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What's blocking sustainability? Human nature, cognition, and denial

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In 1992, 1,700 of the world's top scientists issued a public statement titled *The World Scientists' Warning to Humanity*. They reported that "a great change in our stewardship of the Earth and the life on it is required if vast human misery is to be avoided and our global home on this planet is not to be irretrievably mutilated." More than a decade later, the authors of the Millennium Ecosystem Assessment were moved to echo the scientists' warning asserting that "[h]uman activity is putting such a strain on the natural functions of the Earth that the ability of the planet's ecosystems to sustain future generations can no longer be taken for granted." Ours is allegedly a science-based culture. For decades, our best science has suggested that staying on our present growth-based path to global development implies catastrophe for billions of people and undermines the possibility of maintaining a complex global civilization. Yet there is scant evidence that national governments, the United Nations, or other official international organizations have begun seriously to contemplate the implications for humanity of the scientists' warnings, let alone articulate the kind of policy responses the science evokes. The modern world remains mired in a swamp of cognitive dissonance and collective denial seemingly dedicated to maintaining the status quo. We appear, in philosopher Martin Heidegger's words, to be "in flight from thinking." Just what is going on here? I attempt to answer this question by exploring the distal, biosocial causes of human economic behavior. My working hypothesis is that modern *H. sapiens* is unsustainable by nature—unsustainability is an *inevitable* emergent property of the systemic interaction between contemporary technoindustrial society and the ecosphere. I trace this conundrum to humanity's once-adaptive, subconscious, genetic predisposition to expand (shared with all other species), a tendency reinforced by the socially constructed economic narrative of continuous material growth. Unfortunately, these qualities have become maladaptive. The current coevolutionary pathway of the human enterprise and the ecosphere therefore puts civilization at risk—both defective genes and malicious "memes" can be "selected out" by a changing physical environment. To achieve sustainability, the world community must write a new cultural narrative that is explicitly designed for living on a finite planet, a narrative that overrides humanity's outdated innate expansionist tendencies.

KEYWORDS: human behavior, ecosystem stability, survival value, world economy, cultural values, social organization

The (Un)sustainability Conundrum

In his review of Tim Flannery's book *The Weather Makers*, Andrew Nikiforuk (2006) drew a graphic verbal sketch of modern humans' ecological behavior (i.e., our *economic* behavior):

> Let's face it: *Homo economicus* is one hell of an over-achiever. He has invaded more than three-quarters of the globe's surface and monopolized nearly half of all plant life to help make dinner. He has netted most of the ocean's fish and will soon eat his way through the world's last great apes. For good measure, he has fouled most of the world's rivers. And his gluttonous appetites have started a wave of extinctions that could trigger the demise of 25 percent of the world's creatures within 50 years. The more godlike he becomes the less godly *Homo economicus* behaves.

This is the same enigmatic behavior that in 1992 inspired the Union of Concerned Scientists (UCS) to abandon the usual skeptically reserved language of science and to issue the following strident assessment: "We the undersigned, senior members of the world's scientific community, hereby warn all humanity of what lies ahead. A great change in our stewardship of the Earth and the life on it is required if vast human misery is to be avoided and our global home on this planet is not to be irretrievably mutilated" (UCS, 1992).What could be clearer? Some of the best minds on Earth were warning that without dramatic changes in humanity's relationship with the ecosphere, the lives of our descendents might well revert to being a Hobbesian "nasty, brutish, and short." But there is little evidence that the world

community has paid any heed to UCS's ecological call-to-arms. Thirteen years later the Millennium Ecosystem Assessment (MEA), the most comprehensive assessment of the state of the ecosphere ever undertaken, was moved to echo UCS: "At the heart of this assessment is a stark warning. Human activity is putting such a strain on the natural functions of the Earth that the ability of the planet's ecosystems to sustain future generations can no longer be taken for granted" (MEA, 2005).

Just what is going on here? Humans are the self-proclaimed "best evidence for intelligent life on Earth." Yet when the world's top physicists, ecologists, and climatologists warn repeatedly that current development strategies are undermining global life support systems and risking catastrophe for billions, the responses range from negligible to ineffective. True, "triple bottom-line" corporate planning is now fairly commonplace; various protocols for "green-building" compete to influence building codes; "new urbanism," "smart growth," and the ecocities movement are gaining ground everywhere; hybrid and electric vehicles are increasing their market share; and green consumerism is becoming mainstream in many developed countries—but none of this activity has made much difference (apart from fostering the illusion of progress) (Rees, 2009a). Almost all mainstream sustainability measures implicitly assume that the problem can be solved through greater material and economic efficiency and technological "fixes," ignoring the evidence that, to date, such strategies have actually *increased* the human ecofootprint.[1] Few challenge the fundamental beliefs, values, and assumptions underpinning market-based consumer societies or examine the hidden motivators of human individual or group behavior. On the contrary, all major governments and international development agencies are committed to maintaining the growth in *per capita* income that has characterized industrial countries for more than a century and to extending consumer culture to the three-quarters of the world's people who have yet to join the party (see Stutz, 2010 in this issue).[2] Efficiency gains are thus overwhelmed by a combination of material growth and the rebound effect in even the world's most efficient economies (Layke et al. 2000). With no government or mainstream international agency willing openly to contemplate, let alone articulate in public, the revolutionary policy responses evoked by our best science, the modern world remains mired in a swamp of cognitive dissonance and collective denial (Pratarelli, 2008; Pratarelli & Aragon, 2008; Rees, 2009a). Meanwhile, the loss of ecosystem integrity accelerates around the world.

Looking Ourselves in the Eye

This article's overall purpose is to advance a relatively novel partial explanation for humanity's self-destructive behavior. The framing questions are: What are the "drivers" that have created our present (un)sustainability impasse? How can we explain the gap between people's knowledge of ecological degradation and their actual behavior toward the environment (Kollmuss & Agyeman, 2002)? Why is the global community so far unable to respond proportionately to the scale of the crisis? How do the answers to the foregoing affect both individual responsibility and prospects for a genuine social transformation toward achieving sustainability?

Most analysts approach the sustainability conundrum by addressing *proximal* causes and obvious solutions. For example, the ecological crisis is said to stem from excessive energy and material consumption and ineffective regulation (with resultant high pollution loads) on the one hand, or from chronic poverty and primitive technology on the other (poor people are more concerned with basic survival and cannot afford to pay for a "clean environment"). Occasionally, population growth is identified as a driver, but only by special interest groups not concerned about political correctness. And, as noted above, greater material efficiency, more ecologically benign technologies, and continued growth (to relieve poverty and generate the resources necessary to "clean up" the "environment") remain the only politically acceptable solutions.[3] The lack of support for more determined policy is generally blamed on popular ignorance, the lack of caring, or apparent disbelief (Norgaard, 2009).

This article takes a different tack. I look more for the root or *distal* causes of unsustainable behavior and corresponding transformative solutions. In this context, the immediate questions become: Why,

[1] This counterintuitive result is known as the Jevons or "rebound" effect. Consider that efficient or technologically advanced firms are able to lower prices, gain market share, and increase wages and salaries to employees. As this phenomenon propagates through the economy, more money chasing cheaper goods and services results in increased consumption/pollution (back to where it would have been, or close, had the technological innovation not happened).

[2] Presently, the richest 20% of the world's population take home 76.6% of global income; the poorest 20% subsist on 1.5% (UNDP, 2007; Shah, 2010). As China and India move toward "developed" lifestyles, their environmental impact will become even more unsustainable than that of the West due to the huge numbers of people involved.

[3] This rationale is based on naïve interpretations of the so-called "environmental Kuznets curve"—proponents allege that environmental quality first deteriorates and then improves with rising incomes (see Stern, 2004; Richmond & Zencey, 2007), but they often fail to distinguish among pollutants or account for the offshore migration of dirty industries from rich to poorer countries.

given the opportunity, do humans tend to overconsume? How, in this age of plenty, can we explain the persistence of poverty? What drives the continuing growth of the human enterprise? I argue that we can answer these questions, and come to a fuller understanding of the modern sustainability conundrum, only if we examine them through the lens of human evolutionary biology.

The Human Nature of Unsustainability

This perspective owes much to the Russian-born geneticist Theodosius Dobzhansky (1964) who famously asserted that "nothing in biology makes sense except in the light of evolution." If we accept that *H. sapiens* is a product of evolution and that both the human brain and gene-based elements of individual/social behavior have been as much exposed to Darwinian selective pressure as any other genetically influenced human qualities, it is really not much of a leap to assert that *nothing in human affairs—including much of economic and socio-political behavior—makes sense except in the light of evolution* (Rees, 2009b).

Let me be clear. I am not arguing "genetic determinism" or that other factors do not contribute to humanity's unsustainability dilemma. Rather, I am asserting that our perception of the problem will remain unintelligibly incomplete, and our capacity to "deal" with it will be severely constrained, unless we factor in the bioevolutionary contribution.[4] If innate tendencies, including denial (Pratarelli & Aragon, 2008), play a significant role in human eco-economic behavior and we do not acknowledge their existence, we will not be able successfully to manage them. As cyberneticist Stafford Beer (1981) observed, "We cannot regulate our interaction with any aspect of reality that our model of reality does not include."[5]

It is also important to underscore that an inherited tendency or genetic predisposition is, by definition, not an inevitability. Rather, it is a *propensity* that is likely to play out in the absence of countervailing circumstances such as moral codes, cultural taboos, legal prohibitions, or other social inhibitors. For example, humans are not naturally monogamous. Many cultures have therefore invented both social and material signals (e.g., elaborate ceremonies and wedding rings) to advertise marital unions and inhibit extramarital sexual activity for the sake of community stability. The point is that even partial control of innate behaviors requires, first, that we acknowledge and raise them to consciousness so that they can, in fact, be included in "our model of reality" for "regulatory" purposes.

Hypothesis: Humans are Unsustainable by Nature

Ecologists sometimes describe nonhuman species in terms of their reproductive strategies in different types of environments (e.g., Pianka, 1970; Matthews & Kitching, 1984). Unpredictable or unstable environments select for relatively short-lived organisms with small body size, early maturity, high fecundity (capability of producing numerous offspring), and good dispersal abilities. As might be expected, such species are characterized by high juvenile mortality rates and widely fluctuating populations. Because their evolutionary success is dependent on high *potential* population growth *r*ates, such organisms are called r-strategists. Among mammals, small rodents are typically r-selected.

At the other end of the spectrum are so-called K-strategists, organisms usually associated with relatively predictable or stable ecosystems. K-strategists are typically large-bodied, long-lived and late-maturing. They generally have low reproductive and dispersal rates, but also extended parental care and thus high survival rates to maturity. The populations of K-strategists are therefore relatively stable and tend to press up against the fluctuating carrying capacities (K) of their ecosystems. Indeed, they are said to be K-selected, because their individual survival and overall evolutionary success depend on competitive superiority at high population densities under conditions of resource scarcity. Humans are clearly K-strategists, a distinction we share with other large mammals ranging from tapirs through elephants to blue whales.

What has all this to do with consumption, sustainability, and social transformation? I suggest that the failure of the sustainability project to date has much to do with the modern world's failure to face up to basic facts of human nature. My working hypothesis is that because of certain evolutionary traits, many associated with K selection, modern *H. sapiens* is biased against sustainability. Moreover, humanity's technological prowess and society's addiction to continuous material growth reinforce the biological drivers, making the problem particularly intractable. More specifically, I hypothesize that unsustainability is an inevitable emergent property of the systemic interaction between contemporary technoindustrial society and the ecosphere. Both genetic and sociocultural factors contribute to the conundrum (Rees, 2009b).

[4] For similar arguments in the context of reforming economics, see Gual & Norgaard (2010) and Waring (2010).

[5] Beer's observation recalls Ashby's (1957) law of requisite variety, which can be stated as follows: The variety (number of possible system states) of an effective regulatory system must be equivalent to the variety of the system it regulates.

The Biological "Presets"

As an evolved species, *H. sapiens* shares basic reproductive and survival traits with all other species. Most importantly, experiments with organisms ranging from bacteria cultured in Petri dishes to reindeer introduced to previously uninhabited islands reveal the following universal properties of life: unless or until constrained by negative feedback (e.g., disease, starvation, self-pollution), all species' populations expand into all accessible habitats and use all available resources (where, in the case of humans, "available" is determined by the state of technology).[6]

Moreover, in the competition for habitat and resources characteristic of K-selected species, natural selection favors those individuals who are most adept at satisfying their short-term selfish needs whether by strictly competitive or through in-group cooperative means (see Pratarelli, 2008).[7] That is, individuals strongly predisposed to "instant gratification" may enjoy a selective advantage over individuals who are less aggressive in expressing their material demands. Humanity's well-known tendency to discount the future—as incorporated into most economic planning models—has almost certainly evolved by natural selection.

In the course of evolution, humans have had to compete, not only with other people, but also with other consumer species for food and habitat. And who can doubt that humans have prevailed in the competition? *H. sapiens*' capacity for growth and domination "vastly outstrip those of all other species" (Waring, 2010). Is there any sizable patch of habitable landscape on Earth that has not been claimed and occupied by *H. sapiens?* Our species has the greatest geographic range of any ecologically comparable species—we have occupied the entire planet. And imagine the territorial dispute that would ensue if, miraculously, we were to discover some resource-rich continent long lost in the vastness of the Pacific Ocean. It is a safe bet that the conflict would not be over how best to conserve and protect the new find in its pristine state. Consider the international response to disappearing sea ice in the Arctic Ocean. A fully rational species might react with alarm and redoubled efforts to negotiate a climate change-mitigation treaty. Instead, circumpolar nations trip over each other as they compete to claim the newly exposed resource endowment of the ocean floor, including more of the petroleum and natural gas that are the source of the problem in the first place! (Gamble, 2009).

This is actually the typical human response to any resource trove. Fowler & Hobbs (2003) show that in terms of energy use (and therefore carbon-dioxide emissions), biomass consumption, and various other ecologically significant indicators, human demands on their ecosystems dwarf those of similar species by ten or a hundredfold. Human consumption of biomass, for example, exceeds the upper 95% confidence limits for biomass ingestion by 95 other non-human mammal species by two orders of magnitude. These and related data show that *H. sapiens* has become, directly or indirectly, the dominant macroconsumer in all major terrestrial and accessible marine ecosystems on the planet.[8] Indeed, our species may well be the most voraciously successful predatory and herbivorous vertebrate ever to walk the Earth (Rees, 2009b).

There is, however, a compound problem. First, despite material abundance, humans' innate competitive drive as K-strategists seems relentless. We do not have a built-in "off" switch that is tripped by sufficiency (see Princen, 2010 in this issue).[9] Indeed, we habituate to any level of consumption (once a given level is attained, satisfaction quickly diminishes) so the tendency to consume and accumulate ratchets up. This is particularly so if we perceive that another social group—or country—is "getting ahead" faster than we are. Even within wealthy societies, widening income gaps lead to personal frustration and declining population health (Wilkinson, 1996), so efforts to "keep up with the Joneses" continue unabated.

Second, humanity's technological capacity to exploit nature now exceeds nature's regenerative capacity. Even as fish stocks decline, we both invent new fish-finding technologies to chase remaining schools further and deeper and switch to alternative prey species lower in the food web. To reiterate: like other species, humans tend to use up available resources, a trait that is constantly enhanced by evolving technology.

The combined result of these forces is a defining feature of much so-called resource management, particularly common pool assets: "While there is considerable variation in detail, there is remarkable consistency in the history of resource exploitation: resources are inevitably overexploited, often to the

[6] Deep sea drilling for petroleum is an example of a technology in pursuit of the last deposits of "available" resources. The 2010 blowout at BP's well in the Gulf of Mexico underscores the increasing risk associated with exploitation at the technological frontier.

[7] Within-group (e.g., family, tribe, or nation) cooperative behavior can increase between-group competitive success.

[8] Ironically, economists and other technological optimists argue falsely from monetary analyses that the human enterprise is "dematerializing" or "decoupling" from nature.

[9] It does not help matters that we have "socially constructed" consumerism as our preferred way of life.

point of collapse or extinction" (Ludwig et al. 1993).[10]

Sociocultural Reinforcement

Humans are not only biological entities, but also social and cultural beings. Much of the basis for human evolutionary success is thus derived from species attributes that are largely sociocultural in origin. The major means by which the products of "nurture" accumulate include written language and humans' unmatched capacity for social learning.

It is appropriate at this point to evoke the concept of the "meme" as first introduced by evolutionary biologist Richard Dawkins (1976). A meme is a unit of cultural information that, like a gene, can be passed between generations and that influences the "phenotype"—the outward appearance or expression—of the society concerned. Memes are the basis of cultural inheritance and include persistent beliefs, entrenched assumptions, and prevailing values, as well as scientific concepts and working technologies.

Memes have a significant "evolutionary" advantage over genes in that they can spread horizontally among living individuals in the *same* generation or population. Cultural evolution is therefore much faster than genetic evolution and is actually accelerating (as evidenced by humanity's ever-accumulating technological toolkit). Clearly, adaptive memes or meme complexes endow *H. sapiens* with a powerful "leg up" in the Darwinian struggle for existence.[11]

Note that people acquire much of their memetic endowment passively, simply by growing up in a particular culture and being exposed to various social contexts, including school, religious institutions, workplaces, and the family home. The key point is that, once acquired, such "cultural programming" (like genetic programming), asserts considerable, often subconscious, influence over both individual and group behavior (Wexler, 2006).

With this in mind, let us consider a particularly powerful "meme complex" whose effect is to *reinforce* humanity's K-selected expansionist tendencies. I submit that most of the world today is in the thrall of a grand, socially constructed vision of global development and poverty alleviation centered on unlimited economic expansion fueled by open markets and more liberalized trade (Rees, 2002). This mythic construct springs from the demonstrably flawed assumption that human well being derives from perpetual income growth, yet it has shaped and distorted the lives of more people than any other cultural narrative in all of history.[12] It has also lodged itself in the heart of the (un)sustainability conundrum.

Allegiance to perpetual growth has actually taken hold in a remarkably short period of time and is still propagating into the developing world. It is true that previous cultures experienced slow growth and development (ultimately followed by collapse) (Tainter, 1988). But only eight or ten generations of people have experienced sufficient economic growth or related technological change in their lifetimes to notice it, and certainly the fourfold increase in human numbers to six billion in the twentieth century is completely unprecedented. In effect, 99.9% of human history has been no-growth history (see Stutz, 2010 in this issue).

As an *influential* memetic construct, the growth imperative is actually only *two* generations old. It was only in the 1950s that economic growth emerged from nowhere to become the "supreme overriding objective of policy" in many countries around the world (Arndt, 1978).

Again, the problem for sustainability is that the perpetual growth myth knows no ecological bounds. Mainstream academic models of the economy make no functional reference to the ecosystems that contain it. Collateral damage to "the environment" is considered to be a mere "negative externality" that can be corrected by appropriate pricing (e.g., pollution charges or taxes). Resource shortages? No matter—we can relieve local shortages through trade, and should the problem be more widespread, we play the technology card—the expansionist myth asserts that human ingenuity will find a substitute for any depleting resource. As the late Julian Simon (1995) was fond of stating:

> Technology exists now to produce in virtually inexhaustible quantities just about all the products made by nature…We have in our hands now…the technology to feed, clothe and supply energy to an ever-growing population for the next seven billion years.

Simon's assertion is so arithmetically challenged that it should be dismissed out of hand.[13] Neverthe-

[10] Not only do people deplete *real* natural resources, they create *virtual* resources—bank loans and credit cards for example—and use these to capacity as well.

[11] A "meme complex" is an internally consistent set of conceptually related, mutually reinforcing memes.

[12] There is actually a second layer of nature-nurture interaction at play here. Humans are genetically predisposed to storytelling. The social construction of (perceived) reality, including disciplinary paradigms, political ideologies, and cultural myths is a universal property of human societies (Grant, 1998). While the tendency to mythmaking is yet another vessel cast from our genes, what we put into it is determined by sociocultural context.

[13] When challenged on this statement, Simon backed down, stating that the text should have read "for the next seven million years," a

less, true believers in the expansionist myth have helped boost the human enterprise beyond long-term global carrying capacity.

Beyond Carrying Capacity: The Ecofootprints of Technoexuberance

Evidence for humanity's culturally amplified success as a K-strategist is clearly revealed by ecological footprint analysis (EFA) (Wackernagel & Rees, 1996; Rees, 2006; 2008; WWF, 2008). The EFA is based on material consumption and waste production. For any specified population, EFA estimates the exclusive area of productive land and water ecosystems required to produce the resources that the population consumes and to assimilate some of its wastes.

Since consumption reflects income, national per capita ecofootprints are strongly correlated with gross domestic product (GDP) per capita. Thus, the citizens of rich countries need in the range of four to ten global average hectares (gha) (10 to 25 acres) *per capita* to support their lifestyles while the poor get by on less than half a hectare (one acre). The EFA thus graphically translates socioeconomic inequity into biophysical terms.

Ecofootprinting is a uniquely powerful sustainability indicator. Unlike monetary measures such as GDP per capita that have no theoretical limits, ecofootprints can be compared to finite supplies. For example, EFA shows that densely-populated rich countries such as the UK, the Netherlands, Germany, and Japan have ecofootprints several times larger than their domestic productive land-water areas. Even the much more sparsely populated United States is living beyond its ecological means (see WWF, 2008). All such countries have long exceeded their domestic carrying capacities and are running *ecological deficits* with the rest of the world—poor countries, relatively low-density countries like Canada, and the global commons.

Most critically, the global average citizen has an ecofootprint of about 2.7 gha, while there are only about two hectares of bioproductive land/water per capita on Earth (WWF, 2008). In other words, the total human ecofootprint already exceeds global human carrying capacity by over 30%. Humanity is in a state of "overshoot" living, in part, by depleting accumulated stocks of "natural capital" (e.g., fish, forests, and soil) and degrading critical ecosystems.[14]

These data reveal the dangerous futility of the world's present growth-based approach to global "development," especially poverty alleviation. The consumer lifestyles of the wealthy cannot be extended sustainably to the poor using currently available technologies (see Stutz, 2010 in this issue). To sustain just the present world population at North American, material standards (EF = 9.2 gha) would require the equivalent of three to four additional Earth-like planets (and we have yet to account for the additional 2.5 billion people expected by midcentury). By depleting natural capital and eroding life-support systems, continued material growth undermines the future of global civilization.

Reason, Emotion, and Instinct: Understanding the Triune Brain

So far, I have argued that human behavior is influenced by subconscious predispositions. However, this does not explain why *H. sapiens*' defining intelligence (i.e., the capacity for abstract reasoning, for logical thought processes) seems to play so small a role in our collective response to escalating global change. Here, I suggest that at least part of the reason resides in the incomplete evolution of human consciousness—*H. sapiens* is very much a work in progress.

Consider an evolutionary vector that begins with totally subconscious, autonomic, or instinctive behavior and leads ultimately to actions based all but entirely on conscious awareness, logical analysis, and free will. Humans like to think that we have arrived at the *free will* end of this spectrum, but much of modern cognitive science suggests that this is largely illusion. Psychologist Robert Povine argues from the available evidence that the starting assumption in behavioral psychology should be "that consciousness doesn't play a role in human behavior. This is the conservative position that makes the fewest assumptions" (cited in Buchanan, 2007).

The material basis for the gradient of consciousness is that most complex of evolved organs, the human brain. Neurologist Paul MacLean (1990) argues that the human brain has actually evolved in at least three broadly overlapping phases, each with its own anatomical subcomponent having distinct functions, memory, and "intelligence." MacLean refers to the three quasi-independent structures of the human brain as the reptilian or R-complex (the brainstem and ce-

major concession indeed. Even so, physicist Albert Bartlett (1998) showed that, starting from the 1995 population of 5.7 billion people, growing at just 1% per year, the human population after "only" seven million years would be 2.3×10^{30410}. This is an unimaginably large number, something like "thirty-thousand orders of magnitude larger than the number of atoms estimated to be in the known universe!"

[14] Eventually, of course, remaining biocapacity will be insufficient to support prevailing population and consumption levels, so the entire system must decline or crash.

Box 1 Elements and functions of the "Triune Brain" (MacLean, 1990).

- The *reptilian complex* is concerned with autonomic functions associated with the body's physical survival (e.g., circulation and breathing). It also influences instinctive social behavior (e.g., pertaining to territoriality, social stature, mating and dominance, and other qualities subject to K-selection), executes the fight or flight response, and controls other mainly hard-wired ritualistic or instinctive behaviors.
- The *limbic system* is the primary seat of emotions (e.g., happiness, sorrow, pleasure, pain), personal identity and related behavioral responses (e.g., sexual behavior, play, emotional bonding, separation calls, fighting, fleeing). It also houses our affective (emotion-charged) memories and seems to be the seat of value judgments and informed intuition.
- The *neocortex,* or "rational brain," is the most evolutionarily recent, but occupies over two-thirds of the human brain by volume. The neocortex is responsible for the higher cognitive functions that distinguish humans from other mammals; it is the seat of consciousness and the locus of abstract thought, reason, and logic. It makes us uniquely capable of moral judgment and forward planning. The neocortex also facilitates language, speech, and writing and, with these, the very possibility of civilization.

rebellum); the limbic or paleomammalian system; and the neocortex or neomammalian brain. These three sub-brains are concerned with basic survival instincts, emotions/value judgments, and conscious logical reasoning respectively (see Box 1). While some critics argue that MacLean's model oversimplifies the evolution and anatomy of the human brain, neurological research supports his general theory (Panksepp, 1998; Ellis et al. 2009).

Whatever the human brain's evolutionary details, and however localized its macrofunctions might be, the healthy brain generally acts as an integrated whole—the various components that express instinct, emotion, and reason are intricately interconnected, each continuously influencing the others (e.g., emotion stimulates thought and thinking may trigger emotion). This means that the individual's emergent behavior and overall personality is the blended product of diverse thoughts, emotions, and instincts. Critically, however, there will periodically be circumstances in which one of the sub-brains, with its distinct capacities and limitations, assumes dominance—*and the individual involved may not be fully aware of what part of the brain is in control.*

This last point is particularly important in the context of (un)sustainability. Humans think of themselves as exemplars of conscious self-awareness—after all, we "live" in consciousness conferred by the human neocortex. It seems, however, that we greatly overestimate the role of mindful intelligence while remaining paradoxically unaware of unconscious influences over individual and group behavior that spring from the lower brain centers. Intelligence and reason may not be the primary determinants of human behavior at any social scale. Indeed, the circumstances in which reason and logic dominate our actions may actually be quite limited and their effect relatively trivial in the grand evolutionary context.

The situation implies that much of expressed human behavior, from routine one-on-one social interaction to international political posturing, is shaped, at least in part, by subconscious mental processes and their associated chemical/hormonal agents. These subconscious processes include the innate propensities that qualify *H. sapiens* as a dogged K-strategist in the competition for resources and habitat. The problem for sustainability is that "[b]iological drives…can be pernicious to rational decision-making in certain circumstances by creating an overriding bias against objective facts" (Damasio, 1994).

Everyone is aware from personal experience that passion will trump reason in shaping one's responses to emotionally charged or life-threatening encounters. Indeed, we often do foolish or regrettable things simply to enhance our social status or maintain our self-esteem. Most importantly, in situations of conflict or resource scarcity—situations that will become increasingly frequent and severe in the international arena—basic survival-oriented bio-behavioral predispositions that operate beneath consciousness (i.e., in the limbic system and reptilian brain stem) may well override rational thought processes. This tendency may be particularly evident among political leaders. In addition to being innately loyal to their tribes and psychologically hard-wired to their political ideologies, politicians may be more than usually enslaved to brainstem-based survival instincts, particularly the deep-seated need to retain their wealth, prestige, and political power.

The key point is that *humanity is a deeply conflicted species*. We are torn, on the one hand, between what reason and moral judgment say we should do and what pure emotion and baser instincts compel us to do, particularly in stressful circumstances. As Damasio (1994) explains, "There are indeed potions in our own bodies and brains capable of forcing on us behaviors that we may or may not be able to suppress by strong resolution." The neocortex, the seat of reason and logic, is a relatively late arrival on the evolutionary stage and does not always play a commanding role. In this light, it would be folly to assume that either individuals or society, especially *global* society, will necessarily deal rationally with evidence for accelerating global ecological change.

Toward Resolution: Can Humanity Become Sustainable?

> [For humanity to survive the sustainability crisis] we must rely on highly-evolved genetically-based biological mechanisms, as well as on suprainstinctual survival strategies that have developed in society, are transmitted by culture, and require for their application, consciousness, reasoned deliberation and willpower (Damasio, 1994).

H. sapiens is clearly the highly successful product of millions of years of K-selection, but evidence is mounting that something has gone awry. Ironically, it is precisely humanity's evolutionary success that has generated our current unsustainable state. The innate behavioral traits that assured the competitive supremacy and long-term survival of primitive peoples—e.g., the tendency to act on short-term individual (and tribal) self-interest, to discount the future, and to adhere to successful mythic constructs—have become maladaptive on a finite planet in the much changed circumstances *created by the expanding human enterprise itself*. Matters are complicated by the fact that our dominant cultural narrative, the growth-based progress myth, reinforces our now disadvantageous behavioral predispositions.

Human societies have always coexisted, indeed, coevolved with the ecosystems that sustain them (Gual & Norgaard, 2010). But human population growth, increasing material demands, and negative technological impacts are now conspiring in ways that reduce the "fitness" of industrialized countries and, indeed, of our increasingly integrated global socioecosystem. A concise Darwinian portent of the potential outcome is that *both bad genes and inappropriate memes may well be "selected out" by the rapidly changing ecosphere*.

Many thoughtful people do understand our biophysical circumstances, appreciate the ravages of inequity, acknowledge wealthy countries' ethical responsibility to the poor, and agree that the problem cannot be solved through material growth. However, humanity's collective response is not consistent with either our best science or the moral imperative. As noted at the outset, most sustainability campaigns, corporate responses, and government policies emphasize "simple and painless" (read "marginal and ineffective") actions that require only modest adjustments to personal lifestyles and none at all to the economic growth ethic or other key beliefs, values, and assumptions of technoindustrial society (Thøgersen & Crompton, 2009). Green consumerism may make people feel good, but it is still consumerism and its modest gains are nullified by the Jevons effect. Meanwhile, the world community is doing nothing significant to address inequity directly. According to Pratarelli & Aragon (2008), whenever there is clear acknowledgment of a dire problem, yet no volition to address it, we witness a "form of universal human behavior we will label denial or self-deception."

The inevitable result in the present context is an accelerating global growth dynamic whose benefits and costs are grossly inequitably distributed. The rich get predictably richer while billions of people—half the human family—remain malnourished and materially deprived. Meanwhile, resource consumption and waste production *per capita* are still rising (even in the richest and most efficient wealthy economies), ecosystems are collapsing, and the income gap is still widening. It is increasingly plausible that the total social costs of growth (many of which go unaccounted) now exceed the measurable benefits. If so, the world has entered an era of uneconomic growth, growth that impoverishes (see Daly, 1999; Siegel, 2006).

Can We Reframe the Future?

> [M]an today is in flight from thinking.
> —*Martin Heidegger, 2003 [1955]*

The much-hyped quest for sustainability has failed to date in part because the global community is in collective denial of reality.[15] Assuming our best science is correct, the only certain way to address poverty while avoiding irreversible overshoot and "irretrievably mutilating" our planetary home is to rejig the growth machine and to implement a world program for income/wealth redistribution. Some movement toward income equalization is necessary because, apart from being morally reprehensible, gross income disparity will eventually lead to social unrest—possibly geopolitical chaos—thus making the achievement of ecosustainability impossible.

This is not entirely a novel proposal. As early as 1993, a workshop report by the Business Council for Sustainable Development (now the World Business Council for Sustainable Development) concluded that "[i]ndustrialised world reductions in material throughput, energy use, and environmental degradation of over 90% will be required by 2040 to meet the needs of a growing world population fairly within the planet's ecological means" (BCSD, 1993) (note the

[15] Hundreds of well-funded "climate-change denial" and other contrarian organizations and websites have emerged in recent years, swelling the ranks of those unwilling to accept the basic science. However, this is only part of the denial—even those who accept climate change resist making necessary changes.

concessions to both gross carrying capacity and global equity). Similarly, mainstream climate scientists agree that the world should be aiming for a 50%-80% reduction in carbon-dioxide emissions below 1990 levels by 2050 to avoid dangerous climate change. One recent study specifically argues that to avoid reaching a catastrophic greenhouse-gas level of 650 parts per million by volume of carbon-dioxide equivalents (ppmv CO_2e), the affluent nations will soon have to begin decarbonizing at the "draconian" rate of 6% per year, likely requiring a "planned economic recession" (Anderson & Bows, 2008). Finally, ecological footprint studies suggest that if North Americans were serious about achieving global sustainability they would be planning to reduce their ecological footprints by 77% (from 9.2 gha to their equitable Earth share of 2.1 gha). All such measures would ease pressures on the ecosphere while creating the "ecological space" required for justifiable growth in the developing world (Rees, 2008).

Fortunately, tools are available to ease the transition should we muster the will to attempt it. For example, with the right incentives, available technology could enable an 80% reduction in energy and (some) forms of material consumption without substantially affecting standards of living (von Weizsäcker et al. 2010). Even more important, it is increasingly clear that the present material standards of high-income countries may actually not be worth defending. Evidence is growing that greater income/consumption no longer contributes to objective indicators of population health or to subjective well being in affluent countries (Myers & Diener, 1995; Lane, 2000; Siegel, 2006). Indeed, with the right policies, wealthy countries could make the necessary deep cuts in material and energy use in ways that would actually *enhance* their citizens' quality of life (Siegel, 2006; Victor, 2008; Jackson 2009).[16] Existing policies that privilege the wealthy and increase inequity, even in rich countries, actually undermine population health and felt well being (Wilkinson, 1996; Wilkinson & Pickett, 2009).

It is commonly argued that in every crisis is opportunity. The (un)sustainability crisis thus provides the world community with the unique privilege of intentionally scripting a new, ecologically adaptive, economically viable, and socially equitable cultural narrative (see Wilk, 2010 in this issue). The rate of biological evolution may be fixed, but there is nothing to prevent us from assuming conscious control over the pace—and content—of cultural evolution.

Certainly, we have reached a crucial juncture in human evolutionary history. On a crowded planet facing an ecological crisis and overstocked with nuclear weapons, *short-term individual and "tribal" interests have all but converged with humanity's long-term collective interests*. Ecological and social selection pressures have thus dramatically shifted. In today's tinderbox world, genes and ideology that effectively urge "every man for himself!" might well mean destruction for all. In these circumstances, long-term selective advantage may well have shifted to genes and memes that reinforce cooperative behavior, even mutual altruism.[17]

Fortuitously (and although they are completely ignored by mainstream economic theory), other-regarding emotions such as compassion, empathy, love, and altruism are key components of the human behavioral repertoire (Manner & Gowdy, 2010). The central question is whether we can muster the national and international political will required purposefully to create a set of "memetic mutations" that reinforce these natural "other-regarding" feelings (both for other people and other species). A useful analogy underscores the potential here. The field of "epigenetics" recognizes that particular qualities of the biophysical environment can enhance or suppress the phenotypic expression of various gene functions without affecting the underlying DNA sequencing (see Qiu, 2006; Talbott, 2010). Similarly, qualities of the sociocultural environment (e.g., various forms of peer pressure) can encourage the expression of desirable social behaviors and suppress those that have become situationally maladaptive. In present circumstances, the global community should therefore consciously exploit the potential of *social* epigenetics as a tool in the quest for sustainability. It is time to create or reinforce cultural memes that can put the potential of social engineering to beneficial use.[18]

[16] We need comprehensive programs involving tax and related fiscal incentives to induce the development and use of more efficient technologies and encourage greater investment in public infrastructure. These measures would be combined with social programs for greater income equity, shared work, shorter work weeks, enhanced leisure, and investment in social capital (as a substitute for personal consumption). The overall goal would be both to increase economic security and to create greater ecological stability.

[17] There is a counter view. It holds that some people—most likely among the rich and militarily powerful—would survive any human-induced apocalypse. Should this argument prevail, ancient self-interested intelligence of the reptilian complex and limbic system will have won out (but it will not be a pretty sight).

[18] A program of planned social engineering will seem repugnant to some people. However, we should recognize that all forms of socialization are, in effect, "social engineering," including today's misplaced affection for the market as the primary instrument of social and economic policy. Note, too, that for several decades the fields of public relations and advertising have deliberately used "the social construction of reality" to create the consumer culture, to convert active citizens into passive consuming cogs that serve the industrial machine. In short, the present generation represents the largest and arguably most successful experiment in social engineering ever conducted.

Survival 2100

In a more rational world, political leaders faced with today's problems would probably assemble in a special forum specifically to renounce the failing global growth paradigm and to formally declare the need for a worldwide "Survival 2100" project. They might even acknowledge the complex origins of maladaptive intergroup behaviors that have long been the bane of civilization (the twentieth century was the bloodiest in history). Humanity must specifically confront once-adaptive genetic predispositions that have become hazardous on a crowded planet and abandon the socially constructed memes that reinforce them.

It is true that people can be individualistic, unfeeling, and selfish. But, as noted above, they are also capable of social engagement, compassion, and generosity of spirit. While the former qualities reflect the dumber instincts of primitive K-strategists, the latter must come to prevail in support of collective survival in an ecologically full world. Again, the key is to recognize that while all these colors can be found in the full spectrum of human behavior, *society can make deliberate choices about which tints and shadings to emphasize* in the creation of its cultural narratives.

Certainly, achieving ecological stability and economic security for all will require unprecedented heights of international cooperation in service of the common good. To reduce the human ecofootprint, the fetishistic emphasis in free-market capitalist societies on individualism, competition, greed, and accumulation must be replaced by a renewed sense of community, cooperative relationships, generosity, and a sense of sufficiency; short-term material wants must give way to long-term basic needs.

"Survival 2100" would thus explicitly acknowledge the myopic futility of a global "development" model based on perpetual growth on a finite planet. We need an economy oriented toward greater material equity and true development (getting qualitatively better) rather than efficiency and mere untargeted growth (getting quantitatively bigger). The ultimate goal would be the creation of a dynamic, more equitable steady-state economy serving the entire human family within the means of nature.[19]

The absolute reduction of material and energy consumption globally would obviously be a critical material objective of "Survival 2100." (As noted above, this will involve "contraction" by the wealthy to free up the biocapacity—resource stocks and waste sinks—required to support morally justifiable material growth in poor countries.) However, reduced gross energy and material throughput is, in itself, insufficient for sustainability. "Survival 2100" would also emphasize global population reduction. No other action program would generate higher returns for the planet per dollar invested. The ecosphere simply could not sustain increasing material standards for the poor if world population continues to increase.

How would the program be implemented? It should already be obvious that "Survival 2100" would require a variety of new transnational institutions, including treaties and accords designed to reduce the population, reverse ecological decline, restore essential natural capital stocks, regulate trade, and generally create the framework for a global steady-state economy. It will also need new agencies to implement, monitor, and enforce these yet to be written treaties.

Success in "Survival 2100" could put the human enterprise and nature—the global socioecosystem—on a new, adaptive, mutually beneficial coevolutionary path. However, there are plenty of thorns and potholes along the way. The required unprecedented level of mutual trust among nations and the loss of some national sovereignty represents two such major stumbling blocks.[20] Consider, too, the difficulty associated with just one probably necessary sustainability tool—a global system of ecological tax reform (e.g., global carbon taxation or "cap-and-trade" scheme for various critical resources) designed to ensure the true cost pricing of ecologically significant goods and services. Unsustainability may be the greatest example of market failure, but corrective measures that involve significant government intervention in the economy would undoubtedly provoke strident resistance from a world "socially engineered" to worship the market god and to view government—particularly international government—as the devil incarnate.

Inevitable Pushback

Indeed, it would be naïve to think that any attempt to articulate a new sustainability-oriented cultural narrative would not be met by strenuous pushback. We have already shown how reluctant society is to respond consistently to evidence that the world is on a collision course with biophysical reality. Few people opt for "voluntarily simplicity" or decline unnecessary salary increases; unions rarely bargain for decreased wages and benefits. "Contraction" is

[19] "Steady-state" implies a more or less constant rate of energy and material throughput compatible with the productive and assimilative capacities of the ecosphere (Daly, 1991). However, this does not imply stagnation. Scientific progress and artistic endeavors would be unaffected and some economic sectors would be growing and developing even as obsolete "sunset" industries are being phased out.

[20] Conceivably, global goals and national targets could be set by transnational accord but implemented by individual nation states. This might overcome some of the objection to loss of sovereignty.

simply not a narrative that resonates with the times. On the contrary, most people are psychologically committed to continuous economic growth, the illusion of ever-increasing material prosperity, and the myth of progress (see Princen, 2010 in this issue). Powerful and privileged elites, those with the greatest personal stake in the status quo, control the policy levers that are steering us onto the ecological rocks.

The means by which people become so deeply committed to particular beliefs has only recently been revealed. Neurobiologists and cognitive scientists are showing that cultural norms, beliefs, and values can effectively be imprinted on the human brain (Wexler, 2006). (A mechanism for social epigenetics?) In the normal course of individual development and maturation, repeated social, cultural, and sensory "inputs" actually help to imprint the individual's synaptic circuitry in neural images of those experiences. Once entrenched, these neural structures alter the individual's perception of subsequent experiences and information. People tend to seek out experiences that reinforce their preset neural circuitry and to select information from their environment that matches these structures. Conversely, "when faced with information that does not agree with their internal structures, they deny, discredit, reinterpret, or forget that information" (Wexler, 2006) (i.e., denial has a neurological basis).

Clearly, then, restructuring the world will not be a simple matter of applied logic. We witnessed President Barack Obama's "cap-and-trade" approach to climate change be whittled to ineffectiveness by various special interests in its passage through Congress and then ultimately defeated. The oil industry openly supported "public" protests of the legislation that would limit emissions and require permits to pollute (Krauss & Mouawad, 2009). Worse, some public meetings on healthcare reform in the United States attracted angry opponents openly carrying weapons. Such belligerent and intimidating displays of emotion abolish all logic, destroying the opportunity for the necessary informed discourse on critical social change.[21]

The lesson here is that any attempt to engineer a social transition must confront the fact that humans are naturally behaviorally conservative. We are indeed creatures of habit. Once an individual's synaptic pathways and associated behaviors are well entrenched, it is difficult for that person to adapt to significant changes in either the sociocultural or biophysical environments. To re-establish cognitive consonance between programmed perceptions and new environmental realities requires that the affected parties engage in the willful restructuring of their own neural pathways and associated belief systems. This requires conscious effort and will not always be successful. Even when people accept that such "reprogramming" is necessary, the process can be lengthy, difficult, and unpredictable (Wexler, 2006). That said, the human brain, even when damaged, has proved to be remarkably plastic and responsive to determined effort (e.g., Doidge, 2007).

It seems to boil down to this: Modern society has been paralyzed by deep-seated cognitive dissonance, collective denial, and political inertia in dealing with the unsustainability conundrum. The problem has roots in both innate behaviors and socially constructed beliefs that seem literally to program the brain. What individuals hear and pay attention to (or ignore) can thus be understood only within the context of both social norms and the broader political-economic environment (Norgaard, 2009).

Mere information, including scientific analysis of a problem, is generally not enough to stimulate policy reform or effective action. However, assuming a sufficient level of fear, international agreement on the nature of the problem, general commitment to a collective solution, unprecedented political will, and the creative engagement of modern communication technologies, the world community could theoretically *choose* to educate the next generation from scratch in a whole new sociocultural paradigm for survival. This new narrative is essential to override humanity's now maladaptive expansionist tendencies and to enhance other behaviors and predispositions regarding our present cultural fitness. It is even conceivable that cooperative action at the highest levels through something like the "Survival 2100" project would inscribe the new narrative on the resistant psyches of the present generation. Arguably, success in this endeavor is the only way to bring global sustainability within our grasp.

Of course, for the many reasons presented earlier in this article, there is only an infinitesimal probability that anything like "Survival 2100" will actually be initiated. Nevertheless, the effort to bring it forth is worth the potential reward. By achieving a planned sustainability, humanity, that wondrous "work in progress," would gain an opportunity to pull itself up another rung on the bioevolutionary ladder, one in which collaborative, reasoned intelligence plays a larger role in moderating maladaptive emotion and instinct.

[21] In August, 2009, a colleague informed me that during his presentation to a healthcare forum in the United States "a local contractor shouted his readiness to shoot the President. He threatened to beat me. No one recoiled in horror. Another defeated political candidate instructed me that this was 'free speech.' These symptoms are being manifest everywhere in the country" (Mikulecky, 2009).

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References

Anderson, K. & Bows, A. 2008. Reframing the climate change challenge in light of post-2000 emission trends. *Philosophical Transactions of the Royal Society A* 366(1882):3863–3882.

Arndt, H. 1978. *The Rise and Fall of Economic Growth: A Study in Contemporary Thought*. Melbourne: Longman Cheshire.

Ashby, W. 1957. *An Introduction to Cybernetics*. London: Chapman and Hall.

Bartlett, A. 1998. The New Flat Earth Society. http://www.albartlett.org/articles/art1998jan.html. August 10, 2010.

Beer, S. 1981. I said, you are Gods. *Teilhard Review* 15(3):1–33.

Buchanan, M. 2007. What made you read this? *New Scientist* 195 (2611):36–39.

Business Council for Sustainable Development (BCSD). 1993. *Getting Eco-Efficient*. Report of the BCSD First Antwerp Eco-Efficiency Workshop, November. Geneva: BCSD.

Daly, H. 1991. *Steady-State Economics.* Washington, DC: Island Press.

Daly, H. 1999. *Ecological Economics and the Ecology of Economics*. Northampton, MA: Edward Elgar.

Damasio, A. 1994. *Descartes' Error: Emotion, Reason and the Human Brain*. New York: Avon.

Dawkins, R. 1976. *The Selfish Gene*. New York: Oxford University Press.

Dobzhansky, T. 1964. Biology, molecular and organismic. *American Zoologist* 4(4):443–452.

Doidge, N. 2007. *The Brain that Changes Itself*. New York: Viking.

Ellis, A., Abrams, M., & Abrams, L. 2009. *Personality Theories: Critical Perspectives*. Thousand Oaks, CA: Sage.

Fowler, C. & Hobbs, L. 2003. Is humanity sustainable? *Proceedings of the Royal Society of London B* 270(1533):2579–2583.

Gamble, J. 2009. Arctic landgrab. *Scientific American* 19(1):58–63.

Grant, C. 1998. *Myths We Live By*. Ottawa: University of Ottawa Press.

Gual, M. & Norgaard, R. 2010. Bridging ecological and social systems coevolution: a review and proposal. *Ecological Economics* 69(4):707–717.

Heidegger, M. 2003 [1955]. *Martin Heidegger: Philosophical and Political Writings* (trans. J. Anderson & E. Freund). New York: Continuum International.

Jackson, T. 2009. *Prosperity Without Growth? The Transition to a Sustainable Economy*. London: Sustainable Development Commission. http://www.sd-commission.org.uk/publications/downloads/prosperity_without_growth_report.pdf.

Kollmuss, A. & Agyeman, J. 2002. Mind the gap: why do people act environmentally and what are the barriers to pro-environmental behavior? *Environmental Education Research* 8(3):239–260.

Krauss, C. & Mouawad, J. 2009. Oil industry backs protests of emissions bill. *The New York Times* August 19:B1.

Lane, R. 2000. *The Loss of Happiness in Market Democracies*. New Haven, CT: Yale University Press.

Layke, C., Matthews, E., Amann, C., Bringezu, S., Fischer-Kowalski, M., Hüttler, W., Kleijn, R., Moriguchi, Y., Rodenburg, E., Rogich, D., Schandl, H., Schütz, H., van der Voet, E., & Weisz, H. 2000. *The Weight of Nations: Material Outflows from Industrialized Economies.* Washington, DC: World Resources Institute. http://pdf.wri.org/weight_of_nations.pdf.

Ludwig, D., Walters, C., & Hilborn, R. 1993. Uncertainty, resource exploitation, and conservation: lessons from history. *Science* 260(5104):17–36.

MacLean, P. 1990. *The Triune Brain in Evolution: Role in Paleocerebral Functions*. New York: Plenum Press.

Manner, M. & Gowdy, J. 2010. The evolution of social and moral behavior: evolutionary insights for public policy. *Ecological Economics* 69(4):753–761.

Matthews, E. & Kitching, R. 1984. *Insect Ecology*. Brisbane: University of Queensland Press.

Mikulecky, D. 2009. Personal Communication., Center for the Study of Biological Complexity, Virginia Commonwealth University. August 19.

Millennium Ecosystem Assessment (MEA). 2005. *Living Beyond Our Means: Natural Assets and Human Well-Being*. Statement from the Board. MEA. http://www.maweb.org/documents/document.429.aspx.pdf.

Myers, D. & Diener, E. 1995. Who is happy? *Psychological Science* 6(1):10–19.

Nikiforuk, A. 2006. At war with our planet. *The Globe and Mail (Toronto)* March 4.

Norgaard, K. 2009. *Cognitive and Behavioral Challenges in Responding to Climate Change*. Policy Research Working Paper Series No. 4940. Washington, DC: World Bank.

Panksepp, J. 1998. *Affective Neuroscience*. New York: Oxford University Press.

Pianka, E. 1970. On r- and K-Selection. *American Naturalist* 104(939):592–597.

Pratarelli, M. 2008. *Myopic Man: On the Nature and Universality of Self-Deception and its Long-Term Effects on Our Environment.* Beulah, CO: Medici Publishing.

Pratarelli, M. & Aragon, C. 2008. Acknowledging the "primitive origins of human ecological dysfunction:" a view toward efficacy and global ecological integrity. *Globalization* 8(1):1–17.

Princen, T. 2010. Speaking of sustainability: the potential of metaphor. *Sustainability: Science, Practice, & Policy* 6(2). http://ejournal.nbii.org/archives/vol6iss2/communityessay.princen.html.

Rees, W. 2002. Globalization and sustainability: conflict or convergence? *Bulletin of Science, Technology, and Society* 22(4): 249–268.

Rees, W. 2006. Ecological footprints and bio-capacity: essential elements in sustainability assessment. In J. Dewulf & H. Van Langenhove (Eds.), *Renewables-Based Technology: Sustainability Assessment*. pp. 143–158. New York: Wiley.

Rees, W. 2008. Human nature, eco-footprints and environmental injustice. *Local Environment* 13(8):685–701.

Rees, W. 2009a. The ecological crisis and self-delusion: implications for the building sector. *Building Research and Information* 37(3):300–311.

Rees, W. 2009b. Trudeau Lecture: Are Humans Unsustainable by Nature? Newfoundland: Memorial University. January 28.

Richmond, A. & Zencey, E. 2007. Environmental Kuznets Curve. http://www.eoearth.org/article/Environmental_kuznets_curve April 30, 2010.

Qiu, J. 2006. Unfinished symphony. *Nature* 441(7090):43–45.

Talbott, S. 2010. Context matters—the epigenetics revolution. *In Context* 23:15–19.

Shah, A. 2010. Poverty Facts and Stats. http://www.globalissues.org/article/26/poverty-facts-and-stats. March 28, 2010.

Siegel, C. 2006. *The End of Economic Growth.* Berkeley, CA: Preservation Institute. http://www.preservenet.com/endgrowth/EndGrowth.html.

Simon, J. 1995. *The State of Humanity: Steadily Improving*. Cato Policy Report 17(5). Washington, DC: Cato Institute.

Stern, D. 2004. The rise and fall of the environmental Kuznets curve. *World Development* 32(8):1419–1439.

Stutz, J. 2010. The three-front war: pursuing sustainability in a world shaped by explosive growth. *Sustainability: Science, Practice, & Policy* 6(2). http://ejournal.nbii.org/archives/vol6iss2/1001-001.stutz.html.

Tainter, J. 1988. *The Collapse of Complex Societies*. New York: Cambridge University Press.

Thøgersen, J. & Crompton, T. 2009. *Simple and Painless? The Limitations of Spillover in Environmental Campaigning.* Surrey: WWF-UK. http://assets.wwf.org.uk/downloads/simple_painless_report.pdf.

Union of Concerned Scientists (UCS). 1992. *1992 World Scientists' Warning to Humanity*. Cambridge, MA: UCS.

United Nations Development Program (UNDP). 2007. *Fighting Climate Change: Human Solidarity in a Divided World*. Human Development Report 2007/2008. New York: UNDP.

Victor, P. 2008. *Managing Without Growth: Slower by Design, Not Disaster*. Northampton, MA: Edward Elgar.

von Weizsäcker, E., Hargroves, K., Smith, M., Desha, C., & Stasinopoulos, P. 2010. *Factor Five: Transforming the Global Economy Through 80% Improvements in Resource Productivity*. London: Earthscan.

Wackernagel, M. & Rees, W. 1996. *Our Ecological Footprint: Reducing Human Impact on the Earth.* Gabriola Island, BC: New Society Publishers.

Waring, T. 2010. New evolutionary foundations: theoretical requirements for a science of sustainability. *Ecological Economics* 69(4):718–730.

Wexler, B. 2006. *Brain and Culture: Neurobiology, Ideology, and Social Change*. Cambridge, MA: MIT Press.

Wilk, R. 2010. Consumption embedded in culture and language: implications for finding sustainability. *Sustainability: Science, Practice, & Policy* 6(2). http://ejournal.nbii.org/archives/vol6iss2/0912-040.wilk.html.

Wilkinson, R. 1996. *Unhealthy Societies: The Afflictions of Inequality*. New York: Routledge.

Wilkinson, R. & Pickett, K. 2009. *The Spirit Level: Why More Equal Societies Almost Always Do Better*. New York: Bloomsbury Press.

World Wildlife Fund (WWF). 2008. *Living Planet Report 2008.* Gland, Switzerland: WWF. http://assets.panda.org/downloads/living_planet_report_2008.pdf.