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BOOK REVIEW

The Fate of the Extended Genome

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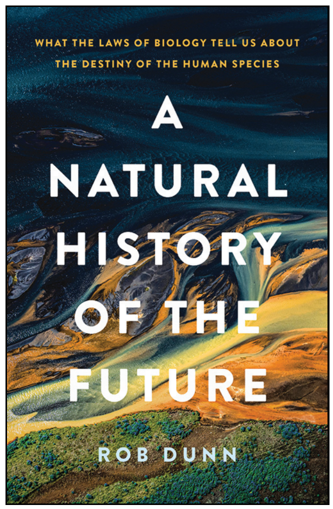
In *The Impact of Science on Society*, published in 1952, the English philosopher Bertrand Russell concluded that "life is a brief, small, and transitory phenomenon in an obscure corner," and "not at all the sort of thing that one would make a fuss about if one were not personally concerned."

This humbling perspective on human existence was bolstered by the etymologist Terry Irwin, who in the 1970s provided definitive evidence of our irrelevance. His study of tree-dwelling beetles living in the canopy of the Panamanian rainforest within a single species of the tree *Luehea seemannii* identified a total of 1200 different beetle species. Extrapolating, he conjectured that there may be as many as 30 million tropical beetle species globally, the majority uncharacterized.

These multifarious creatures are themselves trivialized by the estimated trillion or so bacterial species worldwide. Indeed the species of these microscopic beasts are so numerous that to a greater approximation, all species on Earth are bacterial. In the context of such overwhelming diversity, it is hard to contend that humankind, beetles, or any other macroscopic organisms are anything more than historic whimsies. We are but imperceptible twigs on a robust, bushy, and expansive bacterially inspired evolutionary tree.



A Natural History of the Future: What the Laws of Biology Tell us About the Destiny of the Human Species by Rob Dunn (Basic Books, 2021).

In his wonderful and thought-provoking book, *A Natural History of the Future*, the author Rob Dunn energetically explores the diversity, interconnectivity, and interdependency of life on Earth. He also examines the impact that humankind's decimation of species and their habitats may have on the future of the natural world.

While perceiving ourselves as an "exceptional" species that is "above" rather than organically part of nature, Dunn reminds us that our genomes and those of other species are inexorably entangled with those of a complex web of other organisms. We might regard this as the "extended genome" of a species. Our fragmentary understanding of the structure of this convoluted penumbra of accessory genetic material complementing individual genomes suggests that the extinction of component species will have unpredictable consequences. Rather than being dispensable, the species that live in, on, and around us, contributing to extended genomes, comprise the invisible backbone of living things.

The preservation of life's complexity and grandeur at every scale is, as a result, of singular importance. This is especially the case as our documentation of most species and their ecology is rudimentary. Our understanding of how vertically inherited microbial genes contribute to our biochemistry is, for example, highly limited. But by providing genetic widgets and mechanisms unavailable to our own genomes, the genes furnished by our microbiomes allow us to acquire new functions by proxy.

As our technological sophistication increases, it is apparent that the genomes of species are treasure troves of genetic virtuosity. Genes providing rudimentary immune functions to select bacterial species, for example, may be repurposed as editing tools for genomes. While conferring some immediate benefits, the genetic sequences and gadgetry of different species may also be relevant to future problems. We destroy the genetic heritage of Earth's species at our own peril.

The high rate of species extinction has, until now, resulted from attempts to control and subjugate nature through overhunting and the habitat destruction accompanying pollution, deforestation, intensive monoculture, and urbanization. The exponential increase in the global human population and industrialization over the past 2000 years has, however, generated a new phenomenon—the Anthropocene. Through its effects on global warming, it is poised to have a catastrophic impact on natural species.

Of the various scenarios defined by the Intergovernmental Panel on Climate Change for reducing the greenhouse emissions responsible for global warming, Dunn predicts that the "business as usual" outcome—yielding a 4°C increase in the Earth's temperature by 2100—is the most likely. The climate will not just be hotter, it will also be more variable. As a result, most species will have to migrate to new regions. In this dire RCP8.5 scenario,* species in tropical Mexico such as monkeys

*RCP stands for representative concentration pathway.

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and jaguars as well as countless plant, insect, and bacterial species will, for example, be obliged to make their way to Miami. Those in Florida will have to migrate to Washington, DC.

Dunn outlines a bleak vision of the future, in which climate change and species dislocations produce a flurry of existential challenges, including disease, pestilence, crop destruction, and behavioral alterations, which could precipitate societal collapse. We must plan for this before it is too late. Fortunately, some simple biological laws enable predictions and suggest corresponding solutions.

The late E.O. Wilson and Robert MacArthur's landmark study of island ants in Melanesia—*The Theory of Island Biogeography* (1967)—observed, for example, that larger islands housed more species. Mathematical modeling showed that extinction rates on small islands were higher than those on large islands, whereas immigration and speciation were lower. These principles derived from geographical islands generalize to other patches of habitat, from islands of green space in Manhattan through to "British woods in a sea of agriculture" and foci of urbanization such as cities.

This predicts that ancient species are "going extinct in shrinking patches of forests, grasslands, and swamps around the world." One way to address this is to generate conservation corridors that connect patches of habitat, thereby favoring species diversity and facilitating migration. Swathes of monoculture crops, however, behave like large islands, favoring the speciation of weeds, pests, and parasites. As the climate changes, areas once free of the ravages of diseases such as malaria might transform into endemic regions. The increased connectivity of human populations will also increase the frequency of pandemics.

Dunn's book is a sobering antidote for those who believe that we can effortlessly engineer our way out of global climate change through genome writing and other synthetic biology strategies. Its focus on ecological complexity and the extent of what we do not know about existing species and their complex webs of interactions and dependencies are at odds with the optimism of authors such as Beth Shapiro, who in *Life As we Made it* asserts that "the world is on the precipice of a metamorphosis beyond which lies a new nature."

So although genetically engineered coral reefs may, for example, have a better chance of surviving in warming oceans, we will need to proceed cautiously before embracing synthetic incarnations of nature's future. Dunn's book reminds us of how little we know about species and reminds us of their value. It should be read by government agencies and its recommendations adopted on a global scale.

A Natural History of the Future is also a harbinger of the potential hubris that will invariably accompany attempts to deconstruct species without considering their broader ecological context, and an urgent rallying cry for the preservation of species and their increasingly fragile habitats.

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