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Technology and Global Change

Surviving the Anthropocene: A Darwinian Guide

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The fundamental theory of the survival of life on this planet is Darwinism. Darwinian evolution is about coping with change by changing, using what you have on hand to survive. The fuel for this process is evolutionary potential, which resides in preexisting variation. This preexisting variation allows living systems to move forward into an uncertain future. The biosphere is a complex evolutionary system that generates, stores, and uses its own potential to survive. This makes ecosystems robust, not fragile. That suggests we can use the biosphere without destroying it, but we need some guidelines. Those guidelines are embodied in the Four Laws of Biotics, which tell us how we can interact with the biosphere without endangering ourselves further. We can further improve humanity's chances of survival as a technological species by (1) implementing the *economics of well-being*, (2) *reducing population density* by finding space in rural areas and revitalizing them into circularized economies, (3) *regrowing sustainably* by creating networks of cooperating circular economies, adding new modules when growth occurs, not consolidating into new densely populated and vulnerable urban centers, and (4) modifying social institutions to be responsive to the desires of the grassroots, even when those desires do not produce the expected outcomes. Darwinian principles provide humanity with a middle ground, a third way, between unattainable utopia and unacceptable apocalypse. We can alter our behavior now according to Darwinian principles, at great expense and difficulty, and extend or even improve upon the current state of the Anthropocene, or we can fail to act on our own behalf, experience a general collapse of technological society, and rebuild using those Darwinian principles to provide a more survivable future.

INTRODUCTION

Humanity is heading for a fall in the near future. Whether it will be falling to its knees or falling on its face we cannot say. But a fall is imminent, due in large measure to the mistaken belief in the illusion that humans are capable of controlling the planet to the benefit of humanity. The belief in control is sustained by a strong need for drama, a strong attraction to magic, and a strong aversion to bad news, especially news that involves taking personal responsibility, that seem universal among humans, despite manifest evidence to the contrary. This is most pronounced when people are frightened, as many are today. It will take all of humanity's collective rationality and self-awareness to overcome those tendencies and survive.

We must first accept that humanity cannot stop global climate change, and likely cannot even slow it much at this point. Our survival going forward will be based on how well we accept and adapt to the coming changes. And that requires changing the fundamental narrative from control and its corollary, sustainability, to evolution and its corollary, survivability. We believe Darwinian principles can increase the odds that humanity will survive whether it falls to its knees or on its face. The reasons for this are (1) Darwinian evolution is the only theory of survival that we have; (2) Darwinian evolution is the only natural process that has allowed the biosphere to survive massive environmental perturbations and rediversify; (3) Darwinian evolution has never failed in more than four billion years; and (4) Darwinian evolution is possible precisely because it has no central control mechanism.

Most of what follows is excerpted from *A Darwinian Survival Guide: Hope for the Twenty-First Century* (Brooks and Agosta 2024) (hereafter *DSG*). We begin with a short précis of how nature works.

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> ... there are two factors [in evolution]; namely, the *nature of the organism* and the *nature of the conditions*. The former seems to be much more important.—Darwin, 1859

Life uses *metabolism* to bring high-grade energy into the system, which it stores and degrades to do work in the system, and then exports back out of the system to the surroundings as heat and other forms of low-grade energy. This is how organisms *exploit* their surroundings, creating a sense of Circular Time. *Inheritance* allows organisms to *explore* their surroundings, creating a sense of Linear Time through irreversible processes (growth, ontogeny, reproduction, evolution, speciation) that produce a distinction between past and future. To persist indefinitely, life needs to be *evolvable*, and this requires constantly exploiting without losing the ability to explore. This is the nature of the organism.

Living systems not only disturb material space but create an abstract space specifying the capacity to engage functionally with the surroundings, the nature of the conditions. *Capacity space* emerges from the inheritance system, which provides the material information and causal capacity for organisms to impose themselves on their surroundings for survival and reproduction. *Potential capacity* comprises all possible inheritances; *realized capacity* comprises those possibilities that actually occur. As reproduction occurs, realized capacity grows but potential capacity grows even more, ensuring an ever-present realm of possibilities—an "adjacent possible"—for the inheritance system to explore, given opportunities provided by the nature of the conditions. Capacity space limits how these opportunities may be used. The intersection between capacity and opportunity is *fitness space*, realized opportunity space that supports survival and reproduction. The portion of *fundamental fitness space* accessed by organisms at any given time and place is *realized fitness space*; the difference between these is proportional to how "sloppy" fitness space is—i.e., how much capacity there is to do something new when conditions change (Agosta 2006; Agosta and Klemens 2008). This is the *nature of the conditions* for living systems. The historically conservative and largely autonomous nature of inheritance produces reproductive overrun, creating natural selection in proportion to the degree of *misfit* between organisms and their environments. The primary mechanism for resolving such conflicts is *ecological fitting*, an umbrella term for various ways in which living systems can cope with the conditions by exploring novel portions of fitness space using preexisting inherited information capacities.

Evolution is intimate, yet impersonal. The conditions of life are completely indifferent to our pain and suffering and aspirations. But life includes a built-in drive to survive through oscillating between exploration and exploitation. The biosphere is not a collection of diverse static entities; it is a collection of inheritance systems with an indefinite ability to survive even massive environmental insult through a sort of rope-a-dope. Life lurches along, always slightly out of sync with the surroundings, but imbued with that relentless drive to survive.

Darwinism is a theory of *coping with change by changing*. The old will inevitably pass away, but there is a positive note. Each mass extinction triggered by global climate change has been a mass evolutionary reset. Each time, the biosphere lost many species, but those that remained were capable of sustaining a transitional biosphere and evolving a new diversifying one. Evolution keeps extinction from being a death sentence. It is never "extinction," it is "extinction and renewal," always beginning with something marginal becoming amplified and forming the basis for persistence.

What does Darwinism now teach us that is relevant to human survival in a time of accelerating global climate change? Fundamentally that evolution is intimate, brutally shortsighted, and relentless, and all resolutions produce unanticipated consequences. Thinking in terms of stopping or directing change is utopian thinking and is a death sentence for the survival of any evolutionary system. Evolution is at its best in a crisis—whatever it has on hand is deployed as much as possible to see what might work; exploring is at a premium, in response to conflict and changing conditions, and any place where you can survive away from the conflict and change, you settle down and begin to exploit the new conditions. When times are good, evolution is a wastrel, just fiddling around, messing with new ideas that are not necessary and do not solve any immediate problems; invention comes during the good times when you can afford to make mistakes. The time for innovation is when one has time to innovate, not when one is pushed into a corner at the barrel of a gun or an approaching tsunami.

In evolution, *necessity* is never the *mother of invention*. Rather, it is the *mother of desperately trying to cope* with environmental perturbations using whatever capacities are at hand, fleeing the crisis if you cannot cope, and dying if you cannot flee. *Control* and *evolution* are thus antithetical. "Survival of the fittest" is perhaps one of the most insidious examples of error propagation in human thinking. Life would have ceased to exist long ago if evolution were a matter of survival of the fittest. Evolvable life is a complex *evolutionary* system, in which persistence in time, rather than growth or adaptation, is the key to survival; survival of the fit, not the fittest. This is why the application of standard management practices based on optimal design and control has made things worse.

HOW DID HUMANITY GET ITSELF INTO THIS MESS?

Humans of various forms have been around for at least 3 million years, about 150,000 generations, and for 149,250 generations they were an increasingly diverse and widespread Darwinian system. In one of the relatively minor table-clearing episodes in the history of life on this planet, the Last Glacial Maximum (LGM) opened a pathway for humans to dominate the planet. Humans had an extensive knowledge base that enabled them to capitalize on opportunities emerging in the aftermath of the LGM. Every step of the way, human decisions all seemed like a good idea at the time, and sometimes they worked, for a while. What hu-

mans began to do about 15,000 years ago, however, set the stage for a fundamental shift from a Darwinian existence to the Anthropocene.

Five popular definitions of the Anthropocene all represent part of a larger story (Brooks and Agosta 2024). *The Great Transition* began about 15,000 years ago, with the emergence of agriculture and domestication as a way of life emerging from plant and animal husbandry—knowing the natural history of plants and animals well enough to take advantage of what was desirable and available. This set the stage for *The Great Amplification,* about 12,000 years ago, characterized by the emergence of *high-intensity* agriculture and domestication and a focus on few, more productive, species along with the construction of permanent settlements associated with those efforts. From a Darwinian perspective, both of these episodes represented enhanced exploitation of local resources.

During this time, although many humans lived increasingly sedentary lives, whenever a natural disaster made a settlement incapable of supporting the people living there, the site was abandoned and people migrated away, seeking better living conditions, where they started over. This accorded with humanity's Darwinian heritage. Urban settings grew increasingly prone to collapsing during natural disasters, and about 9,000 years ago, some humans committed themselves to a new behavior. Rather than abandoning a place when conditions changed and exploring new territory in search of better conditions, they decided to take from their neighbors what they needed in order to remain in place.

War arose out of fear and weakness, not strength. And with the rise of defended cities, human groups began to wall themselves off from the rest of the world, believing they could control their futures from behind the walls. *Evolutionary history* never repeats itself, but for the past 9,000 years or so *human history* has repeated itself constantly. Committing ourselves to an arms race dynamic did not lead to control, it led to a death spiral, conflict creating conflict with no resolution. No one truly wins a war; they simply stop it. In the absence of resolution, conflict simmers beneath the surface and reemerges. War is not an evolutionary imperative; it is a human choice made about 9,000 years ago to which we have become so accustomed we think it is part of our nature. And that leads to a fallacious justification for constant war. The Latin author Publius Flavius Vegetius Renatus's tract *De Re Militari*, published in the 4th or 5th century AD, wrote "Igitur qui desiderat pacem, praeparet bellum" ("Therefore let him who desires peace prepare for war"). This was the *Great Tragedy* of the Anthropocene.

The blind commitment to war set the stage for another transition. The generally accepted arbitrary date for the beginning of this fourth episode of the Anthropocene is 1753, the year in which the first industrial-grade steam engine came into operation. This marked the beginning of the Industrial Revolution. The Industrial Revolution was notable for its insatiable appetite for human labor as well as for triggering a massive increase in technological innovation. That spawned a kind of anti-exploration phase in human history, in which people flocked to the now industrialized urban centers from rural agricultural settings believing they could have a better life in the cities and factories. The agricultural areas became depleted of farmers, increasing food insecurity, while the cities became so full of people their local food supplies could not keep up, increasing food insecurity even more. Despite increasing food insecurity, people who had come to the cities to work in the factories, as well as those who profited from their labor, continued to have children. This resulted in a marked increase in human population growth—the *Great Deflection* of the Anthropocene, when human population and human technology both increased dramatically.

The proportion of humans engaged in exploration in search of new living conditions had diminished while the proportion of humans engaged in exploration to exploit distant conditions to the benefit of their growing, and increasingly static, home settings increased. Growth in the emerging industrial urban centers was partially offset by the importation of food from other places (sometimes produced by slave labor, sometimes simply taken with the aid of superior weapons) and by technological innovations amplifying high-production agriculture, but the overall result was an increase in the number of poor and undernourished urban inhabitants. This in turn fueled fairly constant warfare among the newly industrial countries, culminating in two world wars in the first half of the twentieth century.

Some vestiges of our Darwinian legacy still persisted, and during the decade or so of relative peace after the end of the Second World War, technological innovation exploded, creating the *Great Amplification* of the Anthropocene, whose beginning is dated arbitrarily to 1950. This transition was driven not only by the technological innovation but also by a growing belief that technological innovation would allow us to control the world and ourselves, solving all the problems that led to war. Not everyone believed this—many felt that the emergence of atomic weapons was evidence that technological growth was at the very least a double-edged sword, with an unknown relationship between benefits and costs. They pointed to the atomic bomb, to evidence of atmospheric warming associated with industrial production, and to the potential impacts on biodiversity associated with human population growth. But the image of magical innovations leading to heroic solutions to humanity's problems was too attractive. Our species sowed the wind and is now reaping the whirlwind.

DARWINIAN GUIDELINES FOR COPING WITH THE TWENTY-FIRST CENTURY

The 1948 Universal Declaration of Human Rights was a reaction to the actual horrors of World War II. Humanity now needs a *Universal Declaration of Human Rights and Responsibilities* based on the *potential* horrors of not responding to the emerging impacts of climate change. Darwinian evolution is about coping with change by changing, using preexisting information to resolve conflicts with the environment by ecological fitting in sloppy fitness space, reinforced

by natural selection in the context of the conditions of the moment. Evolution is therefore shortsighted (it cannot predict the future), but conflict resolution is assured because there is no rigid control mechanism at work, just accumulated potential. The implications of these statements can be summarized by seven principles (see also Agosta and Brooks 2020; Brooks and Agosta 2024): (1) the only sense of progress in evolution is persistence in time (it is all about survival); (2) the vast majority of traits that species use for persistence and coping with the conditions are persistent elements of conservative inheritance (it's all about using what you already have, not about waiting around for the "right adaptation at the right time"); (3) if a species persists long enough, evolution may result in a better solution for coping with the conditions, but the solution will always be contingent and temporary because the conditions are always changing (what is highly fit today will be unfit tomorrow, and what is marginally fit today will be fitter tomorrow); (4) there will always be unanticipated consequences no matter how good a solution appears to be (conflict resolution produces new conflict); (5) the consequences of overgrowth can be deferred but never escaped (there is no unlimited growth in biology); (6) the longer the penalties for overgrowth are deferred, the greater the chance of extinction (the larger the system grows without diversifying, the more vulnerable to extinction it becomes); (7) evolution is powered by renewable inherited information, but inheritance systems constantly change.

These principles lead to the *Four Laws of Biotics*, guidelines for how technological humanity should interact with the rest of the biosphere, with each other, and with sociopolitical institutions. In analogy with Isaac Asimov's terminology associated with the Four Laws of Robotics and with the Zeroth Law of Thermodynamics, we use the term "zeroth law" to refer to a law that was proposed after the initial first, second, and third laws, and is so fundamental it creates the context for the remaining three laws.

THE ZEROTH LAW

Zeroth Law: Humanity may not harm the biosphere, or by inaction, allow the biosphere to come to harm. *The most fundamental form of "harm" is restricting the biosphere's ability to cope with changes, including those produced by any species.*

The biosphere has an indefinite capacity to survive because its constituent species have indefinite capacities to cope with change by changing—to evolve. This is good news. At the same time, evolution does not favor the persistence of any particular species. The ability of the biosphere to cope with large-scale climate change and other perturbations means there will be a spike in unanticipated and unwanted events—charismatic species may go extinct, new diseases will emerge, biological control programs will fail, local ecosystems will change species compositions and ecological interactions forever—all by-products of the biosphere coping with climate change. Whatever works, persists. Whatever doesn't work, goes extinct. The biosphere is more robust than any individual species, and evolution is indifferent to the fate of any given species. No dinosaurs, no problem. No people, no problem. While humanity faces an existential crisis, the biosphere is indifferent, no matter how self-important humans feel. The biosphere will keep moving along, doing what it always does, coping with change by changing, as species alternately accumulate and use evolutionary potential.

The biosphere is already adapting to global climate change without asking our permission and without waiting to see if we will decide to be one of the survivors. This must guide conservation and management decisions and must be better internalized by the research community. The literature on climate change is filled with reports about changes in species distributions, abundances, interactions, behaviors, growth, development, reproduction, and physiology. These changes are usually viewed as prima facie evidence that something bad is happening, signs of a system collapsing, giving cause to intervene and stop it. Darwin showed the world that change is the *expected outcome* of an evolutionary system responding evolutionarily to change in the conditions of life. It is a sign of the robustness of the biosphere, not the opposite. While some species may be on a path to extinction, many are simply on a path to survival. We must understand that a reduction in growth, productivity, geographic range, or even population size for a given species may be an indication that evolution is underway, and not a violation of the zeroth law. If we misunderstand such events and intervene, we risk violating the zeroth law. It may be productive for some to view the political doctrine of *Mutual Assured Destruction* (MAD) as a form of the zeroth law.

THE FIRST LAW

First Law: Humanity may not injure any portion of the biosphere or, through inaction, allow any portion of the biosphere to come to harm, except when required to do so in order to prevent greater harm to the biosphere itself. *Humans can use some portions of the biosphere, and protect themselves from others, so long as the ability of the biosphere to cope and persist is not endangered.*

Humans can actively participate in ensuring their own survival by ensuring the survival of the evolutionary potential in the current biosphere. Humans can manipulate parts of the biosphere in their favor, so long as they do not take away its fundamental ability to cope with change, and so long as it is understood that there will be unintended consequences. This law helps humans judge whether action is required when changes occur. Humans must not allow emotions to cloud their understanding of the biosphere's response to change, whether caused by humans or other factors. Policies that attempt to impose stasis based on emotional ties to particular parts of the biosphere will restrict the evolutionary commons, and will ultimately fail, and could make the situation worse. The *Precautionary Principle* is a critical element of decision-making in this context. In brief, it states that incomplete knowledge is not a reason to hesitate to act. Each application of the Precautionary Principle, however, must be coupled with "stop

rules" specifying the kinds of observations that would necessitate modifying or terminating some actions. Compromise based on prevailing consensus is the worst option. When something unexpected occurs, the consensus always turns out to have been wrong. Half measures gradually implemented make things much worse. Researchers and policymakers can afford to be wrong, but humanity cannot afford for them to refuse to admit they are wrong and continue with business as usual. The first law implies that humanity should allow as much of the biosphere as possible to exist as a functioning *evolutionary commons* (Agosta and Brooks 2020; Brooks and Agosta 2024), a concept discussed in more detail below.

THE SECOND LAW

Second Law: Humanity may exploit any portion of the biosphere, except where such exploitation would conflict with the first two laws. *Humanity can use its understanding of the biosphere to determine the maximum amount of allowable exploitation.*

Humans are part of the biosphere and cannot be separated from it. Like all organisms, humans are exploiters and explorers of their surroundings. They require resources to fuel metabolism to "stay alive" and cannot help but degrade their surroundings as a consequence. But that does not give them permission to simply maximize exploitation, using as many resources as possible as quickly as possible. The constituent members of ecosystems form an interconnected metabolic economy in which the degraded energy of one species is high-grade energy for another species. Therefore, within ecosystems, exploitation itself does not restrict the biosphere's ability to cope with change. What harms the biosphere is a policy of *maximum exploitation for maximum growth*. Cutting down all the forest to build the largest cities possible, as fast as possible, is short-term gain for long-term loss. Humans cannot continue to be cavalier about efforts to engineer. The notion that it is possible to "be in control" of the environment is a myth. Global climate change is a side effect of sustained attempts at engineering the biosphere. No matter how much a "maximum exploitation" approach makes it look like we are "in charge," this is an illusion because we have paid for maximum exploitation by diminishing our capacity to explore new options when conditions change. It is in the context of the second law that principles of *Sustainability* can be effectively applied.

THE THIRD LAW

Third Law: Humanity may protect its existence as long as such protection does not conflict with the first three laws. *Humans cannot destroy the biosphere in an effort to preserve themselves. Humanity must live within its means or go extinct.*

Humans require a viable biosphere. Maximizing growth is the quickest path to extinction, eliminating options to escape conflict no matter how much potential capacity technology may create. Humanity needs to change from "hurry up and get bigger" to "slow down and live within your means." Human activities can harm the biosphere enough to destroy humanity. Global climate change today alters the fitness space for every species on the planet, including us. Those changes in the nature of the conditions will result in the disappearance of some—perhaps many—species, and the survival and spread of others. It is an evolutionary reset—life will continue as always, but nothing will ever be the same. The risk that the biosphere will evolve is at the highest level possible—in fact, that is already happening. If humans want to be part of what survives, they must learn how to live within the parameters of the evolving biosphere. The third law mandates that humanity take seriously the concerns for life on a finite planet articulated in *Limits to Growth* (Meadows et al. 1972; see also Turner 2014).

POLICIES FOR SURVIVAL: APPLYING THE FOUR LAWS OF BIOTICS

Species live in an eternal present, adapting only to the conditions they meet. They tend to synchronize with the pace of changing conditions to the extent allowed by their inherited conservatism and the opportunity to access new opportunities. They can never match environmental change completely, but evolvable life on this planet has done a good enough job to diversity, survive, and rediversify for more than 4 billion years. If humanity decides to make the rational decision to adopt evolutionary guidelines for survival, there is time to act without panic. All that is needed to adapt to anticipated 2050 conditions is to plan to meet those conditions at that time. That would eliminate the sense of anxiety and uncertainty stemming from trying to control accelerating climate change in a vain attempt to slow, stop, or reverse it.

HUMANS AND THE BIOSPHERE

Contemporary conservation biology traces its roots from the writings of Alexander von Humboldt at the end of the 18th century to 20th-century classics such as Aldo Leopold's 1949 *Sand County Almanac* and Charles Elton's classic book *The Ecology of Invasions by Animals and Plants* in 1958. It emerged as a distinct field of study in the 1970s and has become the primary arena for discussions about how to deal with the biodiversity crisis in a period of global climate change. From the beginning, conservation biology's approach to protecting and managing biodiversity has involved three common non-Darwinian beliefs. The first is the idea that nature is fragile; we must protect nature because it is fragile, where any change can cause the destruction of its delicate balance.

But nature is not fragile. It is robust because it copes with change by changing. The notion of a delicately balanced nature is antithetical to an evolutionary system. In evolution, change is the fundamental mechanism that allows living systems to persist. The biosphere is dynamic, not static, and resilient, not brittle. Most biologists readily accept

this, recognizing that any appearance of stasis in nature is an illusion. Still, the message seems to have been missed by much of conservation biology, including researchers and policymakers, and by the public, which looks to conservation biology for insight and understanding. The *Gaia hypothesis* represents the idea that the biosphere acts as a set of coordinated subsystems working to maintain a system-level homeostasis—that mythical balance of nature. This reinforces the idea that without human interference, the biosphere would somehow exist in a timeless, unchanging state of perfection. From this emerge nonevolutionary ideas about "returning nature to the way it was"—the rewilding of the planet typically inspired by a nostalgia for idyllic nature in a past state of "perfect balance" that never actually existed.

The *butterfly effect* is another popular metaphor for describing the state of the biosphere. It rests on the common misconception that ecosystems are so delicate, the extinction of even one species can cause entire ecosystems to collapse. Meteorologist Edward Lorenz proposed the metaphor in 1972 as a thought experiment in the context of predicting the weather. The idea is that small changes in one part of the system—like a butterfly flapping its wings in Brazil—could have large effects on the whole system—such as causing a tornado in Texas. The butterfly effect metaphor was co-opted by environmentalists as a true description of the delicate balance of nature. It represents a dire warning about the loss of any species, and the need to urgently maintain nature in its current or even in some previous state. Yet nature is a complex evolutionary system, so the butterfly effect is an extremely poor metaphor to portray it.

A key feature of complex systems is that they are made of multiple levels of organization, with the higher levels generally immune to perturbations at the lower levels. This degree of insensitivity of higher to lower levels is a fundamental characteristic of complex systems that makes them robust in the face of both internal and external disturbances. Think of a colony of ants. If one or a few ants die, the colony will be largely unaffected and unlikely to collapse. The same goes for multicellular organisms, where the whole organism is generally unaffected by the loss of any given cell. And the same is also true for ecosystems and the emergent biosphere. As complexity increases, more levels of organization can emerge, increasing system-level robustness by providing a buffer against lower-level perturbations. This reflects the fundamental indifference of evolution to any particular species, no matter how self-important.

Diversity itself is a source of robustness in complex systems and can be understood through two simple concepts. *Averaging* refers to the fact that if there is a diversity of types, be it species in an ecosystem or stocks in a portfolio, then there is some security in the face of future uncertainties. This is a way to reduce the probability of really bad outcomes for an ecosystem as a result of bad outcomes for particular species. Surviving requires achieving a fitness or payoff above some threshold, and more diverse systems have a greater diversity of potential ways to achieve this payoff. For the whole system, this diversity can prevent performance from falling below a survivable threshold because the average performance of individuals is positive. *Diminishing returns to type* refers to the fact that the marginal return in productivity or payoffs per individual of a particular type decreases with the more individuals of that type that are in the system. In economics, additional workers of the same type contributing diminishing returns to total production is known as the diminishing marginal product of labor. In ecosystems, additional members of the same species might contribute to diminishing returns to ecosystem performance, relative to adding members of different species. The combined effect of averaging and diminishing returns to type implies that diversity, along with multilevel structure, increases the robustness of complex systems by providing a buffer against bad outcomes, like the extinction of species within ecosystems. All of these features, combined with the capacity for ecological fitting in sloppy fitness space, contribute to the ecosystems' evolutionary ability to withstand lower-level perturbations and extinctions of species and their interactions, an *anti-butterfly effect*.

All complex systems, however, have a vulnerability threshold beyond which disturbances can no longer be absorbed, causing the system to collapse. At this point, the threat of the butterfly effect becomes real. While some parts of the biosphere may already be close to or even at their tipping points, the biosphere's constituent ecosystems are still functioning—changing, yes, but not falling apart. It is critically important for conservation biology to internalize this message. When an ecosystem responds to a perturbation by its species moving away in geographic (e.g., dispersing to new areas) or functional (e.g., colonizing new hosts) fitness space, both local abundance and productivity will decrease, but that is not a mutually exclusive sign of collapse; rather, it is the expected outcome of spending evolutionary potential to cope with the change. Spreading out and generalizing in fitness space implies local population declines, but local declines are not clear indicators of widespread extinction or collapse, and efforts by humans to control and reverse those declines may violate the zeroth law.

The biosphere's supposed fragility gave rise to the notion that humans must protect nature by separating themselves from it, controlling it in its current state or back to a previous state that was "better." In *The Conservation Revolution*, sociologists Bram Büscher and Robert Fletcher call this the *neo-protectionist* approach to conservation. Neo-protectionists promote the expansion and enforcement of protected conservation areas that effectively keep humans out, separated from what they view as a "pristine" nature that can only be ruined by us. Although the idea of separating ourselves from nature has been around since the beginning of conservation biology, it has seen a resurgence of being espoused, such as by E. O. Wilson in his final book, *Half-Earth: Our Planet's Fight for Life*, and the conservation campaign Nature Needs Half. This contrasts with what Büscher and Fletcher call the *new conservation* movement. New conservationists seek to do away with the idea of "pristine nature" and the notion that places can be conserved as "untouched protected areas, away from humans."

Both groups agree that humans impact the biosphere significantly, but whereas the new conservationists believe humans are a part of nature and should accept and even embrace that the biosphere is changing in response to their activities, neo-protectionists fear the only way to save nature is to put a fence around it and keep people away.

Missing in all the discussions of various aspects of conservation biology is the notion that evolution is the fundamental process that allows the biosphere to cope with change by changing. Most conservation is based on ideas of stasis, nostalgia, and delicate balance. These are not relevant principles for describing an evolutionary system, especially one that is being perturbed. We can only guess that those most centrally involved do not understand that evolution is the only process by which the biosphere has survived all previous environmental perturbations large and small, no matter what caused them, and that it has never failed.

THE EVOLUTIONARY COMMONS

If Gaia and the butterfly effect are not appropriate metaphors, what might replace them? When Aldo Leopold published *Sand County Almanac* in 1949, he laid out an integrated view of contemporary humans and their interactions with nature from the perspective of a field biologist and naturalist operating within a Darwinian tradition. He asserted that the biosphere is robust, not fragile, capable of persisting indefinitely if its own evolutionary capacities are allowed to operate. He was among the first conservation biologists to place the responsibility for safeguarding the biosphere squarely on humans, nearly a decade before Elton. With a clear appreciation of Darwinian principles, Leopold identified high-density human settlements as a major threat to successful preservation of the biosphere. This led him to strongly criticize the notion that for-profit nature conservation could lead high-density human populations to conserve biodiversity. Instead, he advocated conservation based on principles of survival—in this case, the mutual survival of humans and the biosphere upon which they relied.

The biosphere is full of life, full of evolutionary potential, but it is not alive. This explains why efforts to control "the biosphere" were doomed to failure and have arguably made matters worse by diverting attention from the significant good that can be accomplished through local initiatives. Ecosystems lack a single inheritance system, so they do not evolve. The members of any ecosystem are all free to explore new opportunities for survival when conditions change precisely because they are not members of a superorganism. Rather, ecosystems represent collective evolutionary potential, what we call the *evolutionary commons* (Agosta and Brooks 2020; Brooks and Agosta 2024), which is critical to evolution.

In *The Conservation Revolution*, Büscher and Fletcher follow Leopold's vision, making the case for what they call "convivial conservation." *Conviviality* rejects the separation of humans from the rest of nature and focuses on fully integrating humans with the rest of the biosphere. This is largely in line with the "new conservation" or non-neo-protectionist position in mainstream conservation biology, but according to Büscher and Fletcher, differs by deemphasizing conservation-for-profit, a growth-based model that is easily corrupted and often restricts parts of nature to the privileged elite. Büscher and Fletcher, in contrast, call for a more egalitarian approach centered around the idea of an *embedded-nonmonetized value* in nature. As we state in *DSG*:

> We believe the embedded value in nature is the potential stored in the evolutionary commons. For conservation biology to be convivial, it needs above all else to let evolution happen. It needs to be about embracing the biosphere's capacity to cope with change by changing versus putting fences around parts of it in misguided attempts to "protect" it.

At best, current conservation policies detract from safeguarding, maximizing, and facilitating the deployment of the evolutionary potential stored in the existing biosphere. At worst, they direct critical resources to the wrong places, often to misguided efforts to save, reintroduce, or even resurrect a particular species. The biosphere, its constituent ecosystems, and the species that comprise ecosystems are resilient to perturbations, resulting in changes in species abundance and distribution as well as the formation of new species and extinction of others. The primary goal of conservation biology should be to maximize the biosphere's ability to cope with change in a manner that also gives humanity the maximum chance to survive. While we expect species to cope with environmental change by ecological fitting in sloppy fitness space, there is never a guarantee that the efforts will be successful in every location all the time. So sometimes these patterns will presage true extinction. But if we assume imminent catastrophic extinction and intervene, we may be stopping the one and only process—Darwinian evolution—that has been responsible for the survival of the biosphere throughout the history of life on this planet. If we have established conservation areas as evolutionary commons, we will find that loss of trophic connections, decreases in abundance, decreases in diversity, and decreases in productivity are indicators of evolution at work, and understand that human interventions in such cases would make matters worse by impeding the evolutionary process. In an effort to "help," we would actually be violating the zeroth law.

Conservation policies or goals that aim to preserve existing biodiversity as and where it is, return it to a previous state, or separate it from humans are outside the scope of the Four Laws of Biotics. Conservation biology needs to reject these ideas along with notions that nature is static, fragile, delicately balanced, or controllable. Evolution—coping with change by changing—is the fundamental mechanism that allows the biosphere to survive and persist. Change is not collapse: reductions in productivity, abundance, and diversity are the expected signals that its inheritance systems are spending potential, spreading out and exploring new options in fitness space. Observations that are generally considered markers of imminent species extinctions and ecosystems collapses could be signs that

the biological systems are coping with change evolutionarily. Declining local abundance with increasing geographic range could indicate that the species involved are moving away from an area affected by changing conditions in search of better circumstances. The species may indeed disappear from the local area, but their abundance may increase in other places if the species are allowed to follow their evolutionary impulses. As well, decreasing abundance in some species could provide opportunities for other species, including those that previously had marginal existences, to increase in abundance. If we find local extirpation—actual loss of species from a particular area rather than just declining abundance—we would expect to find a corresponding loss of preexisting trophic connections. At the same time, we might expect to find new trophic connections emerging as those remaining species use their capacities for ecological fitting to improve their own conditions of life. When species begin moving away from a given ecosystem, net productivity in that ecosystem will always decline. If, however, those species establish themselves in other places in association with other species, new ecosystems will emerge, and productivity will increase in the new places.

In their 2002 book *The Nature of Diversity*, Daniel Brooks and Deborah McLennan advocated biodiversity policies focused on saving as many different kinds of places as possible, linking them together as much as possible, and letting evolution happen. Some of the ecosystems on which humans depend will cope by changing and yet remain largely intact, and others will break apart and evolve into new ecosystems. Anthropogenic impacts have been too severe to avoid these penalties, but by preserving as much of the existing evolutionary commons as possible, humanity can ensure the biosphere's potential to deal with change, and by extension, its own. For the conservation movement to be more effective, it must fully embrace the reality that to persist indefinitely, life must generate substantial potential, and efforts to engineer or control nature will only reduce potential and increase the unintended consequences of those actions.

As we discuss in *DSG*, we know of no other conservation effort in the world that integrates the principles of convivial conservation, the evolutionary commons, and the Four Laws of Biotics better than the Área de Conservación Guanacaste (ACG) in Guanacaste Province, Costa Rica. The ACG is a UNESCO World Heritage site and considered a model for its revolutionary approach to conservation that, when it began in the 1980s, was unique and far outside the status quo approach of "put a fence around it and keep people out." To be truly wise in interacting with the biosphere, humans must be better integrated with nature, not more separated from it. At the same time, we need to give biodiversity room to move, to explore species' evolutionary potential and inherent capacity to cope with change by changing. By virtue of its sheer size and diversity of habitats, connectivity of those habitats, and symbiosis with surrounding communities, the ACG is currently functioning as an evolutionary commons for neotropical biodiversity and the humans that live around it. It is a spectacularly successful example of the value of a Darwinian approach to conservation.

HUMANS AND EACH OTHER

The human condition needs to be survivable by 2050 if we are to avoid general collapse, and we think this requires adherence to evolutionary, rather than design and control, principles. Whatever policy proposals arise from the decision to follow evolutionary guidelines must be judged by three questions:

1. Does it contravene any of the Four Laws? If not, proceed.
2. Does it enhance survival and well-being? If yes, then proceed.
3. Can it be made more efficient? If yes, then proceed to the extent that the Four Laws and the economics of well-being are not violated.

This leaves an enormous amount of survivable space for human creativity to produce and follow effective plans.

THE ECONOMICS OF WELL-BEING

Humanity is governed by a variety of economic philosophies from the far left to the far right of the political spectrum. All are in trouble, because all share a common anti-Darwinian principle: the solution of all economic problems is growth. Charles Darwin first showed that while growth is a built-in feature of living systems, *unconstrained* growth is inevitably pathological and destructive to the system that is overgrowing. The various resolutions to such conflicts are embodied in *natural selection*. Natural selection is a blunt instrument, not giving preference to any given species. Humans wish to act in a manner that enhances the chances their particular species will survive indefinitely into the future. The economics of well-being provides an alternative framework to the principle of maximum growth for achieving human ambitions in accordance with Darwinian principles.

The economics of growth inhibit the ability of economies at any scale to adapt to changes, hence a preoccupation with control. There is no doubt that the economics of growth and control lead to increased efficiency. Evolution, however, is not about efficiency, it's about sufficiency. Efficiency criteria destroy diversity; sufficiency criteria generate diversity. Dips in productivity are thus a necessary element of economic adaptation, and efforts to promote constant growth are antithetical to survival. The transition to a new and better economic setting is often accomplished through elements termed the *informal economy*, which do not contribute to economic growth. They are, however, essential for economic survival because they represent cases in which economic potential is being explored, much like evolutionary potential is being explored during periods of environmental perturbation. Losses can encourage exploration (Chin, Hagmann, and Loewenstein 2022). Economic growth and profit-making are allowed so long as they do not violate the Four Laws and do not harm the well-being

of others. Better can be bigger. Economic cohesion through cooperation can emerge without the need for efforts at economic control, which will ultimately fail.

The economics of well-being calls for long-tailed business models, in which it is more important that a company persists a long time than it is for the company to have higher profits than any other company. Profit does not tell you if potential was realized, so it cannot tell you about future success/survival. Like fitness, profit is an indication of potential spent, not of potential made. And in nature, there is no deficit spending, so you cannot project future survival from current profits. The more profits are put into potential, the more secure the future. Investing in CEOs is not making potential; maximizing short-term profits to shareholders represents potential lost to the company. Investing in the workers and infrastructure is creating potential. So is investing more income into workers and infrastructure, R & D, and savings for the future. As universities following the corporate model add management, they engage in ever more fundraising to support the management structure and end up with fewer support staff, fewer tenured faculty, frozen faculty salaries and diminishing benefits, crumbling infrastructure, and students inadequately prepared to cope with the future. Companies are finding that the economics of well-being has unexpected benefits

> Essentially, Ethereum moved to a mining process, known as proof of stake [economics of well-being], that requires significantly less computing power than bitcoiners' preferred process, proof of work [economics of growth]. In doing so, Ethereum appears to have reduced its worldwide energy consumption by more than 99%.—Jake Cline, 15 January 2023, "The latest jewel snatched from Sam Bankman-Fried's crypto empire," CNN

POPULATION DENSITY

For at least 12,000 years, humans have been confining themselves more and more to a few small areas, where population densities are very high. Near the end of the 18th century, the Reverend Thomas Malthus recognized that the number of people living in London was too great for local food supplies. At the beginning of the 20th century, about 13 percent of humans, or approximately 200 million people, lived in urban confines. Today, more than half of humanity, or more than 4 billion people, live in cities. All evolutionary biologists, and even the most traditional conservationists, would recognize that crowding increasing numbers of plants and animals into fewer smaller places is a recipe for disaster. Our large cities may be efficient, but they are not sufficient, and many of them are becoming less efficient as they lose the capacity to maintain critical infrastructure—a sign that, like economies, we cannot grow our way out of the problems of overly large cities. Cities, like the economics of growth, are a problem, not a solution. Additionally, many of the largest cities are climate insecure, especially those lining the world's coastlines where they are increasingly threatened by sea level rise and powerful storms.

In his classic 1958 book *The Ecology of Invasions by Animals and Plants*, Charles Elton presciently suggested that the two greatest threats to humanity associated with climate change would be conflict and migration. In addition, and coupled with the threats related to climate change, we are now beginning to see climate migration from large cities. This should be expected, because the evolutionary default to living in areas of overly high population density is to move away. Some claim that urbanites have no place to go, that there are too many people on the planet to accommodate massive climate migration. But this not true—many urbanites come from rural areas that have been largely deserted by younger people attracted to the supposed benefits of urban living.

This is a perfect time to take advantage of the natural instinct to flee from trouble and to provide safe havens for climate refugees by revitalizing small urban centers in recently abandoned rural areas, where usable infrastructure still exists. Such smaller cities also represent excellent opportunities to introduce the economics of well-being by creating circular economies. Circular economies mimic metabolism in organisms and ecosystems, which is circular, replacing economics of maximum short-term gain by linear input-output with recycling and reusing resources for maximum long-term use within the system. "Make and reuse" is cheap and persistent, like evolution, rather than the usual expensive and wasteful "use it and lose it." Communities that grow, harvest, and replant their own trees, for example, will always have wood. The effective exploitation of the surroundings is slow, allowing harvested energy to be stored as biomass and used many times. The circular economy promotes long-term persistence; go slow and live within your means, thereby maintaining bounded growth. Circularized economies can give technological humans a better chance to survive, to "slow down and live," getting more out of harvested resources and buying time to find effective solutions to environmental problems. Circular economies strive to produce as much as possible without violating the Four Laws, maintaining the economics of well-being (H. Brown 2018; H. A. Brown and Brooks 2021).

Smaller settlements can also be governed by social cohesion rather than social control. Coordination among members of cooperating small settlements requires large-scale social institutions, but if they are responsive to the needs and desires of the smaller settlements, as noted in the previous section, they can be of great benefit. As well, successful small, connected circular economies will outgrow their capacity for self-sufficiency and social cohesion. When this happens, we must resist the urge to consolidate, repeating the mistakes of the past, choosing rather to establish new nodes in the network of interconnected cooperating circular economies. They would become human-centered evolutionary commons, analogous to the ACG in Costa Rica. Better can be bigger, growth is possible.

SOCIAL INSTITUTIONS

Social institutions arose in the run-up to the Great Tragedy. From religion to local governance, they originated when

simple social cohesion did not seem robust enough to encourage cooperation among people who were unfamiliar with each other yet relied on each other for their welfare. Most humans wish to avoid conflict, and the social institutions aspired to minimize conflict and resolve conflicts that did occur. But precisely because most humans wish to avoid conflict, the institutions quickly became the means by which a small number of people, sometimes a single charismatic one, could amplify their personal power and take control. When that happened, the social institutions became agents of social control and coercion, exerting surprisingly strong and persistent influences (Duchenne et al. 2023). Those most likely to desire such power are people least likely to care about the desires of those they control. As a result, social institutions have become stumbling blocks, not solutions—they are too rigid and committed to imposing one-size-fits-all solutions everywhere from the top down. Whoever controls the institutions is distrusted no matter what their avowed good intentions are. They have earned their universal distrust. This must change dramatically for contemporary human civilization to have a chance to persist into the future.

We need to establish the needs and desires at the grass roots, then ask the institutions to support them. This will solve problems and possibly restore trust in them. Supportive response from the top to desires from the grass roots can build trust, but not without substantial behavioral changes. The most difficult thing to do is to support grassroots initiatives that will not succeed. When they do not succeed, there will be increased chances that the grass roots will trust institutional suggestions for changing course. Trust in the institutions will build as those suggestions produce positive outcomes.

THE THIRD WAY

Humans impose themselves on the biosphere because that is how living systems exist. They cannot control the biosphere, however, because the biosphere is a global evolutionary system comprising many independent parts with more than 4 billion years of survival to its credit, while humanity is a single evolutionary entity with less than 4 million years of existence. No matter how much we pretend that our technology has, or ever will, overcome those 4 billion years' head start, we are wrong. This is because evolution is about survival and survival means coping with change by changing, not by attempting to stop change through control. Stasis is impossible, and we cannot stop or control the waves of change. The issue is how to navigate the waves of change so as to not be overturned and drowned.

Only one phenomenon has ever led to the biosphere recovering and diversifying anew after major environmental perturbations. And it has never failed. The biosphere will not collapse, yet it will change. Not all ecosystems will be lost, but all will be modified. Not all species will disappear, but the survivors will not remain static. New biological diversity connected to the past will emerge, though not quickly. Evolution has shown us indefinite survival can be achieved in many ways and that having a diversity of sufficient solutions is more survivable than having a single most efficient solution. The short-term fate of a small number of charismatic species, therefore, cannot be the primary focus of attention. The products and processes of evolution are all around us all the time. But to cope effectively with the near future, humanity needs to adopt an indefinite event horizon and imagine life on this planet extending millions of years into the future.

We have left this until very late in the game; these are not the good times when we can afford to make mistakes, especially ones of hubris. Left unattended and unchanged, the current dysfunction of one widespread primate species on this planet is self-correcting. If humans do not act on their own behalf, evolution might marginalize *Homo sapiens* within a post-Anthropocene biosphere or exclude it altogether. Extreme optimists believe technological innovation will produce the capacity to control the planet sufficiently to save us from ourselves. Extreme pessimists believe that humanity has gone rogue and will destroy itself.

Cautious rational optimists believe that even if there is a general collapse of technological humanity, there will be enough humans left to pick up the pieces and rebuild, hopefully not repeating the Great Tragedy. We side with them, believing there is a third way between unattainable utopia and unacceptable apocalypse. Humanity has a singular capacity for controlling its destiny. Humans can choose to abandon 9,000 years of bad behavior and, at great expense, move into the future guided by the Four Laws of Biotics, extending the Anthropocene and giving our species a chance to extend our technological infrastructure more widely. Even if humanity is not able to extend the Anthropocene, however, and inaction leads to the worst-case scenario—the collapse of technological humanity—we can use the Four Laws as guidelines to give humanity a second chance. People could rebuild civilization along survivable lines, not through control but through the accumulation and use of potential for coping with change by changing. What is now in place may collapse first, but that does not mean utter destruction; it can mean falling apart and rebuilding, analogous to the myth of the phoenix.

> *Ce que vous avez perdu dans le feu, vous le retrouverez dans la cendre.*
> (What you lose in the fire, you will find among the ashes.)

COMPETING INTERESTS

Nothing to declare.

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