reduces information, as it involves a simplification and ordering of whatever elements of reality are emphasized by the particular actor or perceptual system. And every human, and human institution, from firms to languages, exists within a context that to a large extent determines perceptual potential.

In addition to psychological, contextual and institutional barriers to perception, there is also the more apparent barrier of perception in that most agents are almost always unaware of the full set of options that are actually available, not to mention being

[58] The traditional argument here is between adherents of subjectivism (the actor imposes its cognitive structure on an otherwise formless external void, a very Kantian position) and objectivism (perception and cognition are organized by the structure of external reality, a position adopted implicitly by most scientists). In either case, however, it is apparent that consciousness perceives only a small amount of that which is occurring, a process that Giddens (1994, at 47-48) argues is not just a filtering process, but a necessary correlate to action: "Selection is . . . a positive rather than a negative process; it expresses the active engagements of agents with their environments." Gorman (2001) points out that reducing cognitive load through perceptual filters is both necessary, and problematic: after all, an important function of ideologies and religious fundamentalism is to reduce cognitive load. In the latter cases, however, reduction of cognitive load past a certain critical point may lead to dysfunctional, even violent responses, as relevant elements of cognitive systems and a complex environment are not perceived.

[59] Redman (1999, at 6-7) notes that "perception is a fundamental aspect of human-environmental relations. The way we perceive the world around us is not uniform for all people at all times, but rather each of us sees it in his or her own way. We create a *cognized environment* that is very real to us, and is the basis upon which we make decisions . . . . Productive strategies, social institutions, and virtually every human interaction with the environment have been conditioned by the existence of that very uniquely human phenomenon – culture." (see also Kempton et al., 1995; Landes, 1998; Noble, 1998; Hacking, 1999; Harrison and Huntington, 2000). More generally, the split between private and public moralities expresses the need for individuals to be embedded in the particular (Kane, 1999; Rorty, 1989, at 153): "To be a person is to speak a *particular* language, one which enables us to discuss particular beliefs and desired with particular sorts of people."

insufficiently knowledgeable about the ones they are aware of to make an informed choice. If, for example, the option space is significantly limited prior to my becoming aware of it, my exercise of intentionality (endogenous freedom), as well as my freedom to participate in a non-dominated discourse (exogenous freedom), have both been significantly limited. Arguably, such a situation is created, for example, when the scientists involved in global climate change implicitly remove sets of technologies, such as geoengineering possibilities, from the negotiating arena (Keith, 2000), thus presenting the broader public, which will not be able to perceive such options on its own, with an already attenuated option space. As any good propagandist knows, control information and you can control perception; control perception and you control the exercise of intentionality. Since the ability to exercise intentionality is a function of the degree of knowledge of the relevant system state, and that is almost always partial, it follows that the pure variety of "free will" is essentially mythic; put another way, the usual framing of the "free will" versus "determinism" argument fails because it is so over-simplistic as to be irrelevant.

The implication of this discussion is clear: we may impute moral responsibility where there is perception, and the possibility of choice (choice being the sin qua non of design), and thus the potential for the exercise of intentionality. We now know that we have created an anthropogenic world, and that knowledge creates an overarching moral responsibility to exercise intentionality – design and management – in ways that are ethical and moral. But the more specific knowledge which would enable moral choices in particular areas – from designing the carbon cycle, to engineering biological systems at all scales, to designing resource areas such as the Everglades, the Baltic, and the Mississippi Delta – is lacking. That, combined with refuge in perceptual systems (e.g., ideologies) that deny knowledge of the anthropogenic world, are at this point enabling denial of moral responsibility, but that posture is becoming increasingly untenable. Given our knowledge, the study of such reasoned responses as earth systems engineering and management (Allenby, 2007) and other responses to the anthropgenic Earth is not discretionary, but, at this point in human history, is a moral imperative.

Integrative cognitivism implies that cognitive networks both enable and restrict intentionality, and that intentionality is a function of systems state (including congealed intentionality). Intentionality as actually expressed is thus an emergent characteristic of the particular state and dynamics of complex systems reflecting the transitory conditions of the particular system. But how it is expressed in particular instances is far less clear. In some cases – a Hitler, a Mao, a Stalin – individuals were able to affect events in ways that were profoundly contingent (because dependent on their unpredictable if bounded exercise of intentionality), but also had far more impact as a result of the scale of the cognitive systems within which they operated. A Hitler without Germany, or a Mao without China, might have still had intentionality, but its exercise would have had far less impact on other systems than was in fact the case.[60] It has already been established that

[60] This point has broader relevance. A major criticism of globalization by anarchists, deep greens, developed country labor organizations, and renegade Marxists is that global capitalism and its attendant institutions are destroying individual freedom. What they are reacting to is the system state of a complex world, for it is arguably true that the complex systems that these institutions limit the ability to exercise

where networks are characterized by a moderate level of connectivity among system components, favorable outcomes can be obtained by choice among options, but where there is a high degree of connectivity, it is much harder to identify favorable outcomes and, in fact, they may not exist (Kauffman, 1993). An analogous principle appears to hold with dynamic complexity: over time, many complex systems, including social systems, can be modeled as cycling through phases, some of which are very stable, making the exercise of intentionality difficult if not impossible, and some of which are chaotic and fluid, and the exercise of intentionality can make discontinuous differences.[61] Thus, periods of chaos can facilitate revolutions in governments, and chance and contingency may throw up the dictators that have such impacts on their times (Rorty, 1989, at 188: "What our future rulers will be like will not be determined by any large necessary truths about human nature and its relation to truth and justice, but by a lot of small contingent facts.").[62] Thus, although ultimately intentionality arguably derives from individual humans, its potential expression, and the form of that expression, are systems dependent. By implication, then, one must understand the nature of the complex systems within which one is embedded before one can act with rationality and ethical responsibility to help evolve them. Again, this makes it clear that authenticity – the continuing difficult effort to perceive with integrity and vision, to reject inappropriate ideologies, and to act – to design – based on that knowledge – is a moral mandate.

In this light, both the denial of external structure, and the solipsistic absolutism of internal structuration, fall short. Authenticity requires that the external world be perceived as it is, not as we merely wish it to be, to the extent possible under existing system conditions, just as it requires that we recognize that we have, and will continue to, create that world in profound ways. The very act of identifying options, a prerequisite to choice, relies both on perception (separation of the object from its background based on some set of differences in exogenous fields) and internal structuration (by what values are choices identified from background). Context thus plays an important duel role: it determines whether intentionality exists at all (does the particular system state allow for any contingency at all?) and, if so, the scope within which intentionality can be exercised. .

---

intentionality in certain ways. The deeper point, however, is that intentionality has always been contextual; the challenge is to understand it in the context of an anthropogenic world.

[61] Such models are quite rough, of course, and are perhaps best thought of as schematics at this point. Westly (1995) offers a social cycle of change which includes: 1) creation of a new social order; 2) encoding and institutionalizing of the new order into organizational structure; 3) increasing rigidity of the social order leading to short term efficiency but long term loss of adaptability; thus paving the way for 4) revitalization and reorganization, a chaotic period of innovation, learning, and experimentation, leading to 5) reintegration leading to the generation of new myths and creation of a new social order. Expression of intentionality is least effective in 2 and especially 3, and most effective in 4 and to some extent 5.

[62] For example, complex systems such as technology (Grubler, 1998, at 114) "can undergo a sequence of evolutionary instabilities at the micro level of economic agents while still maintaining structure and evolutionary stability at the macro levels of industrial sectors and the overall economy." Other human systems, such as urban centers (Dear, 2000; Jacobs, [1961] 1992), and economies (Arthur et al, 1997) are also becoming much more complex over time, and thence displaying similar characteristics. Thus, one could have choice, and free will, at a subsystem level, but not at a systems level, at a particular point in system evolution: a locally contingent but globally deterministic state (the opposite, a globally contingent state with local determinism, is also possible).

III. *Conclusion*

The anthropogenic Earth is one characterized by complex integrated human/natural/built systems, radical contingency, and accelerating – and destabilizing - technological change. This poses enormous perceptual, intellectual, and metaphysical challenges. This paper has offered some initial observations regarding one major implication, the increasing importance of distributed cognitive networks that incorporate human, natural, and technological elements. In doing so, it is difficult to avoid the conclusion that the longstanding arguments over free will are somewhat misdirected, and that a more nuanced approach based on the concept of intentionality offers more utility.

References

Abrams, M. H. 1971. *Natural Supernaturalism: Tradition and Revolution in Romantic Literature.* New York: W. W. Norton & Company.

Allenby, B. R. 2007. Earth systems engineering and management: A manifesto. *Environmental Science & Technology* 41(23):7960-7965.

Allenby, B. R. 2005. *Reconstructing Earth.* Washington, DC: Island Press.

Allenby, B. R. 1999. *Industrial Ecology: Policy Framework and Implementation.* Upper Saddle River, NJ: Prentice-Hall.

Allenby, B. R. and J. Fink. 2005. Toward inherently secure and resilient societies. *Science* 309:1034-1036.

Alroy, J. 2001. A multispecies overkill simulation of the end-Pleistocene megafaunal mass extinction. *Science* 292:1893-1896.

Arthur, W. B., S. N. Durlauf, and D. A. Lane, eds. 1997. *The Economy as an Evolving Complex System II.* Reading, MA: Addison-Wesley.

Baer, J., J. C. Kaufman, and R. F. Baumeister, eds. 2008. *Are We Free?: Psychology and Free Will.* Oxford: Oxford University Press.

Bandura, A. 2008. Reconstrual of "free will" from the agentic perspective of social cognitive theory. In Baer, J., J. C. Kaufman, and R. F. Baumeister, eds. *Are We Free?: Psychology and Free Will.* Oxford: Oxford University Press.

Barabasi, A. 2002. *Linked: The New Science of Networks.* Cambridge, MA: Perseus Publishing Co.

Barrett, W. 1979. *The Illusion of Technique.* Garden City, New York: Anchor Books.

Berger, P. L. and T. Luckmann. 1966 (Anchor edition, 1967). *The Social Construction of Reality: A Treatise in the Sociology of Knowledge.* New York: Anchor Books.

Bijker, W. E., T. P. Hughes, and T. Pinch, eds. 1997. *The Social Construction of Technological Systems.* Cambridge: MIT Press.

Black's. 1990. *Black's Law Dictionary.* St. Paul, MN: West Corporation.

BRDB (Biomass Research and Development Board). 2001. *Fostering the Bioeconomic Revolution in Biobased Products and Bioenergy.* Washington, DC: USGPO.

Brody, H. 2000. *The Other Side of Eden: Hunters, Farmers and the Shaping of the World.* New York: Farrar, Straus and Giroux.

Burge, T. 1998. Individualism and the mental. In P. Ludlow and N. Martin, eds. *Externalism and Self-Knowledge*. Stanford, CA: CSLI Publications. Pages 21-84.

Castells, M. 2000a. *The Rise of the Network Society* (2nd ed.). Oxford: Blackwell Publishers.

Castells, M. 2000b. *End of Millenium.* Oxford: Blackwell Publishers.

Castells, M. 2001. *The Power of Identity.* Oxford: Blackwell Publishers.

Chapin, F. S. III, D. S. Zavaleta, V. T. Eviner, R. L. Naylor, P. M. Vitousek, H. L. Reynold, D. U. Hooper, S. Lavorel, O. E. Sala, S. E. Hobbie, M. C. Mack, and S. Diaz. 2000. Consequences of changing biodiversity. *Nature* 405:234-242.

Check, E. 2005. Designs on life. *Nature* 438:417-418.

Clark, A. 2001. Natural born cyborgs. http://www.edge.org/3rd_culture/clark/clark_index.html. Accessed 01/10/2001.

Clark, G. 2007. *A Fairwell to Alms: A Brief Economic History of the World.* Princeton: Princeton University Press.

Cohen, J. E. 1995. *How Many People Can the Earth Support?* New York: W. W. Norton & Company.

Cronon, W. 1991. *Nature's Metropolis: Chicago and the Great West.* New York: W. W. Norton and Company.

Cronon, W., ed. 1995. *Uncommon Ground: Rethinking the Human Place in Nature.* New York: W. W. Norton and Company.

Dalton, D. 1998. Freedom in the ancient world. *Freedom: The Philosophy of Liberation:Lecture 1.* Springfield, VA: The Teaching Company.

Dear, M. J. 2000. *The Postmodern Urban Condition*. Oxford, UK: Blackwell Publishers.

De Grey, A. D. J. J. 2004. *Strategies for Engineered Negligible Senescence. Annals of the New York Academy of Sciences* 1019.

Damasio, A. 2003. The person within. *Nature* 423:227.

Dennett, D. C. 2003. *Freedom Evolves.* New York: Viking.

Descartes, R. 1637/1641, republished 1998. *Discourse on Method and Meditations on First Philosophy.* 4th edition. D. A. Cress, translator. Indianapolis, IN: Hackett Publishing Company.

Diamond, J. 1997. *Guns, Germs and Steel.* New York: W. W. Norton & Co.

Diamond, J., and P. Bellwood. 2003. Farmers and then languages: The first expansion. *Science* 300:597-603.

DoE (U. S. Department of Energy). 1999. *Carbon Management: Assessment of Fundamental Research Needs*. Washington, DC: Department of Energy.

Erickson, C. L. 2000. An artificial landscape-scale fishery in the Bolivian Amazon. *Nature* 408:190-193.

Ferber, D. 2001. Keeping the Stygian waters at bay. *Science* 291:968-973.

Ferber, D. 2004. Microbes made to order. *Science* 303:158-161.

Fewell, J. H. 2003. Social insect networks. *Science* 301:1867-1870.

Freeman, C. and F. Louca. 2001. *As Time Goes By: From the Industrial Revolutions to the Information Revolution.* Oxford: Oxford University Press.

Gallagher, R. and T. Appenzeller. 1999. Beyond reductionism (special section). *Science* 284:79-109.

Gallagher, R. and B. Carpenter. 1997. Human-dominated ecosystems: introduction. *Science* 277:485.

Galloway, J. N. and E. B. Cowling. 2002. Reactive nitrogen and the world: 200 years of change. *Ambio* 31(2):64-71.

Gandy, M. 2002. *Concrete and Clay: Reworking Nature in New York City.* Cambridge: MIT Press.

Garreau, J. 2004. *Radical Evolution.* New York: Doubleday.

Giddens, A. 1990. *The Consequences of Modernity.* Stanford, CA: Stanford University Press.

Giddens, A. 1984. *The Constitution of Society*. Berkeley, CA: The University of California Press.

Gittleman, J. L. and M. E. Gompper. 2001. The risk of extinction – what you don't know will hurt you. *Science* 291:997-999.

Gorman, M. 2001. Personal communication.

Gorman, M. 1997. Mind in the world: Cognition and practice in the invention of the telephone. *Social Studies of Science* 27:583-624.

Graedel, T. E. and B. R. Allenby. 2003. *Industrial Ecology: Second Edition.* Upper Saddle River, NJ: Prentice-Hall.

Grubler, A. 1998. *Technology and Global Change.* Cambridge: Cambridge University Press.

Gunderson, L. H., C. S. Holling, and S. S. Light, eds. 1995. *Barriers & Bridges to the Renewal of Ecosystems and Institutions.* New York: Columbia University Press.

Habermas, J. 1975. *Legitimation Crisis* (trans. By T. McCarthy). Boston: Beacon Press.

Hacking, I. 1999. *The Social Construction of What?* Cambridge: Harvard University Press.

Harnad, S. 2001. No easy way out. *The Sciences* 41(2):36-42.

Harrison, L. E. and S. P. Huntington, eds. 2000. *Culture Matters: How Values Shape Human Progress.* New York: Basic Books.

Hayles, N. K. 1999. *How We Became Posthuman*. Chicago: University of Chicago Press.

Hofstadter, D. R. and D. C. Dennett, eds. 1988. *The Mind's I.* New York: Bantam Books.

Hugill, P. J. 1993. *World Trade Since 1431: Geography, Technology, and Capitalism.* Baltimore: the Johns Hopkins University Press.

Hutchins, E. 1995. *Cognition in the Wild.* Cambridge: MIT Press.

IEEE *Spectrum.* 2004. Engineering and aging. *Spectrum* 41(9):10, 31-35.

Jacobs, J. [1961] 1992. *The Death and Life of Great American Cities.* New York: Random House. Reprint, New York: Vintage Books.

Kaiser, J. 1999. Stemming the tide of invading species. *Science* 285:1836-1841.

Kaiser, J.. 2005. Resurrected influenza virus yields secrets of deadly 1918 pandemic. *Science* 310:28-29.

Kane, R. H. 1998. *The Significance of Free Will.* Oxford: Oxford University Press.
Kauffman, S. A. 1993. *Origins of Order: Self-organization and Selection in Evolution.* Oxford: Oxford University Press.

Kauffman, S. A. 1995. *At Home in the Universe: The Search for the Laws of Self-Organization and Complexity*. Oxford: Oxford University Press.

Keith, D. W. 2000. Geoengineering the climate: History and prospect. *Annual Review of Energy and the Environment* 25:245-284.

Kempton, W., J. S. Boster, and J. A. Hartley. 1995. *Environmental Values in American Culture.* Cambridge: MIT Press.

Kerr, R. A. 2003. Megafauna died from big kill, not big chill. *Science* 300:885.

Kurzweil, R. 2005. *The Singularity is Near.* New York: Viking.

Landes, D. S. 1998. *The Wealth and Poverty of Nations*. New York: W. W. Norton and Company.

Lanier, J. 2002. The complexity ceiling. In J. Brockman, ed. *The Next Fifty Years: Science in the First Half of the Twenty-First Century.* New York: Vintage. Pages 216-229.

Law, J. 1997. Technology and heterogeneous engineering: The case of Portuguese expansion. in Bijker, W. E., T. P. Hughes, and T. Pinch, eds. *The Social Construction of Technological Systems.* Cambridge: MIT Press. Pages 111-134.

Lovejoy, T. 2002. Biodiversity: Dismissing scientific process. *Scientific American* 286(1):69-71.

Ludlow, P. and N. Martin, eds. 1998. *Externalism and Self-Knowledge.* Stanford, CA: CSLI Publications.

Mann, C. C. 2008. Ancient earthmovers of the Amazon. *Science* 321:1148-1152.

Marks, P. 2008. Rat-brained robots take their first steps. *NewScientist* 199(2669):22-23.

Marshall, J. C. 2001. Final frontier or ultimate mystery? Plumbing the origins of human uniqueness. *Nature* 411:415-16.

Marx, L. 1964. *The Machine in the Garden: Technology and the Pastoral ideal in America.* Oxford: Oxford University Press.

Mathews, J. T. 1997. Power shift. *Foreign Affairs* 76(1):50-66.

McKibben, B. 1989. *The End of Nature*. New York: Random House.

McNeill, J. R. 2000. *Something New Under the Sun*. New York: W. W. Norton & Co.

MEA (UN Millennium Ecosystem Assessment). 2005. *The Condition & Trends Assessment, 2005,* www.millenniumassessment.org/en/global.condition.aspx, accessed 10/7/2005.

Mitchell, W. J. 2003. *Me++: The Cyborg Self and the Networked City.* Cambridge, MA: MIT Press.

Mlot, C. 1995. In Hawaii, taking inventory of a biological hot spot. *Science* 269:322-23.

Mumford, L. [1961] 1989. *The City in History.* New York: Harcourt, Inc.

Nagurney, A. and J. Dong. 2002. *Supernetworks: Decision-Making for the Information Age.* Cheltenham, UK: Edward Elgar.

Nature. 2003. Welcome to the Anthropocene. *Nature* 424:709.

Needham, J. 1956, reprinted 1991. *Science and Civilization in China, Vol. 2, Sections 8-18.* Cambridge, UK: Cambridge University Press.

Noble, D. F. 1998. *The Religion of Technology.* New York: Alfred A. Knopf.

NRC (National Research Council). 2003. *Cities Transformed.* Washington, DC: National Academy Press.

Nye, D. E. 1994. *American Technological Sublime.* Cambridge: MIT Press.

Oberg, J. 1999. Missionaries to Mars. *Technology Review* 102(1):54-59

Palmer, D. 1996. *Does the Center Hold?* (2^{nd} ed.). London: Mayfield Publishing Company.

Palumbi, S. R. 2001. Humans as the world's greatest evolutionary force. *Science* 293:1786-1790.

Pelley, J. 1998. Is coastal eutrophication out of control? *Environmental Science& Technology* 32(19):462A-466A.

Pullun, G. K. and B. C. Scholz. 2001. More than words. *Nature* 413:367.

Quinn, D. 1992. *Ishmael.* New York: Bantam Books.

Redman, C. L. 1999. *Human Impact on Ancient Environments.* Tucson, AZ: University of Arizona Press.

Roberts, R. G., T. E. Flannery, L. K. Ayliffe, H. Yoshida, J. M. Olley, G. J. Prideaux, G. M. Laslett, A. Baynes, M. A. Smith, R. Jones, and B. L. Smith. 2001. New ages for the last Australian megafauna: Continent-wide extinction about 46,000 years ago. *Science* 292: 1888-1892.

Robinson, K. S. 1993. *Red Mars.* New York: Bantam Books.

Robinson, K. S. 1994. *Green Mars.* New York: Bantam Books.

Robinson, K. S. 1996. *Blue Mars.* New York: Bantam Books.

Rorty, R. 1989. *Contingency, Irony, and Solidarity.* Cambridge: Cambridge University Press.

Rosenberg, N. and L. E. Birdzell, Jr. 1986. *How the West Grew Rich: The Economic Transformation of the Industrial World.* New York: Basic Books.

Rowland, M. 1999. *The Body in Mind.* Cambridge, UK: Cambridge University Press.

Ruiz, G. M., T. K. Rawlings, F. C. Dobbs, L. A. Drake, T. Mullady, A. Huq, and R. R. Colwell. 2000. Global spread of microorganisms by ships. *Nature* 408:49.

Russell, B. 1972, original published in 1945. *A History of Western Philosophy.* New York: Simon & Schuster.

Sachs, J. A. D. Mellinger and J. L. Gallup. 2001. The geography of poverty and wealth. *Scientific American* 284:70-75.

Schivelbusch, W. 1977. *The Railway Journey: The Industrialization of Time and Space in the 19th Century.* Berkeley: University of California Press.

Schneider, S. 2002. Global warming: Neglecting the complexities. *Scientific American* 286(1):62-65.

Science special report. 1997. Human-dominated ecosystems. *Science* 277:485-525.

Scott, J. C. 1998. *Seeing Like A State: How Certain Schemes to Improve the Human Condition Have Failed.* New Haven, CT: Yale University Press.

Service, R. F. 2003. Researchers create first autonomous synthetic life form. *Science* 299:640.

Shlain, L. 1991. *Art and Physics: Parallel Visions in Space, Time and Light.* New York: William Morrow.

Singer, E. 2006. Piloting a wheelchair with the power of the mind. *Technology Review:*www.technologyreview.com/printer_friendly_article.aspx?id=17629, accessed October 19, 2006.

Singer, P. 2001. All animals are equal. In M. E. Zimmerman, J. B. Callicott, G. Sessions, K. J. Warren, and J. Clark, eds. *Environmental Philosophy: From Animal Rights to Radical Ecology, 3rd Edition.* Upper Saddle River, NJ: Prentice-Hall. Pages 26-41. Originally published in *Philosophic Exchange* 1(5):243-257 (Summer, 1974).

Smil, V. 1997. *Cycles of Life: Civilization and the Biosphere*. New York: Scientific American Library.

Socolow, R. H. 1999. Nitrogen management and the future of food: Lessons from the management of energy and carbon. *Proc. Natl. Acad. Sci. USA.* 96:6001-6008.

Surridge, C., ed. 2002 Nature insight: Computational biology (special section). *Nature* 420:205-251.

The Economist. 2008. The odd couple: a special report on the Koreas (center section, September 27, 2008). *The Economist.*

Travis, J. 2001. Gene makes tomatoes tolerate salt. *Science News* 160:68.

Turner, B. L., W. C. Clark, R. W. Kates, J. F. Richards, J. T. Mathews, and W. B. Meyer, eds. 1990. *The Earth as Transformed by Human Action.* Cambridge: Cambridge University Press.

Von Bubnoff, A. 2005. The 1918 flu virus is resurrected. *Nature* 437:794-795.

Weber, M. [1904]1998. *The Protestant Ethic and the Spirit of Capitalism.* Trans. by T. Parsons (1930). Los Angeles: Roxbury Publishing Corp.

Westly, F. 1995. Governing design: The management of social systems. In Gunderson, L. H., C. S. Holling, and S. S. Light, eds. *Barriers & Bridges to the Renewal of Ecosystems and Institutions.* New York: Columbia University Press. Pages 391-427.

Williams, M. 2003. *Deforesting the Earth: From Prehistory to Global Crisis.* Chicago: University of Chicago Press.

Vijg, J. and J. Campisi. 2008. Puzzles, promises and a cure for ageing. *Nature* 454(28):1065-1071.

Zubrin, R. and R. Wagner. 1997. *The Case for Mars: The Plan to Settle the Red Planet and Why We Must.* New York: Simon & Schuster.