PERSPECTIVE

Overcoming systemic roadblocks to sustainability: The evolutionary redesign of worldviews, institutions, and technologies

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A high and sustainable quality of life is a central goal for humanity. Our current socio-ecological regime and its set of interconnected worldviews, institutions, and technologies all support the goal of unlimited growth of material production and consumption as a proxy for quality of life. However, abundant evidence shows that, beyond a certain threshold, further material growth no longer significantly contributes to improvement in quality of life. Not only does further material growth not meet humanity's central goal, there is mounting evidence that it creates significant roadblocks to sustainability through increasing resource constraints (i.e., peak oil, water limitations) and sink constraints (i.e., climate disruption). Overcoming these roadblocks and creating a sustainable and desirable future will require an integrated, systems level redesign of our socio-ecological regime focused explicitly and directly on the goal of sustainable quality of life rather than the proxy of unlimited material growth. This transition, like all cultural transitions, will occur through an evolutionary process, but one that we, to a certain extent, can control and direct. We suggest an integrated set of worldviews, institutions, and technologies to stimulate and seed this evolutionary redesign of the current socio-ecological regime to achieve global sustainability.

cultural adaptation | ecology | societal decline

The history of human-dominated socio-ecological systems is one of successive climbs to regional prominence followed by crises that were either successfully addressed, leading to sustainability, or not, leading to decline. Historical research demonstrates that crises leading to a society's decline do not result from a single, easily identifiable cause with easily identifiable solutions (1–4). They usually result from the human-dominated ecosystem moving to a brittle, nonresilient state caused by internal changes or external forcings (2, 5, 6).

For example, the earth's climate has gone through natural and often abrupt variations, creating new conditions, persistent for decades and centuries, that were unfamiliar to the inhabitants of the time (5). Dramatic effects and societal decline, however, occur only when socio-ecological systems have become brittle and unable to adapt due to other causes (1–4), including deforestation and habitat destruction, soil degradation (erosion, salinization, and soil fertility losses), water management problems, overhunting, overfishing, effects of invasive alien species, human population growth, and increased per capita impact of people. Some ancient civilizations that were not able to adapt to climate change, leading to their demise, include:

- The Akkadian empire of Mesopotamia, where a shift to more arid conditions contributed to abrupt collapse about 6,180 years ago (7).
- Parts of low-latitude northeastern Africa and southwestern Asia, where severe drought caused major disruption about 4,300 years ago (8).
- The Tiwanaku civilization of the central Andes, where a prolonged period of drought led to collapse of the agricultural base about 1,000 years ago (5).

Environmental problems also contributed to the decline of the Polynesians of Pitcairn Island, Easter Islanders, Mayans, Greenland Norse, Anasazi, Tang of Ancient China, and the Roman Empire (2–4).

Today, we face a set of interconnected crises that threaten the sustainability of our increasingly brittle global socio-ecological system. These include climate change (5, 9), the imminent peak and decline in key nonrenewable energy resources (10–14), and a loss of biological diversity that may reduce the resilience of our global ecosystem and its ability to provide for human needs (15–17). Although most societies that declined in the past were replaced by new ones (1, 2), those societies were relatively isolated, lacking the interdependency of our current global community and the interconnectedness of the crises that we face today. The possibility that our global society may suffer decline makes this a "no-analog" period in human history in which massive social or environmental failure in one region can threaten the entire system (4).

Effectively adapting to potential collapse requires a thorough realignment of the way we view and interact with our surroundings—what has been called a socio-ecological "regime shift" (18).* A socio-ecological regime is a culture embedded in, and co-evolving with, its ecological context. "Regime" suggests a complete, interacting set of cultural and environmental factors that operate as a whole. When the ecological context changes so that the existing regime is no longer adaptive, societies must either identify and surmount the roadblocks confronting a regime shift or else become unsustainable and decline.

We propose an analytical framework for identifying the conceptual (i.e., worldviews), institutional, and technological roadblocks to societal sustainability and for exploring how their redesign can avoid a global societal decline. Worldviews, institutions and technolo-

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*Although the ability to resist regime shifts is a form of resilience, this form of resilience can actually get in the way of the more substantial adaptations necessary for longer-term sustainability.

gies correspond to Meadows's (19) "leverage points"—"places within a complex system … where a small shift in one thing can produce big changes in everything." Section I introduces an evolutionary framework through which to analyze cultural change over time. Section II describes the current socio-ecological regime and how it came about as an adaptation to inexpensive fossil energy. Section III explains why this regime is no longer sustainable or desirable. Section IV presents some elements of the redesign necessary to overcome the systemic roadblocks to a sustainable and high quality of life. Finally, Section V provides some conclusions.

An Evolutionary Framework for Change

The Components of Culture. A culture can be viewed as an interdependent set of world views, institutions, and technologies (WIT). Worldviews are broadly defined as our perceptions of how the world works and what is possible, encompassing the relationship between society and the rest of nature, as well as what is desirable (the goals we pursue). Our worldview is unstated, deeply felt, and unquestioned. These unconscious assumptions about how the world works provide the boundary conditions within which institutions and technologies are designed to function.

Institutions are broadly defined as a culture's norms and rules (20), and include the key structures that are universal among all cultures: kinship, economy, religion, polity, governance, and education (21). These structures constrain individuals' behavior, define a recognizable culture (18), and serve as problem-solving entities that allow societies to adapt to their environments (21–23). The institution of money, for example, emerged to solve the problem of unacceptably high transaction costs and limited liquidity in barter economies with a well-developed division of labor (21). Technologies are broadly defined as the applied information that we use to create human artifacts (in the example above, a printing press for money), as well as the institutional instruments used to help us meet our goals (in our current monetary system, a decision to lower interest rates).

Change as an Evolutionary Process. Cultural change is an evolutionary process (21, 24) acting on WITs. The evolution of cultures follows rules analogous to those governing the evolution of organisms, but they vary in their units of selection (cultural variants vs. genetic variants) and the method of transmission of successful variants to the next generation (learning vs. genes) (22). Individuals within populations display a variety of traits that relate to their social lifestyles, such as strategies of procuring food, interacting with others, etc. Multiple variants of each trait are possible and can be either conceptually driven (lifestyle choices based on personal preference), institutionally prescribed (belonging to a religion that forbids eating red meat), or enabled by new technology (the advent of petroleum-based travel changing the diets of Alaskan indigenous communities).

For any individual worldview, institution, or technology, there are many variants that a society may adopt, and each variant has its costs and benefits relative to local conditions and selection pressures. The frequencies with which each of these behavioral variants are seen in a population change over time in response to different selection pressures. Selection pressures include changing resource availabilities, environmental conditions, shifts in behavior of other key species or members of the population, and the frequencies of other linked trait variants. Variants that more favorably interact with the socio-ecological context generally increase in their frequency within the population, while those that are less favorable generally decrease in frequency. In this context, the frequencies of all cultural variants make up the culture.

Worldviews, institutions and technologies are mutually interdependent and mutually reinforcing. Although institutions are perhaps the chief traits upon which cultural selection acts (23), a specific worldview or set of worldviews will drive the institutions and technologies we develop by providing boundary conditions (20). For example, if our goal is to improve quality of life, we will develop institutions and technologies that promote that goal, whereas if our goal is endless economic growth, we will develop a different set of institutions and technologies. Conversely, our worldviews are reinforced by the rules our institutions set for us. For example, institutions such as education and the media play a critical role in shaping our worldview and set of goals. Technologies, in turn, have a powerful impact on institutions and worldviews. For example, technologies that allowed us to shift from dependence on the fixed flow of solar power to the stock of fossil fuels that we can extract and use as fast as we like has reinforced the worldview that economic growth can continue forever. A regime shift is not merely technological or programmatic in nature. It will do no good to set up new institutions to monitor pollution if we continue to develop technologies that create pollution, or if we continue to believe that ecosystems can be increasingly degraded without any repercussions. A regime shift cannot occur without changing worldviews, institutions, *and* technologies together, as an integrated system.

The desired outcome of selection on our WITs is to create a society that is adapted to its surroundings and situations (21) and provides for the well-being of its populations. However, it is possible for formerly adaptive WITs to become maladaptive. The ecological context can change, either because of exogenous conditions or through the effects of our institutions and technologies, and so cultures must re-adapt to changed surroundings in an ongoing co-evolutionary process (25, 26), resulting in new socio-ecological regimes. Maladaptation occurs when WITs or variants of WITs become "locked-in." Economic, technical, or political inertia, sunk costs, and other forces can prevent alternative WITs or WIT variants from being implemented (27–29). The result of a society locked-in to a maladaptive WIT is, potentially, a societal decline like those observed in many historical settings, as mentioned above.

These instances of large-scale, permanent societal decline have dramatic consequences, potentially involving voluntary or involuntary reductions in societal complexity, substantial reductions in population, and political disintegration or the reduction of controlled territory (1, 2, 6). Such radical negative socio-ecological regime shifts are often referred to as collapses (1, 2, 4, 30). In some cases, such as the recent example of the fall of the Soviet Union, regime shifts may only introduce temporary negative impacts, while in other more severe instances the resulting decline is permanent and leaves an open niche for another society to emerge and occupy (1, 2). Whether societal declines are permanent or temporary, their occurrence is the result of cultural selection acting within a cultural and environmental context (21).

Transition. To escape a situation of lock-in with multiple, reinforcing maladapted cultural variants, societies can foresee potential decline and develop other cultural variants, thereby allowing a positive regime shift, or one with merely temporary setbacks, thus changing the course of the future. One question inevitably emerges regarding the transition to an alternative socio-ecological regime: will it occur in a controlled, deliberate way that people will find socially acceptable or will it occur in an uncontrolled way that people perceive as harsh, difficult and severe? Put more bluntly, can the transition occur without societal collapse?

Crises are typically defined as a decisive moment or turning point. From an evolutionary standpoint, a period of cultural crisis is one where selection pressures are acting on worldviews, institutions, and technologies strongly enough that changes in WIT variants are required to alleviate the pressure. Given that cultural evolution will necessarily take place through the process of selection, passing through periods of crisis is a necessary part of the process. If we are to transition to a more sustainable society, we therefore cannot evade crisis. Indeed, when selection pressures become powerful enough to reshape society, it will appear to the adherents to the dominant WIT that their world is in a state of crisis. Such crises are best viewed as an opportunity to redesign a socio-ecological regime better adapted to the changing conditions.

Whether the transition can progress with or without decline or collapse is a separate issue. The key point is that cultural transitions involve the rise or fall of metrics that measure specific social elements, such as economic expenditures [i.e., gross domestic product (GDP)] or social complexity. Some of these metrics may well decline after a long period of increase. Declines in some metrics, such as per capita energy consumption, net energy, or social complexity, may be long term and permanent, whereas declines in other metrics may be temporary and rebound once societies adapt to their new realities. The rise and fall of these metrics is not necessarily good or bad for a society, so long as the society is able to adapt its WITs to the changing conditions so that individuals within the society are able to meet their needs throughout the transition.

Although the promise of crisis as a part of cultural transition may seem pessimistic, the transitional process itself need not be difficult. As human beings, we have an awareness of our WITs that other social animals lack, and thus have the potential to study the different variants of these WITs, to make educated guesses as to which variants may serve us better as circumstances change, and to adopt policies that will allow us to transition to these more adaptive institutional variants before the process of cultural selection forces us to. This amounts, in effect, to designing our way through the process of cultural evolution (31, 32). Although we will not avoid every pitfall, taking a proactive approach toward the needed institutional adaptations can reduce the negative impacts and perceptions of crises endemic to cultural transitions and thus make it rewarding (even though it may require transitions). Perhaps the best analogy is with breaking an addiction. A crisis is often required to allow the addicted individual to see and to acknowledge the addiction, and the transition to a post-addiction state can be quite traumatic. However with proper knowledge of the process and with care and foresight, the transition can be both relatively smooth and highly rewarding.

"Empty" World WIT: Our Current Regime

Our current socio-ecological regime is founded on a worldview that emerged during a period—the early Industrial Revolution—when the world was still relatively empty of humans and their built infrastructure (33). Natural resources were abundant, social settlements were sparser, and inadequate access to infrastructure and consumer goods represented the main limit on improvements to human well-being. This set of circumstances has been called an "empty" world (34). In an empty world, it made sense to ignore relatively abundant ecosystem goods and services, and to favor the concentration of wealth in the hands of the few so that it could be invested and focus solely on increasing the consumption of market goods and services, which were relatively scarce. If wealth had to be concentrated in the hands of the few where it would be invested to fuel future growth, rather than distributed to the many where it would be consumed at the cost of growth, this was a sacrifice the present had to make for the future.

Our current worldview of what is desirable and what is possible was obviously forged in this empty world context. For example, "recession," our word for economic decline, is defined as two or more consecutive quarters in which the GDP does not grow. Unending physical growth of the economy is only possible within a system unconstrained by any biophysical limits. Our current institutional and technical approach is also an extension of a long-term trend of adaptation to an empty world. Western society has increasingly favored the institutions that promote the private sector over the public sector, capital accumulation by the few over asset building by the many (35, 36), and finance over the production of real goods and services. Steady decline in median income and marginal tax rates have reduced funding available to spend on public goods while simultaneously contributing to rising income disparity. Technologies are generally designed to maximize the throughput of energy and resources while minimizing monetary and labor costs, with little consideration of future generations. For example, because they are energy dense and bountiful, fossil fuels became the dominant form of energy used by our society, even though they are polluting and nonrenewable.

Fossil fuels have provided the abundant energy necessary for economic growth, and have helped us overcome numerous resource constraints. For example, fertilizers, pesticides, and mechanized agriculture have allowed us to stave off Malthus' predictions. As a result of our success, however, the world has changed dramatically over the past two centuries. We now live in a "full" world, a world relatively full of humans and their built infrastructure. The human footprint has grown so large that, in many cases, limits on the availability of natural resources now constrain real progress more than limits on capital infrastructure. Increasingly complex technologies and institutions, increasing resource constraints, and more expensive energy inputs have made our system more brittle and hence more susceptible to collapse (37).

"Full" World Scenario: A Regime Under Stress

Our current WITs are failing to meet our needs in a changing world. Anthropogenic climate change, peak oil, biodiversity loss, rising food prices, pandemics, ozone depletion, pollution, and the loss of other life-sustaining ecosystem services all pose serious threats to civilization. These crises can be traced back to one, albeit complex problem: we have failed to adapt our current socio-ecological regime from an empty world to a full world.

The aspects of our regime that no longer serve us in a full world can be grouped under two interrelated themes: a belief in unlimited growth, and a growing and unsustainable complexity.

Unlimited Increases in Resource and Energy Throughput Are Physically Impossible on a Finite Planet. An empty world may seem unlimited, but the physical reality of the world we live in is limited and resource constrained. As we continue to grow, the laws of thermodynamics become more apparent. The first law of thermodynamics tells us that we cannot make something from nothing. All economic production requires the transformation of raw materials provided by nature. If not used in human production, these raw materials would otherwise serve as the structural building blocks of ecosystems. Structure generates function, and the ecosystem functions that we lose when these building blocks are consumed include vital life support services without which no species can survive. The global climate crisis is an example of an ecosystem service being consumed at a rate unsustainable by the surrounding ecosystem—Earth.

The first law also tells us that the energy required to do work cannot be created or destroyed. The use of fossil fuels not only creates waste emissions that further degrade ecosystem function but also depletes a nonrenewable resource. Dependence on a single, nonrenewable energy source creates unstable international relations, economic uncertainty, and dangerous resource conflicts. Technology cannot create energy out of nothing. Although the development of alternative energy sources is a priority, no currently feasible alternative can sustain the current rate of global economic growth.

In the absence of a miraculous source of unlimited energy, our worldview that unlimited and/or exponential physical growth is possible for the real economy as a whole is simply incorrect. However, qualitative improvements that generate more economic welfare from fewer resource inputs may be possible. Ecological economists have been making these points for decades (38–40), and in recent years even conventional economists have begun to question both the rationality and the potential for continued growth (35).

Unlimited Increases in Resource and Energy Throughput Do Not Continue to Increase Well-Being. Unlimited economic growth is not only impossible, it is undesirable. GDP actually measures costs, not benefits, as illustrated by recent declines in the supply of energy and food that have sent their prices and share in GDP skyrocketing even as the benefits they generate decline. An indicator of welfare should instead measure years of satisfying life, encompassing both quality and quantity. GDP *does* belong in indicators of economic efficiency, but only in the denominator. The more efficient we are, the less economic activity, raw materials, energy, and work it requires to provide satisfying lives. Real efficiency reduces environmental impacts and increases leisure time. As a major cost of providing satisfying lives, GDP does frequently move in parallel with welfare. In the same way countries that spend more on medical care tend to have better indicators of health. However, concluding that we should therefore maximize medical expenditures, a cost, is absurd. When GDP rises faster than life satisfaction, efficiency declines. Our goal should be to minimize GDP, subject to maintaining a high and sustainable quality of life. The real problem with recession is not that it decreases GDP but that it undermines quality of life by increasing unemployment, poverty, and suffering.

In 1969, the United States came to the end of a four-decade decline in income inequality and poverty. People then consumed about half as much per capita as they do today (39). The genuine progress indicator (GPI), a measure of welfare designed to adjust for the inadequacies of GDP, was nearing its per capita peak and has since stagnated (41). Subjective measures of well-being such as the percentage of people who consider themselves "very happy" have steadily declined since then (42). Empirical evidence therefore suggests that a return to 1969 per capita consumption levels would not make us worse off. On the contrary, returning to 1969 consumption levels would presumably lower our resource depletion, energy use, and ecological impacts by half, so there is every reason to believe that dramatically lowering our per capita consumption could actually make us better off.

Our Institutions Are Designed to Maximize Energy and Resource Throughput and Are Poorly Adapted to the Needs of a Full World. ***Market institutions.*** Market institutions are geared toward economic growth and provide only private goods at the expense of public goods. In the 1950s, before the biophysical limits of a full world were a concern, John Kenneth Galbraith argued that society was too focused on the market provision of private goods and neglected public goods such as education, infrastructure, public health, and so on that would best improve quality of life. Today, not only do we recognize the importance of public goods provided by nature, but we know that the production of market goods inevitably degrades them.

Many governments worldwide have long-standing policies that promote growth in market goods at the expense of non-market public goods generated by healthy ecosystems.[†] These include (*i*) over $2 trillion in annual subsidies for market activities and externalities that degrade the environment (i.e., perverse subsidies) (43); (*ii*) reduced protection or privatization of the commons (44); and (*iii*) inadequate regulations and inadequate enforcement of existing regulations against environmental externalities (45).

Economies have weathered innumerable financial crises. However, the current financial crisis pales in comparison to the biophysical crisis. Yet these more critical crises are pushed off the front page by the financial crisis and the dominant worldview of continued economic growth and consumption. Not only do our current institutions and instruments fail to address the real crisis, they accomplish mutually reinforcing goals that move us in the wrong direction. No attention is given to the relationship between the biophysical crises and the market economy, although continuous economic growth in the wealthy countries is actually a major cause of the biophysical crises (46).

International trade institutions. International trade institutions are competitive, not cooperative. Global climate stability and ecological resilience provided by biodiversity are clearly global public goods requiring cooperative global solutions, whereas fossil fuels are rival and excludable market goods promoting competition and resource struggles. Sustainability demands new energy sources that are nonrival and nonexcludable. For example, if the United States develops inexpensive and efficient solar power, our use of it will not leave any fewer photons for China or India to use. However, international trade institutions such as the World Trade Organization (WTO) prioritize private market goods and services at the expense of public goods.

Privatizing knowledge. As a final example closely related to the previous point, institutions governing knowledge are competitive, not cooperative. Whether new sources of energy are fusion, solar, wind or geothermal, the limiting factor is knowledge. Knowledge, which actually improves with use, is the ultimate nonrival resource. In the example above, not only would China's adoption of solar technology not limit the use of it by the United States (barring serious constraints on resource inputs), China would most likely improve the technology thus conferring benefits to other users. However, if we use patents and prices (protected by the WTO) to ration use, other countries may not be able to afford the technology, and if they continue to burn coal, the technology will do nothing to solve climate change. Only nonexcludable, open-access information will solve the problem. For example, existing patents on non-ozone-depleting compounds drive up their costs, leading India and China to favor ozone-depleting hydrochlorofluorocarbons which generated the worst ozone hole in history in 2006

[†]A good or service is rival if one person's benefiting from it prevents others from also benefiting. A good or service is excludable if it is possible to exclude people from benefiting. Marketed goods and services are, in general, rival and excludable, whereas nonmarketed public goods and services are nonrival and nonexcludable.

(http://ozonewatch.gsfc.nasa.gov/monthly/index.html). When Indonesia sells a strain of avian flu virus to one corporation rather than let hundreds work on a vaccine, the chance of finding a vaccine decreases (47). When a corporation patents a vaccine and rations its use to those who can afford it, the pool of uninoculated will be too large to prevent a pandemic.

Television is a good example of a technology gone awry in the hands of the market. Television has become the most accessible source of information in history, but overall it has reduced information transfer among the population. Instead of promoting two-way communication, it broadcasts information to the audience, with limited means for the audience to respond. "Individuals receive, but they cannot send. They absorb, but they cannot share. They hear, but they do not speak. They see constant motion, but they do not move themselves." (48).

Television uses a financial model relying on advertising revenue. However, this advertisement has also ushered in and sustained a culture of consumerism and materialism (49). It has brought national brands into the forefront of consumer consciousness, creating great inelasticity by presenting the belief that there are few substitutes for a given brand (50). It has also magnified in the public mind problems that in reality are minor, such as gingivitis, athlete's foot, or bad breath (51). Other countries have different approaches to broadcasting, but "the 'have-not' nations stand practically defenseless before a rampaging Western commercialism" (52).

Political advertisements have also been used to sway the populace in elections. Studies have found that candidates can receive a vote for approximately every $10 they spend (53, 54). This creates a system of "one dollar, one vote," which is the definition of a plutocracy, not a democracy.

Envisioning a New Regime

Regime shifts can be driven by collapse or by integrated worldview, institutional, and technological changes. New cultural variants can be developed to offer new goals, rules, and tools. These new variants provide the opportunity to transition away from unsustainable practices and to avoid social, economic, and ecological collapse. Below we provide a partial list of worldviews, institutions, and technologies to stimulate and seed this evolutionary change.

Redefine Well-Being Metrics. In any new context, we first have to remember that the goal of an economy is to sustainably improve human well-being and quality of life. Material consumption and GDP are merely means to that end, not ends in themselves. We have to recognize, as both ancient wisdom and new psychological research tell us, that material consumption beyond real need can actually reduce overall well-being. Such a reorientation leads to specific tasks. We have to identify what really does contribute to human well-being, and recognize and gauge the substantial contributions of natural and social capital, both of which are coming under increasing stress. We have to be able to distinguish between real poverty in terms of low quality of life versus merely low monetary income. Ultimately we have to create a new vision of what the economy is and what it is for, and a new model of development that acknowledges the new full-world context (33).

Ensure the Well-Being of Populations During the Transition. We must ensure that reductions in economic output and consumption fall on those with the lowest marginal utility of consumption, the wealthy. Presently, the U.S. tax code taxes the third wealthiest man in the world, Warren Buffett, at 17.7%, while his receptionist is taxed at the average rate of 30%. And as Buffett said, "I don't have a tax shelter" (55). Recognizing that never-ending exponential material growth of the economy is impossible, we must shift our worldview to one that understands that our economy is sustained and contained by the finite global ecosystem (although qualitative development may continue indefinitely). In fact, existing levels of physical economic output and consumption are already unsustainable and should be reduced.

Reduce Complexity and Increase Resilience. Efforts to create new cultural/institutional variants can benefit from the lessons offered by history, particularly cases of successful adaptation. For example, to say that ancient societies were overwhelmed by environmental change alone, naturally or artificially created, is an overly simplistic explanation. Although environmental factors contribute to decline, equally important are the decisions made during the crises. A society's responses depend on the ability of its political, economic, and social institutions to respond, as well as on its cultural values (2). Civilizations that go into a state of decline often do so after unwise choices in the face of stress (30). These choices are made because of an absence of appropriate understanding of the situation or of institutions to mount a flexible response. Cultures become too locked-in to adapt to a changing environment (27); the ruling polity fails to establish institutions to respond to the crises; and decline occurs.

Institutional resiliency and adaptability can offer a society the chance to avoid decline. In the case of social systems, resilience depends to a certain extent on the capacity of human societies to adapt and to continue functioning in the face of stress and shocks (56). One key element of institutional variants that determines their relative usefulness is the level of societal complexity required to maintain them (23). Some institutional variants are relatively simple and require little social bureaucracy and energy investment, whereas other institutional variants are quite complex and require a substantial social bureaucracy and energy investment (1, 22). Societal complexity carries a substantial cost in energy and resource terms, and voluntary reductions in societal complexity can allow cultures to persevere in times of scarce resources (22). Tainter noted that, historically, favoring the simpler variant increased society's chances of surviving during times of decreased energy surplus, since the energy subsidy necessary for the more complex variant was not available. In times when a higher energy subsidy is available, such as has recently been the case with our use of fossil fuels, the benefits that the more complex option offers can outweigh its additional costs.

Successful historical cases in which decline did not occur include the following:

- Tikopia Islanders have maintained a sustainable food supply, and a convenient but stable and nonincreasing population with a bottom-up social organization (2).
- New Guinea features a silviculture system more than 7,000 years old with an extremely democratic, bottom-up decision-making structure (2).
- Japan's top-down forest policies in the Tokugawa-era arose as a response to an environmental and population crisis, bringing peace and prosperity (2).
- The Moche civilization in northern Peru suffered about 30 years of drought in the late 6th century AD and then severe flooding that destroyed the capital, the fields, and the irrigation system, causing widespread famines. The capital city was moved after the flooding and new, adaptive agricultural and architectural technologies were implemented (5).

Expand the "Commons Sector." Recognizing that we are in a biophysical crisis because of our over-consumption and lack of protection of ecosystem services, we must invest in institutions and the technologies required to reduce the impact of the market economy and to preserve and protect public goods. It is now time to create another major category of institution, the commons sector, which would be responsible for managing existing common assets and for creating new ones. Some assets should be held in common because it is more just; these include resources created by nature or by society as a whole. Others should be held in common because it is more efficient; these include nonrival resources for which price rationing creates artificial shortages (information), or rival resources that generate nonrival benefits, such as ecosystem structure (forests). Others should be held in common because it is more sustainable; these include essential common pool resources and public goods.

Barnes (44) suggests that effective institutions for managing the commons sector are common asset trusts at various scales. Trusts can *propertize* the commons without privatizing them. The Alaska Permanent Fund is one frequently cited example, along with the many land trusts currently in existence. Common asset trusts could protect and restore critical natural capital—those resources provided by nature that are in some way essential to human well-being. Common asset trusts can also generate information and technologies that can protect or enhance public goods. Examples of this include low pollution energy sources, non-ozone-depleting refrigerants, organic agriculture, erosion- and drought-resistant agriculture (e.g., perennial grains), alternatives to trawl fishing, devices that reduce by-catch in fisheries, and so on. All such information should be freely available for whoever chooses to use it.

Remove Barriers to Improving Knowledge and Technology. With the invention of television, political advertisements became a critical outlet for candidates to broadcast their message and to sway voters. However, the decentralized nature of the Internet "allows citizens to gain knowledge about what is done in their name, just as politicians can find out more about those they claim to represent" (57). As a means of two-way communication, the Internet provides voters the ability to speak out within their government without leaving their homes. For the Internet to transform the idea of electronic democracy, universal access is critical. Currently technological, financial, and social barriers exist to such universal accessibility (57). Removal of these barriers thus becomes a major goal for replacement of the current plutocracy with real democracy.

Unlike television, very low technological and financial barriers exist to establishing a presence on the internet. This has the effect of decentralizing information production, and returns control of the distribution of information to the audience, providing a venue for dialogue instead of monologue. Opinions and services previously controlled by small groups or corporations are now shaped by the entire population. Television news networks, sitcoms, and Hollywood productions are being replaced by e-mail, Wikipedia, YouTube, and millions of blogs and forums, all created by the same billions of people who are the audience for the content.

Conclusions

Changes in our current interconnected worldviews, institutions, and technologies (our socio-ecological regime) are needed to achieve a lifestyle better adapted to current and future environmental realities. This transition, like all cultural transitions, will be evolutionary. Cultural selection will, with feedback from other institutions and environmental factors, exert pressure favoring institutional variants that are better adapted to current circumstances, while at the same time exerting pressure away from those variants that are less adaptive. Assuming that our society can overcome path dependence and can avoid becoming locked-in to maladaptive institutions, the process of cultural evolution will push our society toward the adoption of institutions that best suit the new circumstances.

That being said, a major unique feature of cultural evolution is that it is "reflexive" in the sense that our cultural goals affect the process. To a certain extent, we can design the future that we want by creating new cultural variants for evolution to act upon and by modifying the goals that drive cultural selection. If our societal goals shift from maximizing growth of the market economy to maximizing sustainable human well-being, different institutions will be better adapted to achieve these goals. As we learn more about the process of cultural evolution, we can better anticipate the required changes and can more efficiently design new institutional variants for selection to work on.

We have outlined what a few of these variants might look like, but the task is huge and will take a concerted and sustained effort if we hope to make the transition a relatively smooth one. It will require a whole systems approach at multiple scales in space and time. It will require integrated, systems-level redesign of our entire socio-ecological regime, focused explicitly and directly on the goal of sustainable quality of life rather than the proxy of unlimited material growth. It must acknowledge physical limits, the nature of complex systems, a realistic view of human behavior and well-being, the critical role of natural and social capital, and the irreducible uncertainty surrounding these issues.

It is also important to recognize, however, that a transition will occur in any case, and that it will almost certainly be driven by crises. Whether these crises lead to decline or collapse followed by ultimate rebuilding, or to a relatively smooth transition depends on our ability to anticipate the required changes and to develop new institutions that are better adapted to those conditions.

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